JEOL JSPM-5200 INSTRUCTIONS MANUAL

Table of Contents

Table of Contents

INTRODUCTION

PRINCIPAL SPECIFICATIONS

COMPOSITION

INSTALLATION REQUIREMENTS

STANDARD INSTALLATION DIAGRAM

OVERALL CONFIGURATION

MAIN UNIT

SPM Unit

AFM Amplifier

OPERATION UNIT

SPM CONTROL System

Computer System

Oscilloscope (Optional)

PREPARATION FOR STM OBSERVATION

Outline

Mounting the Specimen Holder

Mounting the Scanner Holder

Mounting the SPM Head Unit

Mounting the Cantilever

Mounting the Tip

Inserting the Cantilever Holder or the Tip Holder into the SPM Head Unit

Mounting a Specimen

Specimen Exchange
ADJUSTMENT FOR AFM OBSERVATION
Adjusting the Laser Beam Position
Adjusting the Photodiode Position
Rough Approaching
BASIC USAGE OF WINSPM
Before use
Glossary
Setting the User Name
STARTING THE SCAN (MEASUREMENT) MODE
Selecting SPM Operation Mode
SPM Parameters Window (Measurement Setting Window)
Shortcut Icons
Software Oscilloscope
Lock-In Amplifier
Specimen Temperature Controller (for JSPM-5200)
CCD Camera
Digital Control MFM unit
PREPARING FOR MEASUREMENT
Starting the System in Measurement Mode
Resetting the Controller
Confirming Settings of the Device Setup Dialog Box
Opening the SPM (Measurement) Parameters Window
Checking the Stage Position
Setting an Optional Oscilloscope
AC AFM MODE
AC Mode Tab
MFM Tab
VE-AFM Tab
SKPM Tab

Advanced Tab
CONTACT AFM MODE
Contact Mode Tab
Viscoelasticity Tab
Lateral Modulation FFM Tab
Electrostatic Force Tab
Advanced Tab
STM MODE
STM Tab
Advanced Tab
GENERAL PRECAUTIONS FOR IMAGE ACQUISITION
TERMINATING MEASUREMENT
TERMINATING OPERATION
REFERENCE
SPM Scan Menu
device setup
SPM Parameters (Simple)
operation buttons
SPM Parameters (Advanced)
Setting Lock-in Amplifier
Controlling Specimen Temperature
CCD Camera
PROCESS MODE
IMAGE PROCESSING AND DATA PROCESSING FUNCTIONS
EXAMPLE OF PROCESS FUNCTION
Example of Using the Image Processing Function
Example of Using the Data Processing Function
Arranging the Measured Data
FILE MENU
EDIT MENU

PROCESS MENU (IMAGE PROCESSING FUNCTION)

Filter

Edge Enhance

Differentiate

Normalise

Normalise S.D

Median

Subtract Background

Single Math

Double Math

ANALYSE MENU (IMAGE PROCESSING FUNCTION)

Profile

Measure

Zoom

Trim

FFT (Fast Fourier Transformation)

Particle Analysis

Draw Mesh

Roughness

GEOMETRY MENU (IMAGE PROCESSING FUNCTION)

Translate

Rotate

Mirror

Resize

Pad Points

Drift Correction

Average Unit Cell

Extract Area

Replace Area

LUT (HEIGHT INFORMATION)

Brightness/Contrast

Set Window
Histogram
Display Image LUT
Linearise Image LUT
LUT Math
Fix Z scale
DISPLAY MENU (IMAGE PROCESSING FUNCTION)
Display
Display Parameters
Full Display
Display
Display Colours
Clear Memory (FS)
Grab from Memory (FS)
Change Parameters
Display SPS Measurement Position
MAPPING MENU (IMAGE PROCESSING FUNCTION)
Display Parameters
Special Displays
SPS Mapping Select
Edit SPS Mapping Data Set
Average Images
Duplicate Data Set
Extract Spectra
PROCESS MENU (DATA PROCESSING FUNCTION)
Smooth
Math X, Math Y
Spec Math
Differentiate
Remove DC Bias

ANALYSE MENU (DATA PROCESSING FUNCTION)
Fit Polynomial
Zoom
Measure
Group Plot
Show FFT
DISPLAY MENU (DATA PROCESSING FUNCTION)
Plot
Plot Parameters
SELECT MENU
WINDOW MENU
SPM SCAN MENU
HELP MENU
WINSPM SOFTWARE REINSTALLATION METHOD
Before Re-installing the WinSPM Software
Re-installing Windows
Installing the A/D Board Device Driver in the PC
Reinstalling the WinSPM Software
SETTING UP THE WINSPM PROGRAM
Selecting the instrument
Saving and Loading the Scanner-Sensitivity Settings
Saving and Loading the Motor-Drive Position Calibration Values
CANTILEVER
FILE FORMAT
Standard TIFF File Structure
WinSPM image file
Overall structure of WinSPM image file
WinSPM image file ［1］ (SPM Image)
WinSPM image file ［2］ (Compressed TIFF)
WinSPM image file ［3］ (FFT image file)

WinSPM image file ［4］ (CITS image file)
Spectrum data file
Image file with spectrum data
Report file
STORAGE
Instrument
Cantilever
Handling the Instrument
Maintenance Parts
VIBRATION ISOLATOR
Compressor （optional
Vibration-Isolation Table
SPM HEAD
Laser Beam Focusing
Mirror Angle Adjustment
CCD CAMERA (OPTIONAL)
Installing the CCD Camera
Replacing the Source Lamp
LOCATIONS OF PORTS
USER PORTS
PIN CONNECTION
TOOL SET (OPTIONAL)
Other ManualsLib Projects

JSPM-5200

SCANNING PROBE MICROSCOPE

For the proper use of the instrument, be sure to read this instruction manual. Even after you read it, please keep the manual on hand so that you can consult it whenever necessary.

ITMPM5200-2
MAY2004-17110074
Printed in Japan

JSPM-5200

SCANNING PROBE MICROSCOPE

NOTICE

- This instrument generates, uses, and can radiate radio-frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to the environment, especially radio communications.
- This instrument must not be modified, and products other than those manufactured by JEOL Ltd. must not be attached to this instrument, without prior written permission. If any such modification or attachment is made, all the stipulated warranties and services contracted by JEOL Ltd. or its affiliated company will be void.
- Replacement parts for maintenance of the instrument performance are available for seven years from the date of installation. Thereafter, some of those parts may be available for a certain period of time, and in this case, an extra service charge may be applied for servicing with those parts. Please contact your JEOL service office for details.
- After installation of the instrument, when the instrument will be moved or transported, be sure to contact your JEOL service office. If the instrument is moved or transported by people other than engineers employed or specified by JEOL, JEOL Ltd. cannot accept responsibility for any of the accidents and problems with the instrument after transport.
- The information in this manual, which is based on specifications believed correct at the time of publication, is subject to change without notice due to improvements made in the instrument.
- In order to assist us in preparing future documentation, please advise your JEOL service office if you find any errors in this manual. Kindly note that while the instrument can be used in combination with various attachments to serve a number of purposes, this special feature of the instrument is only briefly described in this manual, which chiefly provides information on basic operations.
- In no event will JEOL Ltd. be liable for direct, indirect, incidental or consequential damages resulting from the use of software described in this manual.

- When this manual or the software described in this manual is furnished under a license agreement, it may only be used or copied in accordance with the terms of such license agreement.

TRADEMARK

- Windows is a trademark of Microsoft Corporation.
- All other company and product names are trademarks or registered trademarks of their respective companies.

MANUFACTURER

JEOL Ltd.
1-2 Musashino 3-chome Akishima Tokyo 196-8558 Japan
Telephone: 81-42-543-1111
Facsimile: 81-42-546-3353

Note: For servicing or inquires, please contact your JEOL service office.

NOTATIONAL CONVENTIONS AND GLOSSARY

■ General notations

⚠ **WARNING :**	A potentially hazardous situation which, if not avoided, could result in death or serious injury.
⚠ **CAUTION :**	A potentially hazardous situation which, if not avoided, could result in minor injury or material damage. Material damage includes, but is not limited to, damage to related devices and facilities, and to acquired data.
– CAUTION – :	Points requiring great care and attention when operating the device to avoid damage to the device itself.
✍ :	Additional points to remember regarding the operation.
☞ :	A reference to another section, chapter or manual.
1, 2, 3 :	Numbers indicate a series of operations that achieve a task.
◆ :	A diamond indicates a single operation that achieves a task.
"File" :	The names of menus, commands, or parameters displayed on the screen are enclosed in double quotation marks.
"File" – "Exit" :	Selecting a menu item from a pulldown menu is denoted by linking the menu and the item with a dash (–). For example, "File" – "Exit" means selecting Exit from the File menu.

■ Mouse terminology

Mouse pointer:	A mark, displayed on the screen, which moves following the movement of the mouse. It is used to specify a menu item, command, parameter value, and other items. Its shape changes according to the situation.
Click:	To press and release the left mouse button.
Right-click:	To press and release the right mouse button.
Double-click:	To press and release the left mouse button twice quickly.
Drag:	To hold down the left mouse button while moving the mouse.

CONTENTS

SAFETY PRECAUTIONS

PRECAUTIONS FOR USE

1. GENERAL

1.1 INTRODUCTION 1-1

2. SPECIFICATIONS AND INSTALLATION REQUIREMENTS

2.1 PRINCIPAL SPECIFICATIONS 2-1
2.2 COMPOSITION 2-2
2.3 INSTALLATION REQUIREMENTS 2-5
2.4 STANDARD INSTALLATION DIAGRAM 2-6

3. CONFIGURATION AND DESCRIPTIONS OF COMPONENTS

3.1 OVERALL CONFIGURATION 3-1
3.2 MAIN UNIT 3-2
3.2.1 SPM Unit 3-2
3.2.2 AFM Amplifier 3-9
3.3 OPERATION UNIT 3-13
3.3.1 SPM CONTROL System 3-14
3.3.2 Computer System 3-16
3.3.3 Oscilloscope (Optional) 3-17

4. PREPARATION FOR OBSERVATION

4.1 PREPARATION FOR STM OBSERVATION 4-1
4.1.1 Outline 4-1
4.1.2 Mounting the Specimen Holder 4-3
4.1.3 Mounting the Scanner Holder 4-4
4.1.4 Mounting the SPM Head Unit 4-5
4.1.5 Mounting the Cantilever 4-5
4.1.6 Mounting the Tip 4-6
4.1.7 Inserting the Cantilever Holder or the Tip Holder into the SPM Head Unit 4-7
4.1.8 Mounting a Specimen 4-8
4.1.9 Specimen Exchange 4-9
4.2 ADJUSTMENT FOR AFM OBSERVATION 4-10
4.2.1 Adjusting the Laser Beam Position 4-10
4.2.2 Adjusting the Photodiode Position 4-14
4.2.3 Rough Approaching 4-17

5. MEASUREMENT OPERATION

5.1 BASIC USAGE OF WINSPM 5-1
5.1.1 Before use 5-1
5.1.2 Glossary 5-1
5.1.3 Setting the User Name 5-4

5.2 STARTING THE SCAN (MEASUREMENT) MODE 5-7
5.2.1 Selecting SPM Operation Mode 5-7
5.2.2 SPM Parameters Window (Measurement Setting Window)............5-9
5.2.3 Shortcut Icons 5-11
5.2.4 Software Oscilloscope 5-12
5.2.5 Lock-In Amplifier 5-13
5.2.6 Specimen Temperature Controller (for JSPM-5200) 5-18
5.2.7 CCD Camera 5-18
5.2.8 Digital Control MFM unit 5-19
5.3 PREPARING FOR MEASUREMENT...5-20
5.3.1 Starting the System in Measurement Mode..................................5-20
5.3.2 Resetting the Controller...5-21
5.3.3 Confirming Settings of the Device Setup Dialog Box..................5-21
5.3.4 Opening the SPM (Measurement) Parameters Window 5-21
5.3.5 Checking the Stage Position 5-22
5.3.6 Setting an Optional Oscilloscope 5-23
5.4 AC AFM MODE 5-26
5.4.1 AC Mode Tab...5-26
5.4.2 MFM Tab 5-37
5.4.3 VE-AFM Tab 5-42
5.4.4 SKPM Tab 5-46
5.4.5 Advanced Tab 5-55
5.5 CONTACT AFM MODE 5-81
5.5.1 Contact Mode Tab..5-81
5.5.2 Viscoelasticity Tab...5-92
5.5.3 Lateral Modulation FFM Tab 5-96
5.5.4 Electrostatic Force Tab 5-100
5.5.5 Advanced Tab 5-103
5.6 STM MODE 5-133
5.6.1 STM Tab 5-133
5.6.2 Advanced Tab 5-144
5.7 GENERAL PRECAUTIONS FOR IMAGE ACQUISITION 5-160
5.8 TERMINATING MEASUREMENT...5-166
5.9 TERMINATING OPERATION..5-167
5.10 REFERENCE 5-168
5.10.1 SPM Scan Menu 5-168
5.10.2 SPM Parameters (Simple)..5-178
5.10.3 SPM Parameters (Advanced)..5-203
5.10.4 Setting Lock-in Amplifier 5-254
5.10.5 Controlling Specimen Temperature 5-260
5.10.6 CCD Camera 5-264

6. ANALYSIS OPERATION

6.1 PROCESS MODE 6-1
6.2 IMAGE PROCESSING AND DATA PROCESSING FUNCTIONS 6-2
6.3 EXAMPLE OF PROCESS FUNCTION 6-4
6.3.1 Example of Using the Image Processing Function 6-4
6.3.2 Example of Using the Data Processing Function 6-11
6.3.3 Arranging the Measured Data...6-14

6.4 FILE MENU 6-17
6.5 EDIT MENU 6-25
6.6 PROCESS MENU (IMAGE PROCESSING FUNCTION) 6-26
6.6.1 Filter 6-26
6.6.2 Edge Enhance 6-29
6.6.3 Differentiate 6-30
6.6.4 Normalise 6-30
6.6.5 Normalise S.D. 6-30
6.6.6 Median 6-31
6.6.7 Subtract Background... 6-32
6.6.8 Single Math 6-33
6.6.9 Double Math 6-34
6.7 ANALYSE MENU (IMAGE PROCESSING FUNCTION) 6-35
6.7.1 Profile 6-35
6.7.2 Measure 6-45
6.7.3 Zoom 6-47
6.7.4 Trim 6-48
6.7.5 FFT (Fast Fourier Transformation) 6-49
6.7.6 Particle Analysis 6-56
6.7.7 Draw Mesh 6-60
6.7.8 Roughness 6-61
6.8 GEOMETRY MENU (IMAGE PROCESSING FUNCTION) 6-63
6.8.1 Translate 6-63
6.8.2 Rotate 6-63
6.8.3 Mirror 6-64
6.8.4 Resize 6-65
6.8.5 Pad Points 6-66
6.8.6 Drift Correction 6-67
6.8.7 Average Unit Cell 6-67
6.8.8 Extract Area 6-68
6.8.9 Replace Area 6-69
6.9 LUT (HEIGHT INFORMATION) 6-70
6.9.1 Brightness/Contrast 6-70
6.9.2 Set Window 6-71
6.9.3 Histogram 6-72
6.9.4 Display Image LUT 6-73
6.9.5 Linearise Image LUT 6-74
6.9.6 LUT Math 6-75
6.9.7 Fix Z scale 6-75
6.10 DISPLAY MENU (IMAGE PROCESSING FUNCTION) 6-78
6.10.1 Display 6-78
6.10.2 Display Parameters 6-78
6.10.3 Full Display 6-81
6.10.4 3D Display 6-82
6.10.5 Display Colours 6-87
6.10.6 Clear Memory (FS) 6-88
6.10.7 Grab from Memory (FS) 6-89
6.10.8 Change Parameters 6-90

6.10.9 Display SPS Measurement Position 6-91
6.11 MAPPING MENU (IMAGE PROCESSING FUNCTION) 6-92
6.11.1 Display Parameters...6-93
6.11.2 Special Displays 6-94
6.11.3 SPS Mapping Select 6-95
6.11.4 Edit SPS Mapping Data Set...6-96
6.11.5 Average Images..6-99
6.11.6 Duplicate Data Set..6-99
6.11.7 Extract Spectra...6-99
6.12 PROCESS MENU (DATA PROCESSING FUNCTION).................6-101
6.12.1 Smooth...6-101
6.12.2 Math X, Math Y 6-102
6.12.3 2 Spec Math...6-103
6.12.4 Differentiate...6-104
6.12.5 Remove DC Bias 6-104
6.13 ANALYSE MENU (DATA PROCESSING FUNCTION) 6-105
6.13.1 Fit Polynomial 6-105
6.13.2 Zoom 6-105
6.13.3 Measure 6-106
6.13.4 Group Plot 6-107
6.13.5 Show FFT...6-108
6.14 DISPLAY MENU (DATA PROCESSING FUNCTION)..................6-109
6.14.1 Plot...6-109
6.14.2 Plot Parameters..6-109
6.15 SELECT MENU..6-111
6.16 WINDOW MENU...6-112
6.17 SPM SCAN MENU...6-113
6.18 HELP MENU..6-117

7. APPENDIX

7.1 WINSPM SOFTWARE REINSTALLATION METHOD.....................7-1
7.1.1 Before Re-installing the WinSPM Software...................................7-1
7.1.2 Re-installing Windows 7-2
7.1.3 Installing the A/D Board Device Driver in the PC.........................7-2
7.1.4 Reinstalling the WinSPM Software..7-7
7.2 SETTING UP THE WINSPM PROGRAM 7-9
7.2.1 Selecting the instrument 7-9
7.2.2 Saving and Loading the Scanner-Sensitivity Settings..................7-11
7.2.3 Saving and Loading the Motor-Drive
Position Calibration Values..7-13
7.3 CANTILEVER 7-15
7.4 FILE FORMAT...7-19
7.4.1 Standard TIFF File Structure..7-19
7.4.2 WinSPM image file 7-21
7.4.3 Spectrum data file...7-50
7.4.4 Image file with spectrum data 7-51
7.4.5 Report file 7-52

8. GENERAL

8.1 STORAGE....8-1
8.1.1 Instrument....8-1
8.1.2 Cantilever....8-1
8.1.3 Handling the Instrument....8-1
8.1.4 Maintenance Parts....8-1
8.2 VIBRATION ISOLATOR....8-2
8.2.1 Compressor（optional）....8-2
8.2.2 Vibration-Isolation Table....8-2
8.3 SPM HEAD....8-3
8.3.1 Laser Beam Focusing....8-3
8.3.2 Mirror Angle Adjustment....8-4
8.4 CCD CAMERA (OPTIONAL)....8-5
8.4.1 Installing the CCD Camera....8-5
8.4.2 Replacing the Source Lamp....8-8
8.5 LOCATIONS OF PORTS....8-10
8.6 USER PORTS....8-10
8.7 PIN CONNECTION....8-11
8.8 TOOL SET (OPTIONAL)....8-12

SAFETY PRECAUTIONS

For the proper use of the instrument, be sure to read the following safety precautions prior to starting operation or maintenance. They contain important information related to safety. Contact your JEOL service office whenever you are unclear about any operation or maintenance.

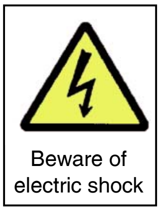
The signs for safety precautions and their meanings used in this instruction manual are as follows:

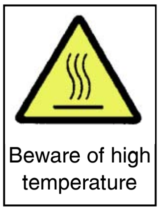
⚠ **DANGER:** An imminent hazardous situation which, if not avoided, will result in death or serious injury.

⚠ **WARNING:** A potentially hazardous situation which, if not avoided, could result in death or serious injury.

⚠ **CAUTION:** A potentially hazardous situation which, if not avoided, could result in minor or moderate injury. Also could mean a potentially hazardous situation which could result in serious damage to facilities and acquired data.

Parts of this instrument where safety precautions are required are labeled with illustration signs as shown below. Do not touch the parts labeled with these signs:





Use the instrument in a proper manner and within the scope of the purposes and usage contained in the brochures and instruction manuals. Never make modifications such as removing protective parts, exchanging component parts, and defeating safety measures.

Be sure to read the "Safety Precautions" given in the instruction manuals of the optional attachments for information about the attachments of this instrument.

⚠ WARNINGS

- **A Class 2 laser is used in this microscope. Do not look directly in the observation instruments such as the optical microscope. Look in the observation instrument indirectly by using a detecting device with CCD.**
- **Be careful not to get irradiation bombardment from the laser radiation aperture locating near the laser source position adjusting knobs.**
- **Look in the AFM head more than 20 cm away from the AFM head since a Class 2 laser is provided in the AFM head.**

- **Be sure to turn off the power to the SPM CONTROL unit in advance when mounting or dismounting the scanner holder, specimen holder or SPM head unit.**
  There is a risk of electric shock due to the high voltage applied to the connector pins from the SPM CONTROL unit.
- **Never exchange a specimen while a high bias voltage is being applied to the specimen.**
  You might get an electric shock due to the high voltage applied to the specimen.
- **When storing the instrument, avoid high humidity.**
  Excess humidity brings deterioration of insulation at the tunneling current detector and scanner high-voltage circuits, causing insufficient instrument performance or electric shock.
- **Be careful not to put your hand under the base plate.**
  You might get your fingers caught.
- **To avoid burns, allow the lamp to cool down for at least 30 minutes before removing it. Never touch the lamp with bare hands because it is very hot immediately after the filament burns out.**
- **When handling the instrument, be sure to wear nylon gloves.**
  Grease from hands may cause deterioration of the vacuum especially when you observe a specimen in the vacuum using an optional evacuation system. At the worst, there is a risk of deterioration of insulation at the tunneling current detector and scanner high-voltage circuits, causing insufficient instrument performance or electric shock.
  If any parts happen to have hand grease on them, softly wipe it off with ethanol-soaked lint-free tissue or cloth.

⚠ CAUTIONS

- **Do not install this instrument in a place where any fluorescent lamps directly illuminate the SPM head.**
  Fluorescent lamps blink at 100 Hz (if the line frequency is 50 Hz) or at 120 Hz (if the line frequency is 60 Hz) and this noise may appear on the displayed image. Concerning the installation and layout plan, please consult your local JEOL service personnel.
- **Handle the scanner holder very carefully since it is a precision device.**
  It could be easily damaged by a mechanical shock.
- **The bias voltage to be applied to the specimen is superposed on the "B+" wire in the heating cable. Therefore, the heating power supply must be electrically isolated from the ground (GND).**
  If one of the heating cable wires is grounded, the bias voltage circuit might be damaged.
- **If the Sample Bias is set by using the slider during image observation, be careful not to move the slider button across 0 V.**
  The tip would collide with the specimen surface if the bias voltage became 0 (zero).

- **When you move the tip close to the specimen using the Coarse Stage window, the tip never stops even if a tunneling current or atomic force is actually detected.**
- **The specimen stub is gold-plated. Be careful not to scratch the stub surface.**
- **Insert or remove the specimen stub horizontally with care.**
  If an excessive force is applied to the scanner holder, the scanner inside it might be damaged.
- **Do not turn off the power while the WinSPM software is running.**
  The software may be damaged if the power is turned off.
- **In order to prevent the tip from colliding with the specimen surface, the speed of the tip movement must not be faster than 200 nm/s.**
- **Upon completion of observation, turn off the computer after terminating the software. Wait 10 seconds or more before restarting the computer.**
- **The software must be terminated before the power is turned off. Never turn off the power while the software is in operation.**
- **To turn off the power of the SPM CONTROL system, first turn off the LD-ON switch of the AFM AMP and then turn off the power of the SPM CONTROL system.**
  The laser luminescence part may be damaged.
- **When you select and use a short cantilever out of two cantilevers, long and short, be sure to remove the long one with a pair of tweezers.**
  Otherwise, the top of the long cantilever touches the specimen before the short one does.
- **Be sure to insert the cantilever along with the groove.**
  Otherwise, the cantilever may be damaged due to an excessive force being applied when the spring retainer is released.
- **Never touch the area around the cantilever on the cantilever holder with bare fingers.**
  If that part is contaminated with hand grease, that might give rise to insufficient insulation, thus possibly causing tunneling current leakage or incorrect operation of the piezoelectric element.
- **Push the spring retainer vertically.**
  If you force it diagonally, the ceramic might be damaged.
- **When applying conductive paste to the cantilever and the cantilever holder, be sure not to apply the conductive paste to the cantilever piezoelectric element. When replacing a cantilever, be sure to confirm that no previously used conductive paste remains on the holder.**
  Otherwise, the cantilever will tilt, causing the reflected laser beam not to irradiate the right position.
- **Cantilevers must be stored in a desiccator when they are not in use.**
  If they are stored at high humidity, the cantilevers could bend, causing the reflected laser beam not to reach the correct position. Especially, a gold-coated Si_3N_4 cantilever is prone to deteriorate with humidity.

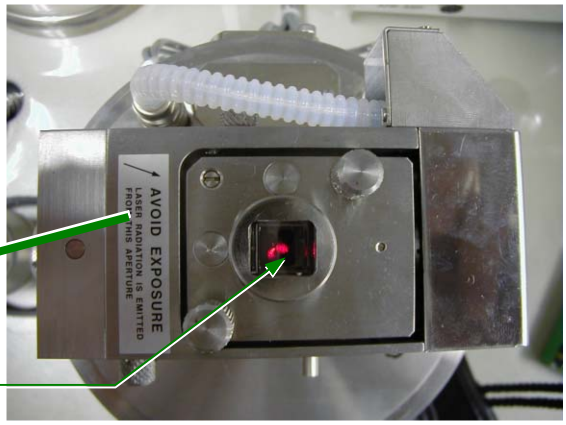
⚠ The labels concerning the operation of the laser

- **This instrument uses a class 2 laser device and emits 670 nm laser (1 mw power). Follow the instruction manual to avoid getting laser irradiation bombardment.**

  The following labels are found on the AFM base unit side panel.

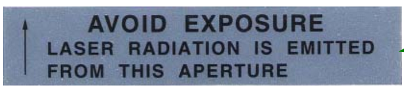
- **Two ports for laser irradiation are provided on this instrument and the labels shown bellow are found on the AFM base unit top and front.**

Aperture



AFM base unit top

Aperture



AFM base unit front

PRECAUTIONS FOR USE

Important precautions, which, if not followed, may result in damage to the device itself, are described below.

- **The software must be terminated before the power is turned off. Never turn off the power while the software is in operation.
  Wait 10 seconds or more before restarting the system.**
- **During initialization, the sample stage can move significantly. Prior to implementing initialization, therefore, separate the probe from the sample to prevent the probe from coming into contact with the specimen or stage, causing damage to the probe.**
- **When you use a short cantilever, be sure to remove the long one with a pair of tweezers. Otherwise, the top of the long cantilever touches the specimen before the short one does.**
- **When applying conductive paste to the cantilever and the cantilever holder, be sure not to apply the conductive paste to the cantilever piezoelectric element. When replacing a cantilever, be sure to confirm that no previously used conductive paste remains on the holder. Otherwise, the cantilever will tilt, causing the reflected laser beam not to irradiate the right position.**
- **If the Sample Bias is set by using the slider during image observation, be careful not to move the slider button across 0 V. The tip would collide with the specimen surface if the bias voltage became 0 (zero).**
- **If you move the motor drive greatly, the tip gets too close to the specimen surface or gets too far from the specimen.**
- **When you move the tip close to the specimen using the Coarse Stage window, the tip never stops even if a tunneling current or atomic force is actually detected.**

1

GENERAL

1.1 INTRODUCTION 1-1

1.1 INTRODUCTION

The JSPM–5200 Scanning Probe Microscope is designed not only to meet researchers' increasing demands for applied observation modes but also to make the most of the intrinsic functions of a scanning probe microscope. This instrument is easy to use and is superb in its expandability, enabling a number of people from novices to professional SPM researchers to use it.

The following are the main features of this instrument.

- It is possible to observe specimens under various conditions, from in a liquid to under high vacuum, not to mention under atmospheric pressure, by attaching optional accessories without making any modification of the basic unit.
- Moreover, it is possible to observe a specimen that is being heated or cooled by attaching a simple optional accessory.
- You can handle quite a variety of modes such as AFM (Contact and AC modes), phase image, FFM, STM, CITS and I-V using the standard instrument configuration. In addition, you can use the observation modes for Kelvin-probe microscope images, viscoelasticity images and pulsed force images by installing appropriate optional accessories on the instrument.
- The control software operates under Windows, and the control panel is of the tab type, with only the minimum necessary controls, thus being easy to use even to SPM novices.
- A personal login function with which you can create your own environment, greatly simplifies the operation of the instrument.

2

SPECIFICATIONS AND INSTALLATION REQUIREMENTS

2.1 PRINCIPAL SPECIFICATIONS 2-1
2.2 COMPOSITION 2-2
2.3 INSTALLATION REQUIREMENTS 2-5
2.4 STANDARD INSTALLATION DIAGRAM 2-6

2.1 PRINCIPAL SPECIFICATIONS

- Resolution
  - AFM: Atomic resolution (mica atomic image in contact mode)
  - STM: Atomic resolution (HOPG atomic image)
- System drift: 0.05 nm/s or less
- Measurement modes
  - AFM: Contact mode
    - Topography image, force image, FFM, force curve, friction-force curve, I-V, CITS, contact electric-current image

    AC mode
    - Topography image, phase image, amplitude image, point-by-point lift mode

    Lateral-modulation FFM (optional)
    Viscoelasticity (optional)
    Surface potential difference (optional)
    Electrochemistry (optional)
    Line-by-line lift mode (optional)
  - STM: STM mode
    - Topography image, electric-current image, CITS

    Spectroscopy
    - I-V, S-V, I-S
- X, Y scanning range: 0 to 10 μm (when the standard scanner is used)
  - Driving voltage: ±150 V
  - Resolution: 25 bits (image offset included)
- Z range: 0 to 3 μm (when the standard scanner is used)
  - Driving voltage: ±150 V
  - Resolution: 21 bits (at a gain of 32×)
- Specimen size
  - Standard: 10 mm × 10 mm × 3 mm (thickness)
  - Maximum: 2-inch wafer
- Specimen movement
  - X, Y specimen movement: ±3 mm
  - Z specimen movement: 5 mm

2.2 COMPOSITION

● SPM Base Unit

- Coarse movement:
  - Z coarse-movement distance: Manually operated up to 5 mm (motor approach included)
  - Approach function: Motor approach up to 1.5 mm
  - X, Y coarse movement function: Manually operated up to ±3 mm
- Stage: Drift-free stage
- Ports: Gas introduction and exhaust port (1 each)
  Exclusive-only port (1)
  Utility ports (2)
  Port for cooling option (1)

● SPM Head

- Scanning method: Specimen scanning
- Scanner: Tube-type scanner (replaceable)
  X, Y = 10 μm, Z = 3 μm (one standard scanner provided as standard)
- Detection method: Light lever
  - Laser-beam source: Class-2 semiconductor laser beam (red)
  - Laser detector: Four-segment photodiode
- Cantilever holder: Holder used in common for contact mode and AC mode
  - Cantilever mounting method: One-touch push-in
  - Current detection terminal: Built-in
  - Mounting method: Slide-in
- Tip holder
  - Tip: 0.3 mm diameter
  - Tip mounting method: Push-in knock-on
  - Holder mounting method: Slide-in

● Vibration Isolation System

- Air suspension: Gimbals piston type, automatic leveling
- Gel damper: Built-in
- Air compressor: Included as standard

● Console Box

- Rack
  - Controller housing rack and operation table: Included as standard
- Power: Single-phase AC100 V, 50/60 Hz, 1.5 kVA (one receptacle with a grounding terminal)
- Power cable: 2.5 m to basic unit

● SPM Control System

- Scanning capabilities

Scanning range:	Continuously variable from 0 to maximum scanning range (25 bits)
Scanning speed:	0.00167 ms to 200 s/point
Bias voltage:	Continuously variable from 0 to ±10 V, 0 to ±150 V (16 bits)
	Scanning in a region of 1024×1024, 512×512, 256×256 and 128×128 pixels and Top Mirror scanning
	Line scanning in 1024, 512, 256 and 128 pixels
	Maximum 4 channels simultaneous input and simultaneous displayed
	Automatic distortion correction, automatic tilt correction, automatic contrast and brightness control
	Zooming at any position
	Scanning rotation: ±180°, in 1° step
	Lithography function

- AFM capability

	Contact mode, Constant-force mode, constant-height mode, force-curve mode and friction-force curve mode
	Force setting: 10^{-8} to 10^{-11} N
AC mode:	
Detection method:	Amplitude detection, phase detection and FM detection
Excitation frequency:	1 kHz to 1MHz

- STM capability

  Constant-current mode, constant-height mode, I-V, CITS, S-V and I-S

  Current setting: 30 pA to 1 μA

- Optional capabilities available

  Surface potential difference, lateral-modulation FFM, viscoelasticity and magnetic force

- Map scan capability

  I-V mapping (CITS), I-S mapping, S-V mapping, force-curve mapping, friction-force curve mapping

● Computer Control System

• Computer:	IBM-PC/AT compatible
• High-resolution color display:	21 inches, 1,280×1,024 pixels
• Keyboard and mouse:	Provided
• External storage:	Magneto-optical disk (optional)

● SPM Software

- File operations

  File writing: TIFF, BMP, Binary and ASCII

  File reading

  File searching

- Image-processing functions

Spatial filters:	10, low-pass, band-pass, high-pass, horizontal smoothing, vertical smoothing and user-defined
Edge enhancement:	5, vertical, horizontal, lower right, lower left and Laplace
Differential filter	
Normalization filters:	2
Median filters:	2
Tilt correction:	X, Y, arbitrary area and entire area
Image processing:	Video inverting, multiplication, division, AND, OR, XOR, constant summation and constant multiplication

- Image-analysis functions

Height analysis	
Line profiling:	Single, multiple, broad and extra
Image enlargement	
Image extracting	
FFT function:	Fourier transform, inverse Fourier transform and windowing
Surface roughness measurement:	Entire area and designated area
Particle-analysis:	Binarizing, particle count and area-measurement
Image rotation and mirror image	
Image-size change	
Drift correction	

- Image-conversion functions

Histogram functions:	Histogram display, equalization, bearing-ratio display and real-time contrast and brightness adjustment
CITS analysis functions	
I-V curve extracting:	Point and arbitrary area

- Display functions

Three-dimensional display:	Wire frame, beam display, contour mapping and shading
Color display:	Pseudo color and user-defined
Fixed-height display	

- Storage media

  CD-R

2.3 INSTALLATION REQUIREMENTS

● Dimensions and Weight

	Height (mm)	Width (mm)	Depth (mm)	Mass (kg)
Main unit	1,150	710	710	250
Operation unit	730 1,450 (monitor included)	570	710	80
Air compressor	530	290 in diameter		17

● Installation Room

- Room temperature: 20 ℃ ±5 ℃
- Humidity: 60% or less
- Acoustic vibration: 50 dB or less (A mode)
- Floor vibration: 5 μm (5 Hz) or less

● Power Supply

- Capacity: Single-phase AC100 V, 50/60 Hz, 1.5 kVA (one receptacle with a grounding terminal)
  When an optional evacuation system is installed, 1.5 kVA × 2 (2 receptacles with grounding terminals)
- Fluctuation: ±10% or less
- Grounding terminal: 100 ohms or less
- Cable length
  Main unit: 2.5 m
  High-vacuum evacuation system and evacuation system:
  2.5 m

⚠ CAUTION

Do not install this instrument in a place where any fluorescent lamps directly illuminate the SPM head. Fluorescent lamps blink at 100 Hz (if the line frequency is 50 Hz) or at 120 Hz (if the line frequency is 60 Hz) and this noise may appear on the displayed image. Concerning the installation and layout plan, please consult your local JEOL service personnel.

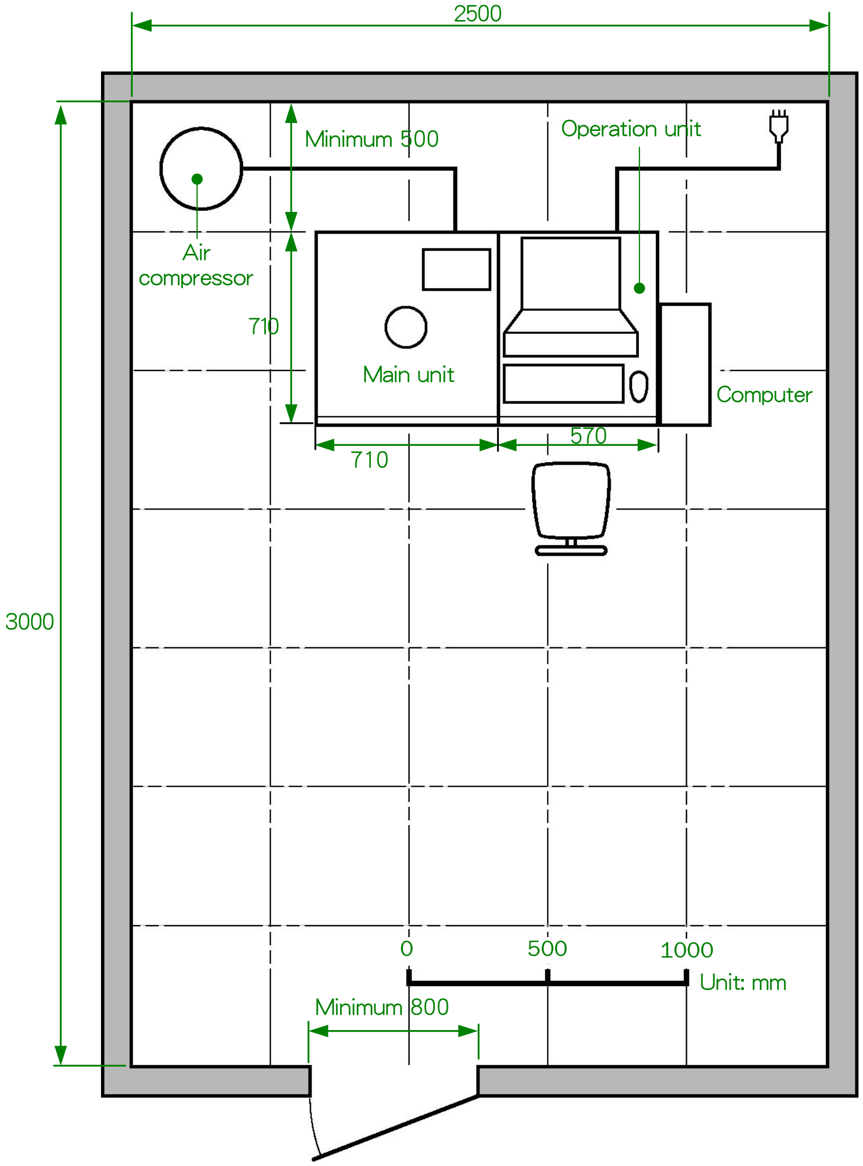
2.4 STANDARD INSTALLATION DIAGRAM

● Installation Room

Floor space:	2,500 mm (W) × 3,000 (D) or larger
Ceiling:	2,000 mm or higher
Entrance:	800 mm (W) × 1,800 mm (H) or larger

✍ When an optional evacuation system is installed, it is necessary to provide a space of 500 mm or more between the rear of the instrument and the wall of the room.

● Typical Installation Layout



3

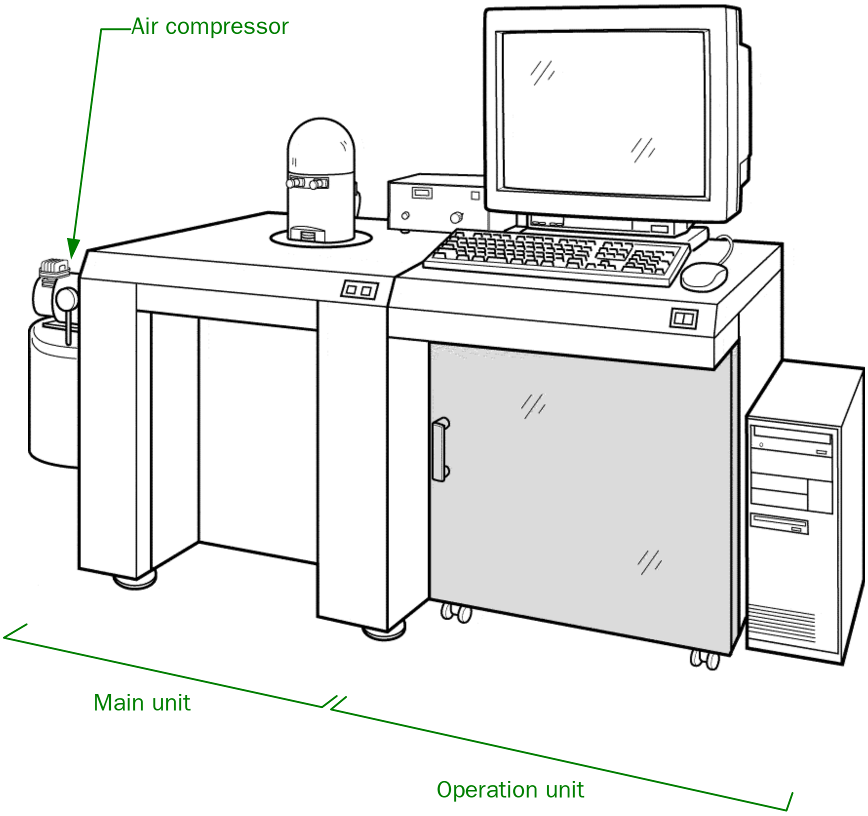
CONFIGURATION AND DESCRIPTIONS OF COMPONENTS

3.1 OVERALL CONFIGURATION 3-1
3.2 MAIN UNIT 3-2
3.2.1 SPM Unit 3-2
3.2.2 AFM Amplifier 3-9
3.3 OPERATION UNIT 3-13
3.3.1 SPM CONTROL System 3-14
3.3.2 Computer System 3-16
3.3.3 Oscilloscope (Optional) 3-17

The name, functions and layout of each unit of this instrument are given in this chapter. Please refer to this chapter when you read the operating procedures below.

3.1 OVERALL CONFIGURATION

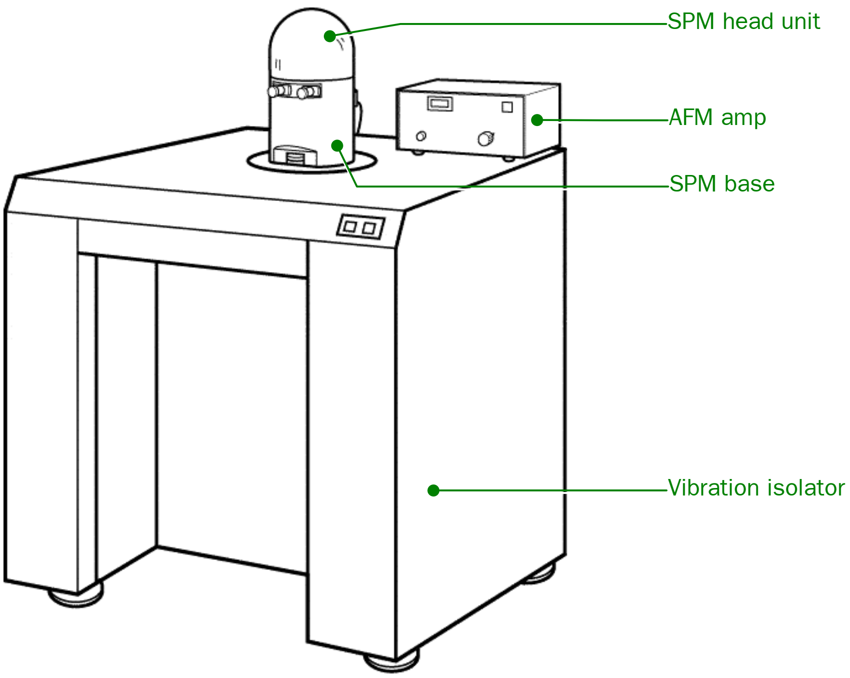
This instrument is composed of a Main unit, a Operation unit (including SPM control and computer system) and an air compressor.



3.2 MAIN UNIT

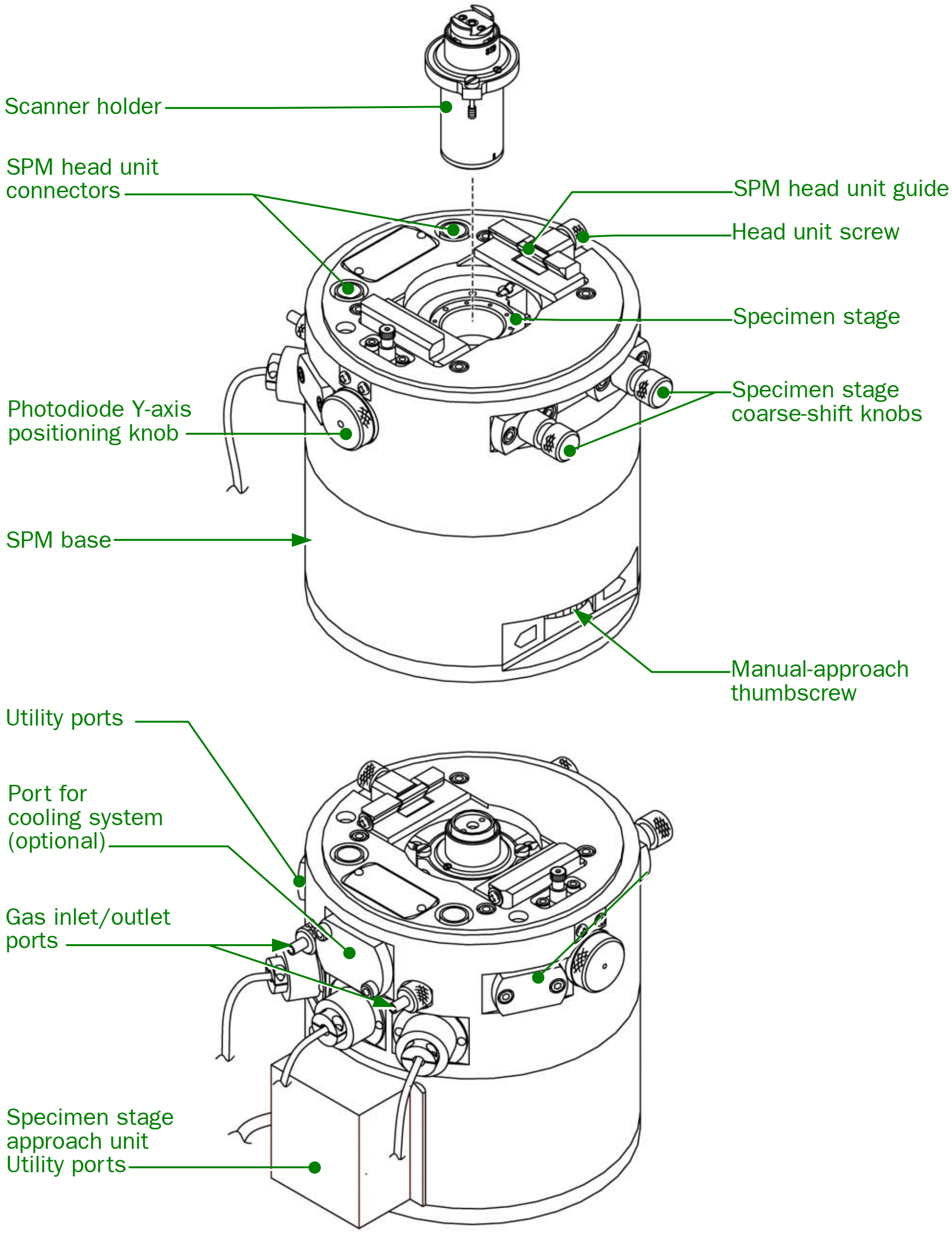
3.2.1 SPM Unit

The SPM unit is composed of a vibration isolator, an SPM base unit and an SPM head unit.



■ SPM base unit

The SPM base unit includes a specimen stage, a stage-approach unit and a stage-shift unit.

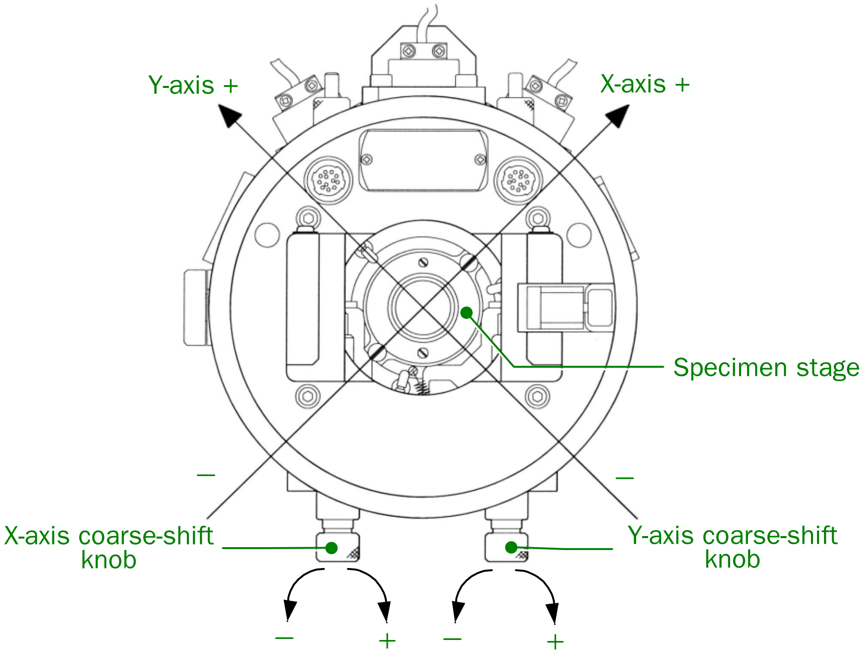


● Specimen stage

The specimen stage is a device on which the scanner holder is mounted. The specimen stage features a drift-free mechanism in which thermal expansion occurs concentrically, with the expansion center always kept at the specimen-observation point.

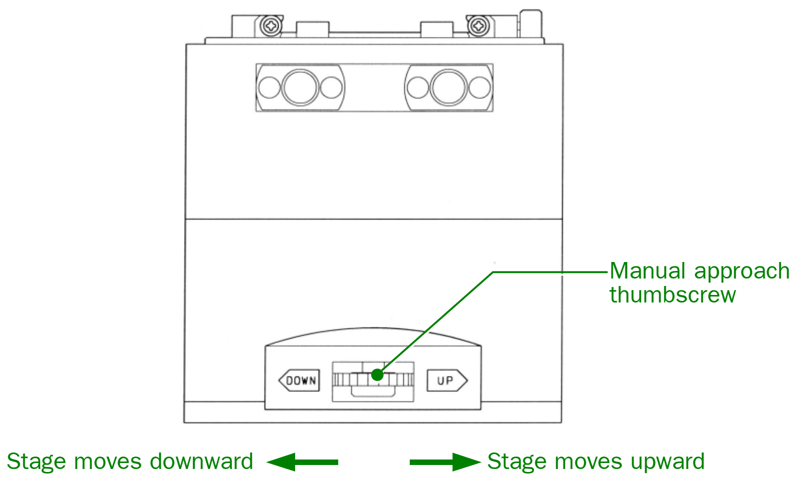
● Specimen stage coarse-shift knobs

These knobs move the specimen stage to any point in a circle with a radius of 3 mm from the stage center. One revolution of the knobs moves the stage by about 0.35 mm. The relationship between the knob operation and the specimen stage movement is shown below.



● Manual approach thumbscrew

This screw moves the specimen stage up and down.



The range of movement is 0 to 5 mm with 0.4 mm per revolution of the screw.

● Specimen stage approach unit

This unit accommodates a motor that moves the specimen stage up and down under the control of the controller. The range of motor-controlled stage movement is up to 1.5 mm.

● Photodiode Y-axis positioning knob (only for AFM)

This knob adjusts the Y-axis position of the photodiode in the SPM head unit for AFM observation.

☞ For more information, refer to Section 5.4.1, "Adjustment of Photodiode Position."

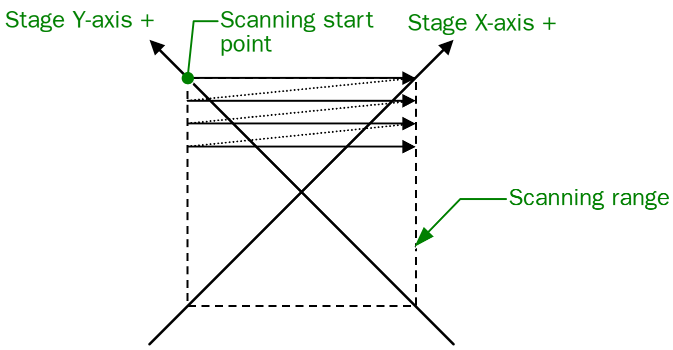
● Scanner holder

The scanner holder consists of a scanner and a specimen-stub holder.

> **⚠ CAUTION**
>
> **Handle the scanner holder very carefully since it is a precision device. It could be easily damaged by a mechanical shock.**

- Scanning direction

  The scanning direction in relation to the specimen stage axes is shown in the figure below (at a scan angle of 0°).



✍ Concerning the specimen stage, refer to the previous item, “Specimen stage coarse-shift knobs”.

● SPM head unit guide

Used to install the SPM head unit along with the SPM head unit guide.

● Head unit screw

Used to attach the SPM head unit to the SPM base unit.

● SPM head unit connectors

Used to connect the signal cables from the SPM head unit.

● Gas inlet/outlet ports

Usually covered with caps. When introducing gas, install the supplied special-purpose gas-inlet/outlet caps.

- **Cooling-system port**

  When you use the optional Cooling System, install the cooling tank on this port. Usually covered with a cap.

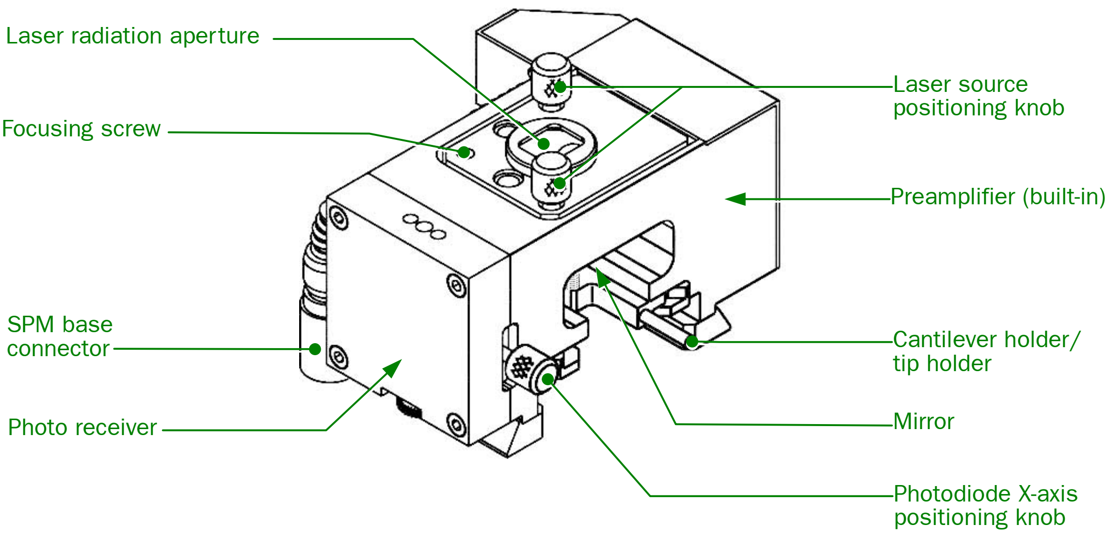
- **Utility ports**

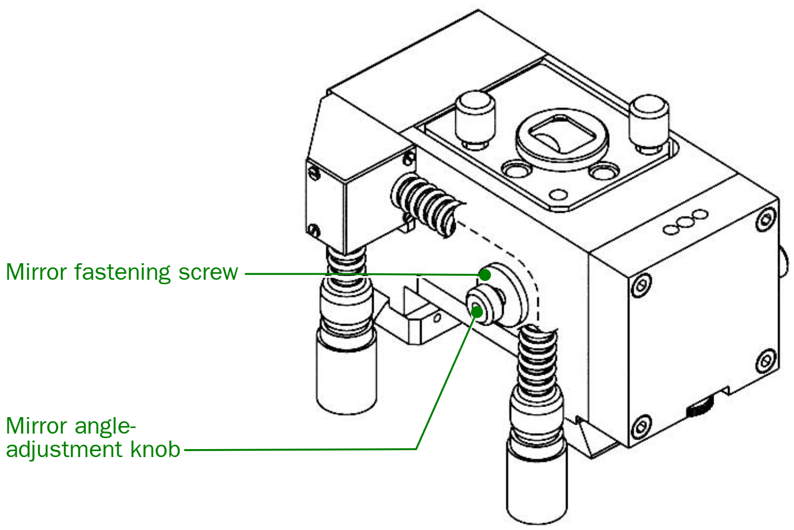
  The JSPM-5200 is provided with two utility ports for use at the user's option. They are usually covered with caps.

  ☞ Regarding the size and details of the utility ports, refer to Chapter 8, "APPENDIX."

■ SPM head unit

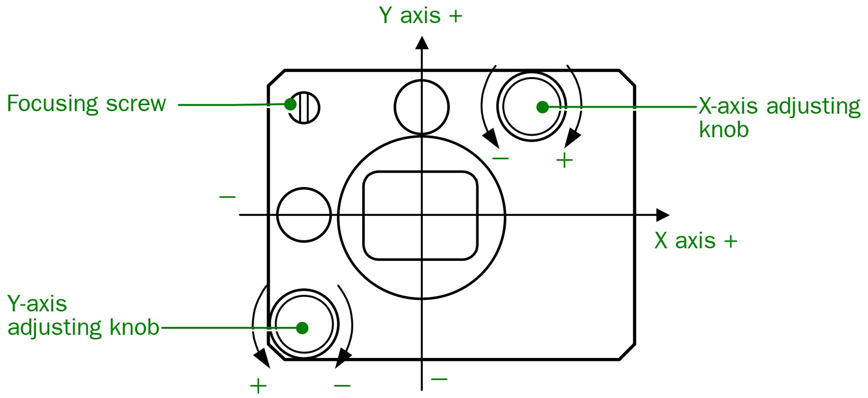
The SPM head consists of a laser source, a detector and a preamplifier.





● Laser source positioning knobs

Adjusting the two knobs positions the point of laser illumination on the cantilever.



The illuminated point moves about 0.64 mm in the X or the Y direction per revolution of either knob. The focusing screw is used to focus the laser beam on the detector.

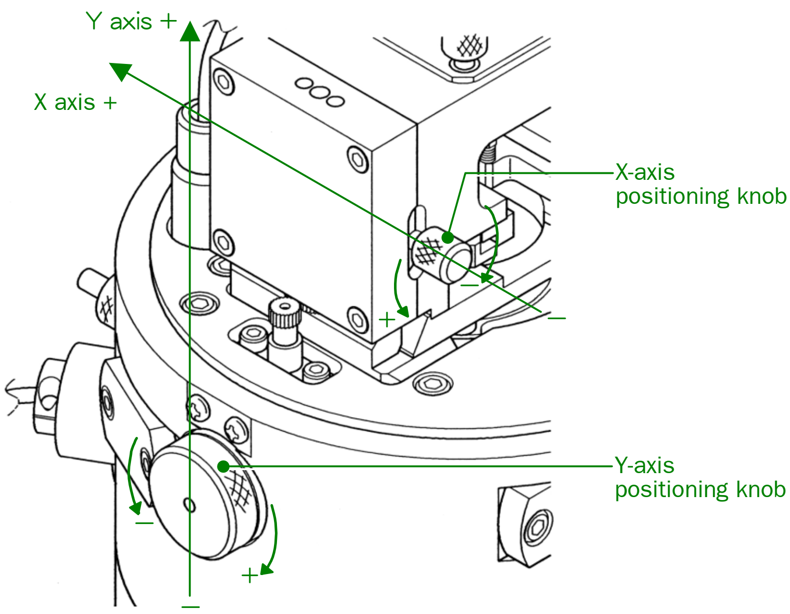
☞ For more information on focusing, refer to Chapter 8.3.1, "Laser Beam Focusing."

● Photo receiver

The photo receiver contains a four-segment photodiode.

● Photodiode positioning knobs

Used to position the photodiode in the detector.



The photodiode moves by 0.5 mm in the X direction or by 0.25 mm in the Y direction per revolution of the respective knob.

- **Mirror**

  This mirror directs the laser beam to the photodiode after it is reflected by the cantilever.

- **Mirror angle-adjustment knob**

  Adjusts the mirror angle so that the laser beam irradiates the detector correctly. Loosen the mirror fastening screw; then adjust the mirror angle by turning the mirror angle-adjustment knob. Tighten the screw.

  ☞ For more information on mirror adjustment, refer to Chapter 8.3.2, "Mirror Angle Adjustment."

- **Preamplifier**

  A preamplifier for the photodiode detector output and a preamplifier for STM tunneling current are housed in the SPM head unit.

- **SPM base unit connectors**

  Connects the SPM head unit to the SPM base unit.

- **Cantilever holder**

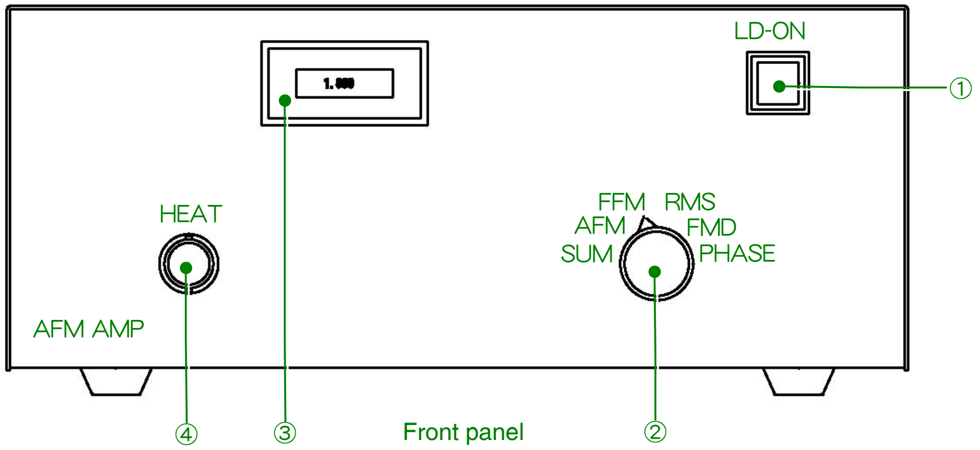
  The holder on which the cantilever is mounted. The cantilever holder is inserted into the SPM head unit.

- **Tip holder**

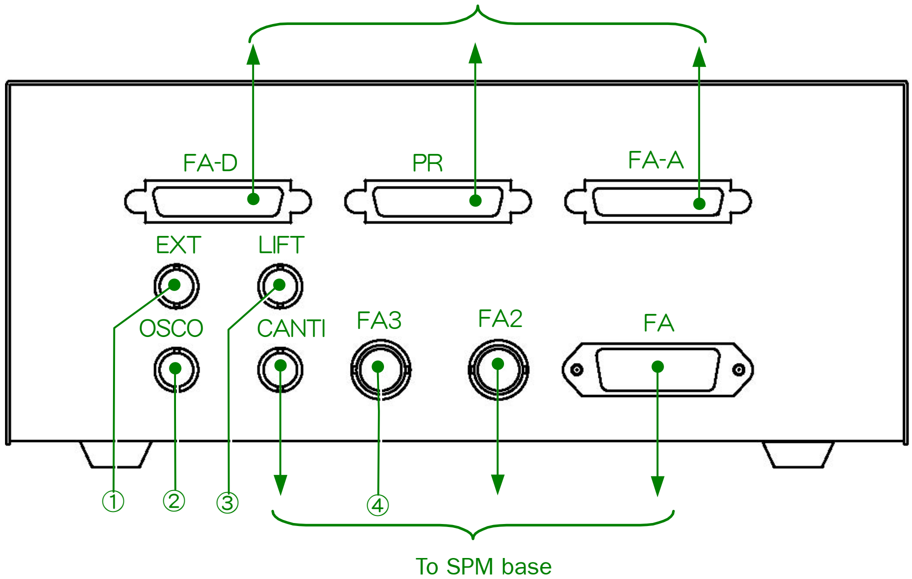
  The holder on which the tip for STM observation is mounted. The tip holder is inserted into the SPM head unit when installing a tip for observation.

3.2.2 AFM Amplifier

This amplifier is used for AFM observation. Below are the names and functions of the switches, knobs and terminals on the front and rear panels of the AFM amplifier.



Front panel



Rear panel

■ Front panel

① LD-ON switch

Turns the semiconductor laser source in the SPM head on and off. While the switch is lit, the laser source is on.

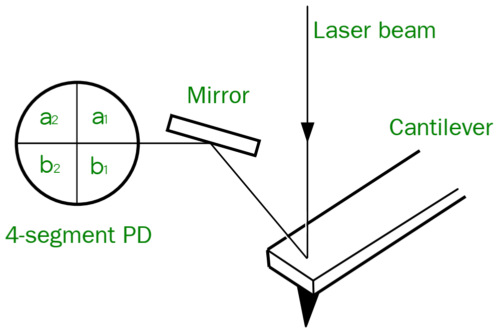
— **CAUTION** —

To turn off the power of the SPM CONTROL system, first turn off the LD-ON switch and then turn off the power of the SPM CONTROL system. The laser luminescence part may be damaged.

② Indicator selection knob

Used to select the photodiode output (SUM, AFM, FFM), the values (RMS, FMD) corresponding to the vibration amplitude and the frequency of the cantilever during AFM observation in the AC mode, and the phase output value (PHASE).

The positional relationship between the photodiode, mirror and cantilever is shown below.



$$\begin{pmatrix} a_1 + a_2 = A & b_1 + b_2 = B \\ a_1 + b_1 = C & a_2 + b_2 = D \end{pmatrix}$$

- SUM
  A+B output
  The summation of the output from all four detector elements is shown on the indicator when the knob is in this position.
- AFM
  (A-B)/(A+B) output
  The relative difference between the total laser beam intensity of the two upper detector elements and that of the two lower detector elements is indicated. If the laser beam irradiates the center of the detector, the indication is zero. If the beam irradiation point shifts upward, the indication becomes negative, and if it shifts downward, the indication becomes positive.
- FFM
  (C-D)/(C+D) output
  The relative difference between the total beam intensity of the two right detector elements and that of the two left detector elements is indicated. If the laser beam irradiates the center of the detector, the indication is zero. If the beam irradiation point shifts to the right, the indication becomes negative, and if it shifts to the left, the indication becomes positive.
- RMS
  This value is the RMS (root mean square) of (A-B)/(A+B) and corresponds to the vibration amplitude at or near the characteristic frequency of the cantilever during the AC mode AFM operation with the Slope-detection method. This value can be changed by setting gain (1×, 5×, 10×, 50×) using the software.

✍ As the RMS value is an output value of the signal input to the RMS-DC circuit, the higher the frequency becomes, the greater the effect of the low-pass filter inserted before the RMS-DC circuit, thus attenuating the amplitude. So, the RMS value sometimes becomes smaller than the (A-B)/(A+B) value that is output to AUX1.

- FMD
  Frequency of the cantilever vibration.
  The indicated value corresponds to the characteristic frequency of the cantilever in the AC mode AFM operation with the FM detection method. Since a PLL (phase-locked loop) is used for the frequency-to-voltage conversion circuit, the indicated value corresponds to the lock-range frequency.
- PHASE
  The indicated value corresponds to the displacement between the phase of the excitation signal to the cantilever and the phase of the (A-B) signal, in the AC mode AFM operation with the Slope-detection method.

③ Indicator

Indicates the output of the signal selected using the indicator selection knob in V (volt).

④ HEAT terminal

Used when heating the specimen on the specimen stage. Usually, it is connected to an optional heating power supply using a special heating cable.

⚠ CAUTION
The bias voltage to be applied to the specimen is superposed on the "B+" wire in the heating cable. Therefore, the heating power supply must be electrically isolated from the ground (GND). If one of the heating cable wires is grounded, the bias voltage circuit might be damaged.

■ Rear panel

① EXT

This is the external oscillator input terminal for inputting a sine wave with amplitude 1.0 V to this terminal. The signal applied to this terminal is adjusted to a suitable output voltage using the SPM software and is added to the cantilever vibration piezoelectric element. Set the frequency using an external oscillator.

② OSCO

This terminal outputs the reference voltage (sine wave with amplitude ±10 V) for the voltage applied to the cantilever-vibrating piezoelectric element when the Slope-detection method is used in the AC mode AFM operation. You can turn the OSCO terminal on and off and change its frequency using the SPM software.

✍ When the OSCO terminal is off, it is disconnected from the DDS, so the terminal is virtually short-circuited to GND (0 V) through the amplifier.

◆ Terminals for connecting optional accessories

③ LIFT

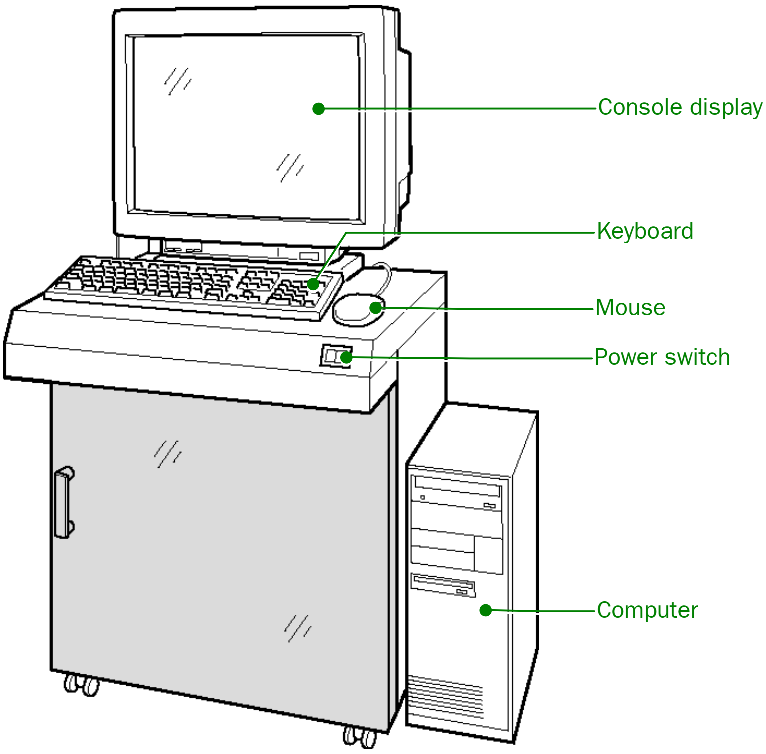
Use this terminal when connecting to the optional Q controller. TTL level HI is output when the cantilever is lifted in the Lift mode.

④ FA3

Use this terminal when connecting to the optional Q controller.

3.3 OPERATION UNIT

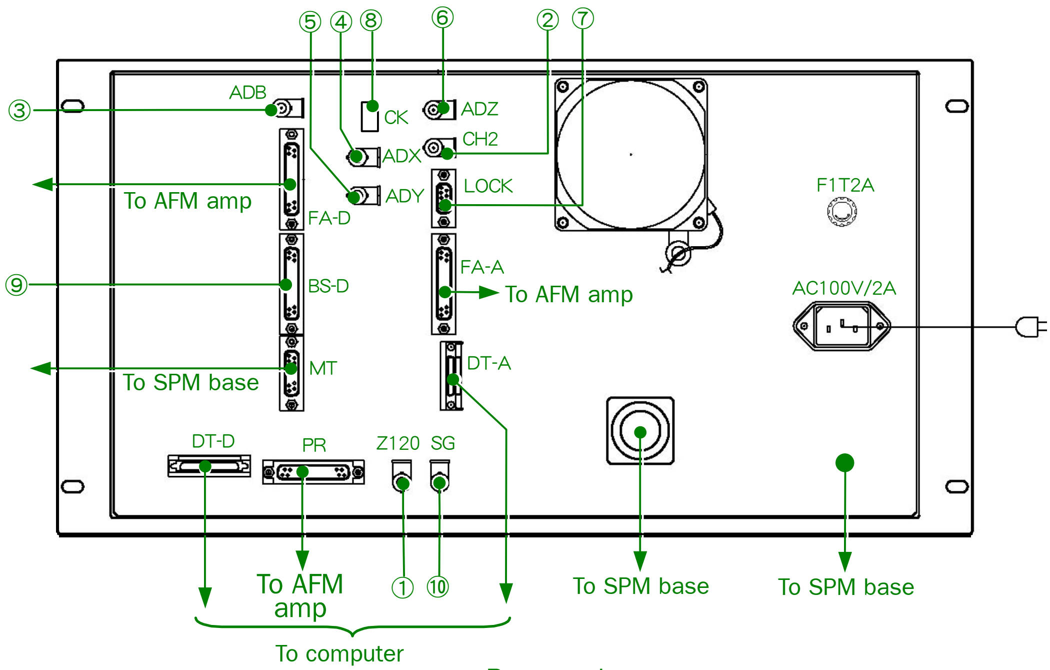
The power supply unit accommodates an SPM CONTROL system that controls the Main unit, a computer system and a console display. It also accommodates power supplies for optional accessories for lateral modulation FFM and viscoelasticity measurements, and the power supply for the evacuation system.



3.3.1 SPM CONTROL System

The names and functions of each knob, button and terminal on the front and rear panels of the SPM CONTROL system are shown below.

Front panel



Rear panel

■ Front panel

① POWER button

This is the power switch of the SPM CONTROL system. When starting the instrument, if this power switch is turned on before the computer power switch is turned on, no reset operation is required.

② POWER lamp

Goes on when the POWER button is turned on and goes out when the POWER button is turned off.

■ Rear panel

① Z/20 terminal

Outputs one twentieth of the output voltage of the Z-axis driving amplifier (the voltage applied to the Z-axis piezoelectric element). This terminal is connected to the oscilloscope.

② CH2 terminal

Outputs the signal selected using the SPM software. This terminal is connected to the oscilloscope.

③ ADB terminal

This is an input terminal used to add an external signal to a specimen bias signal. The maximum input voltage is ±10 V. However, the maximum output voltage that can be applied to the piezoelectric scanner is ±12 V in total (external input signal plus internal bias signal). Check the superimposition of the input signal to the bias voltage using the Scan window.

④ ADX terminal

This is an input terminal used to add an external signal to an X-axis scanning signal. A voltage that is 15 times larger than the input signal voltage is applied to the piezoelectric scanner. The maximum input voltage is ±10 V. However, the maximum voltage that can be applied to the piezoelectric scanner is ±150 V in total. Check the superimposition of the input signal to the X scanner using the Scan window.

⑤ ADY terminal

This is an input terminal used to add an external signal to a Y-axis scanning signal. A voltage that is 15 times larger than this input signal voltage is applied to the piezoelectric scanner. The maximum input voltage is ±10 V. However, the maximum voltage that can be applied to the piezoelectric scanner is ±150 V in total. Check the superimposition of the input signal to the Y scanner using the Scan window.

⑥ ADZ terminal

This is an input terminal used to add an external signal to a Z-axis feedback signal. A voltage that is 15 times larger than this input signal voltage is applied to the piezoelectric scanner. The maximum input voltage is ±10 V. However, the maximum voltage that can be applied to the piezoelectric scanner is ±150 V in total. Check the superimposition of the input signal to the Z scanner using the Scan window.

◆ Terminals for connecting optional accessories

The following terminals are used for connecting optional accessories.

⑦ LOCK

Connects a lock-in amplifier for extensional use.

⑧ CK

Outputs trigger signals.

1. CLOCK: To be output at the same time as image acquisition.
2. GND
3. LINE: To be output when each line starts.
4. NC
5. NC
6. NC

Socket: Kyocera Elco Corporation, Connector 9021, Insulator 6 terminals, Contact 9021 socket

Each trigger is output with a negative logic pulse of 1.6 μs (width).

The JSPM-5200 does not use the following two terminals.

⑨ BS-D

⑩ SG

3.3.2 Computer System

A video printer, a video recorder, a video converter, a video monitor and an MO disk are optional attachments.

■ Computer

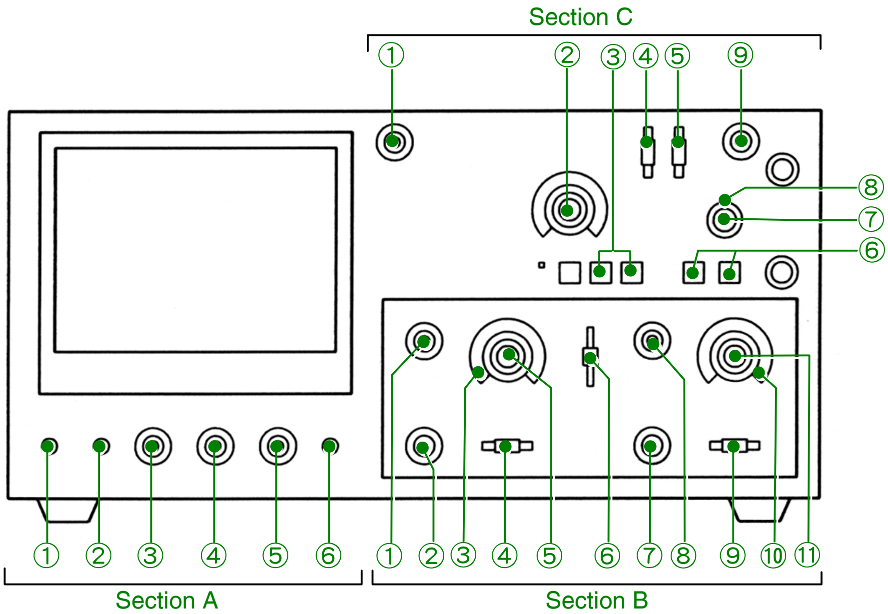
An IBM-PC/AT compatible computer is used as the control computer for this instrument.

■ Display

The control menu and specimen-surface images are displayed on this display. Image files stored in the computer memory and hard disk are also displayed on this display. You can carry out various image-processing operations directly on this display using the mouse.

3.3.3 Oscilloscope (Optional)

Below are the names and functions of the switches, knobs and buttons on the front panel of the oscilloscope.



■ Section A

① POWER

Power ON/OFF switch.

② INTENSITY

A knob for adjusting the CRT brightness. Using this knob, adjust the brightness to make the display easy to see.

③ FOCUS

A knob for adjusting the CRT focus. Adjust the focus in such a manner that the trace on the CRT looks the sharpest.

④ SCALE ILLUM

A knob for adjusting the CRT illumination. Usually, this knob is not used. Leave the knob turned counterclockwise to the limit.

⑤ TRACE ROTATION

This knob is used to correct the tilt of the trace caused by the earth's magnetic field.

■ Section B

① ⇕ (Vertical position control)

A knob for adjusting the vertical position of the trace.

② INPUT

A signal-input terminal. Connect the Z/20 terminal on the SPM CONTROL system to CH1, and the CH2 terminal on the SPM CONTROL system to CH2, using the respective BNC-BNC cables supplied.

③ VOLTS/DIV
A switch for selecting signal input sensitivity for the CH1 and CH2 signals. Usually, set it to 5V/div (turn it counterclockwise to the limit).

④ AC, GND, DC switch
A switch for selecting input-signal coupling mode. Usually, select GND when adjusting the trace position and DC during scanning.

⑤ VARIABLE
A knob for varying the input signal sensitivity continuously. Pulling the knob increases the sensitivity 5 times. Usually push it and turn it clockwise to the limit (the CAL position).

⑥ Display function selection switch
When the switch is set to CH1, only the signal input to the CH1 (Z/20) terminal is displayed. When it is set to CH2, only the signal input to the CH2 terminal (the signal selected with the SELECT knob on the SPM CONTROL system) is displayed. Usually set it to the "CHOP" position.

⑦ INPUT
Same as ② above.

⑧ ⇕ (Vertical position control)
Same as ① above.

⑨ AC, GND,DC
Same as ④ above.

⑩ VOLTS/DIV
Same as ③ above.

⑪ VARIABLE
Same as ⑤ above.

■ Section C

① ⇔Horizontal position control
A knob for adjusting the horizontal position of the trace. Pulling the knob increases the scanning rate 10 times. Usually, push the knob. Adjust the trace with the knob pressed so that it does not go outside of the CRT.

② TIME/DIV
A switch for selecting the scanning rate. Set it to a position so that the observation waveform can be easily seen. Usually, 2 ms/div is used.

③ NORM/AUTO
A switch for selecting the scanning rate. Usually, AUTO is used.

④ Trigger Coupling
A switch for selecting the trigger signal coupling. Usually, AC is used.

⑤ Trigger Source
A switch for selecting the trigger signal. Usually, INT is used.

⑥ Internal Trigger Source

Switches for selecting the trigger signal. These switches are in effect only when the Trigger Source switch ⑤ is set to INT. Usually, VERT (both switches are pressed) is used.

⑦ VARIABLE

A knob for varying the scanning rate continuously. Usually, push the knob and turn it clockwise to the limit (the CAL position).

⑧ HOLD OFF

A knob for adjusting the holdoff time. Usually, turn it clockwise to the limit (the NORM position).

⑨ LEVEL

A knob for setting the trigger level. Usually, turn it counterclockwise to the limit (the FIX position).

4

PREPARATION FOR OBSERVATION

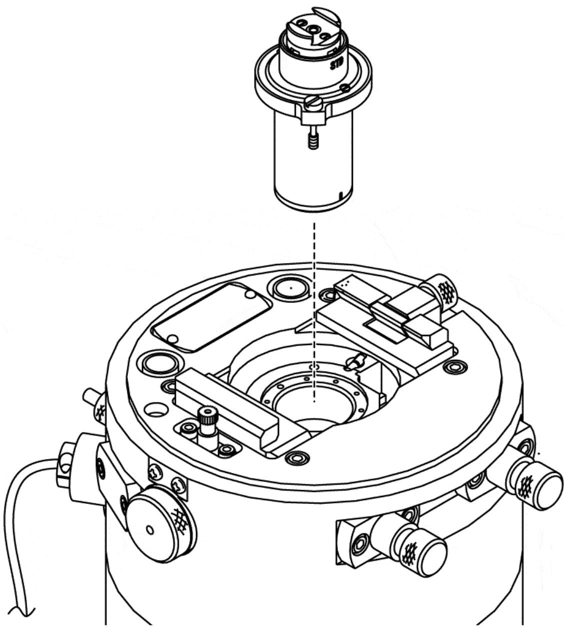
4.1 PREPARATION FOR STM OBSERVATION 4-1
4.1.1 Outline 4-1
4.1.2 Mounting the Specimen Holder 4-3
4.1.3 Mounting the Scanner Holder 4-4
4.1.4 Mounting the SPM Head Unit 4-5
4.1.5 Mounting the Cantilever 4-5
4.1.6 Mounting the Tip 4-6
4.1.7 Inserting the Cantilever Holder or the Tip Holder into the SPM Head Unit 4-7
4.1.8 Mounting a Specimen 4-8
4.1.9 Specimen Exchange 4-9
4.2 ADJUSTMENT FOR AFM OBSERVATION 4-10
4.2.1 Adjusting the Laser Beam Position 4-10
4.2.2 Adjusting the Photodiode Position 4-14
4.2.3 Rough Approaching 4-17

4.1 PREPARATION FOR STM OBSERVATION

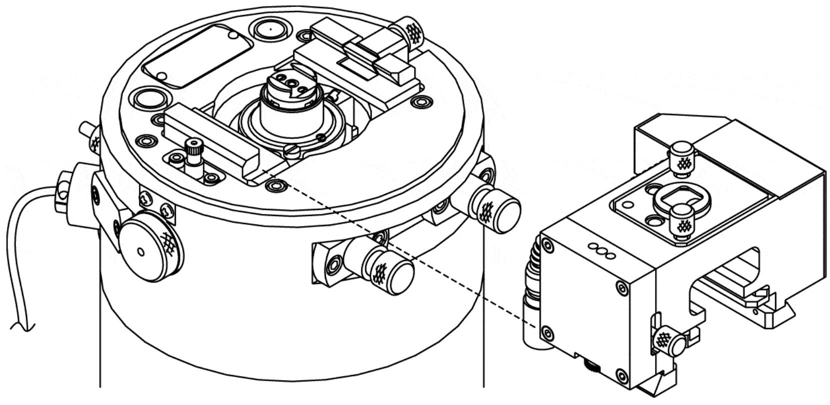
4.1.1 Outline

This section outlines the preparation for SPM observation using the JSPM–5200, from SPM-head unit setting to specimen loading.

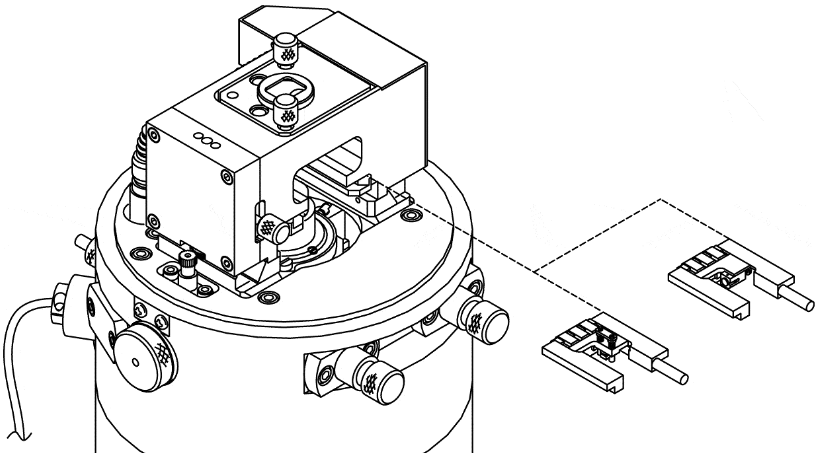
1. Attach an appropriate scanner holder to the SPM base according to the scanning area to be observed.



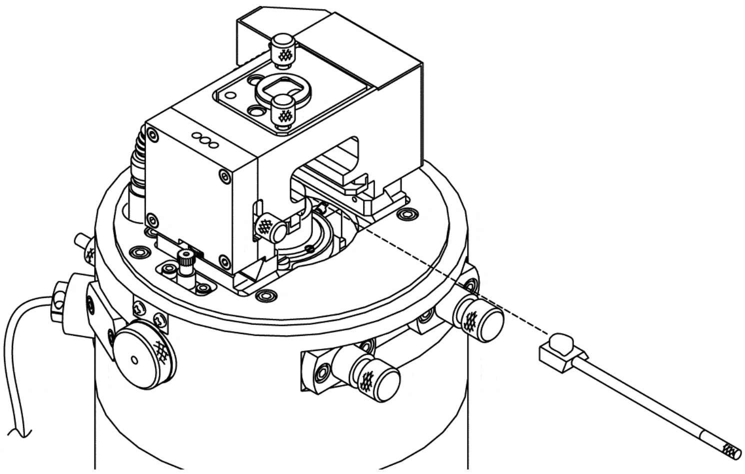
2. Attach the SPM head unit to the SPM base.



3. Insert the cantilever holder or the tip holder to the SPM head unit.

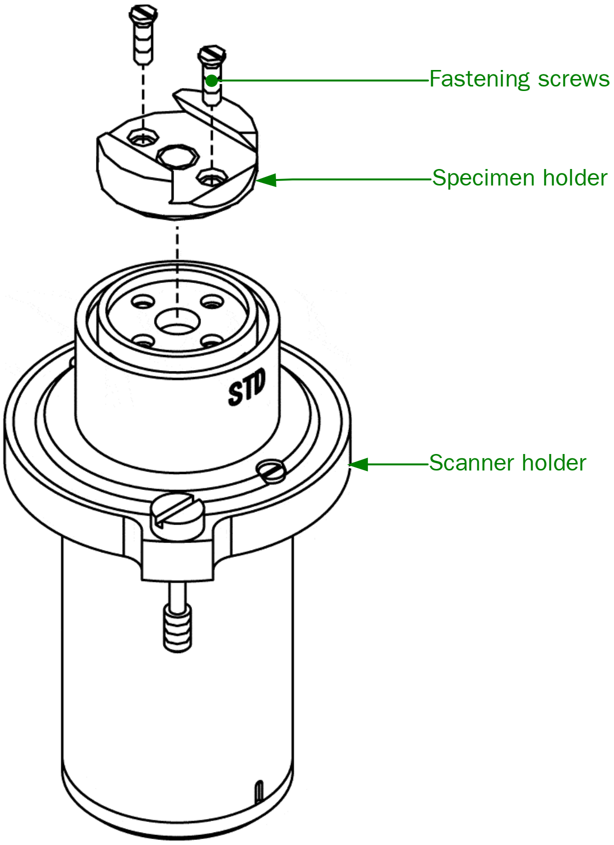


4. Insert a specimen stub into the scanner holder.



4.1.2 Mounting the Specimen Holder

Below is the method of mounting the specimen holder on the scanner holder.
Mount the specimen holder with the beveled side coincides with front of the scanner holder. The engraving on the front of the scanner holder cap identify type of the scanner.



✍ When mounting the specimen holder on the scanner holder, be careful to tighten the two fastening screws evenly.

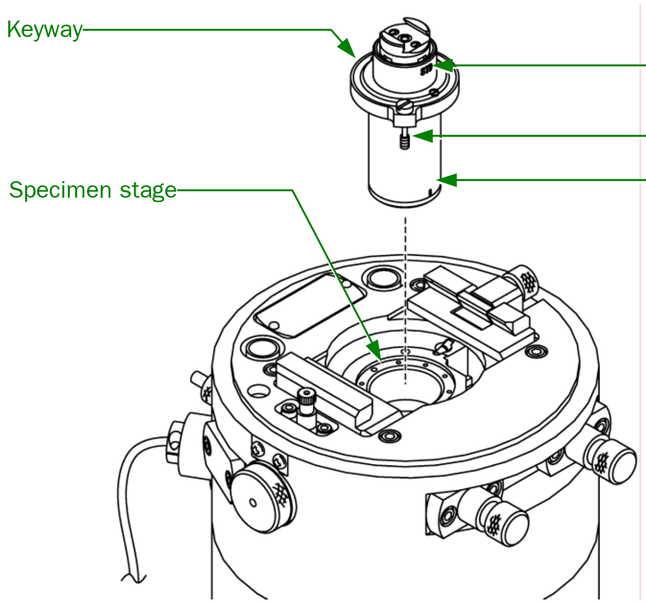
⚠ CAUTION
Handle the scanner holder very carefully. Since it is a precision mechanism, it could be damaged by a strong mechanical shock.

4.1.3 Mounting the Scanner Holder

1. Turn off the SPM CONTROL unit.

> ⚠ **WARNING**
>
> **Be sure to turn off the power to the SPM CONTROL unit in advance when mounting or dismounting the scanner holder, specimen holder or SPM head unit. There is a risk of electric shock due to the high voltage applied to the connector pins from the SPM CONTROL unit.**

2. Select the scanner holder having the most suitable scanning range according to the specimen to be observed (if you have optional scanner holders). Insert it into the specimen stage along the keyway. Then, lock it with the two fastening screws.



When you replace the scanner holder with an optional one, you have to designate the new one using the WinSPM software. For the designating procedure.

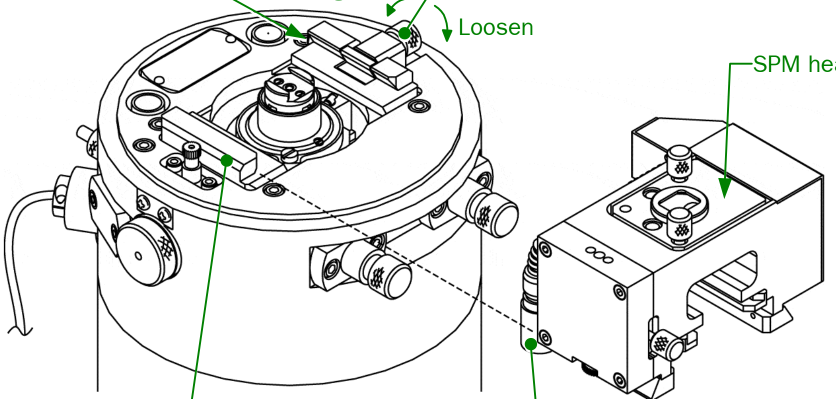
☞ Refer to Section 5.10.1, "SPM Scan Menu."

The engravings of the scanner holder are as follows.

Engraving	Type of scanner	Scanning range	
		X Y	Z
STD	Standard scanner	10	3
NSC	Narrow area scanner	1	1
WSC	Wide area scanner	80	5
WZS	Scanner for biological material	50	10
SWZ	Scanner for rugged surfaces	30	15

4.1.4 Mounting the SPM Head Unit

1. Loosen the SPM head unit fastening screw.
2. Insert the SPM head unit along with the head unit guide rail on the SPM base unit until it touches a stopper. Then, lock it with the head unit fastening screw.
3. Insert the two connectors on the SPM head unit into the receptacle connectors on the SPM base unit, along with the groove, until you hear a click.

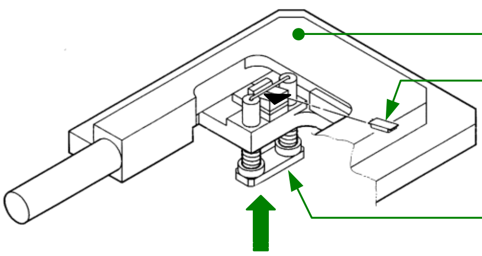


4.1.5 Mounting the Cantilever

Below is the procedure for mounting the cantilever on the cantilever holder in order to perform AFM observation.

☞ When performing STM observation, refer to Section 4.1.6, "Mounting the Tip."

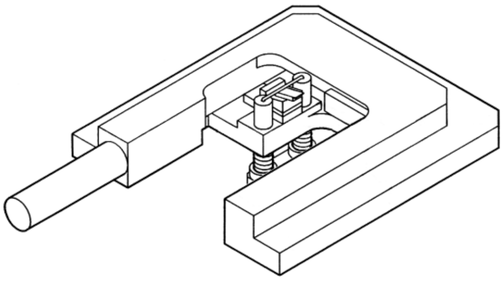
1. Cut out a cantilever element from a strap.
   ☞ For more details about handling the cantilever, refer to the instruction manual coming with the cantilever.
2. Insert the cantilever element into the cantilever groove while pushing up the spring retainer (for example, by pushing the cantilever holder body using a desk).



⚠ CAUTION

1. **Be sure to insert the cantilever along with the groove. Otherwise, the cantilever may be damaged due to an excessive force being applied when the spring retainer is released.**
2. **Never touch the area around the cantilever on the cantilever holder with bare fingers. If that part is contaminated with hand grease, that might give rise to insufficient insulation, thus possibly causing tunneling current leakage or incorrect operation of the piezoelectric element.**
3. **Push the spring retainer vertically. If you force it diagonally, the ceramic might be damaged.**

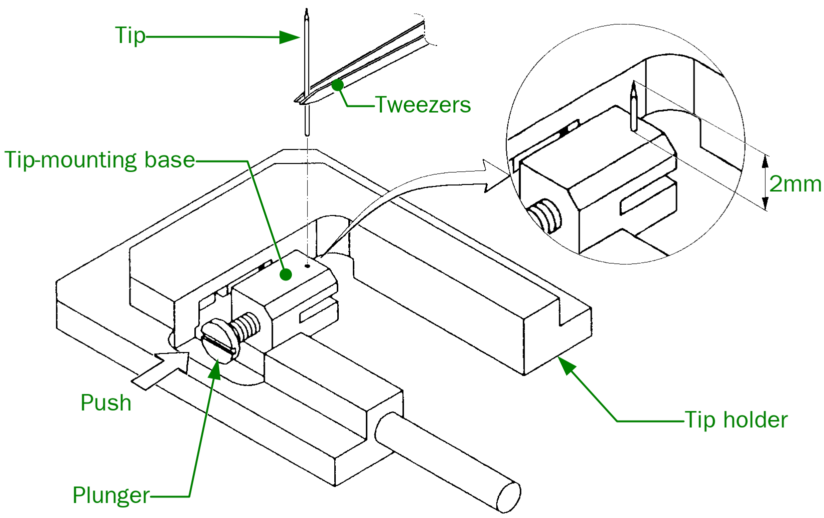
3. Release the spring retainer slowly to lock the cantilever in place.



4.1.6 Mounting the Tip

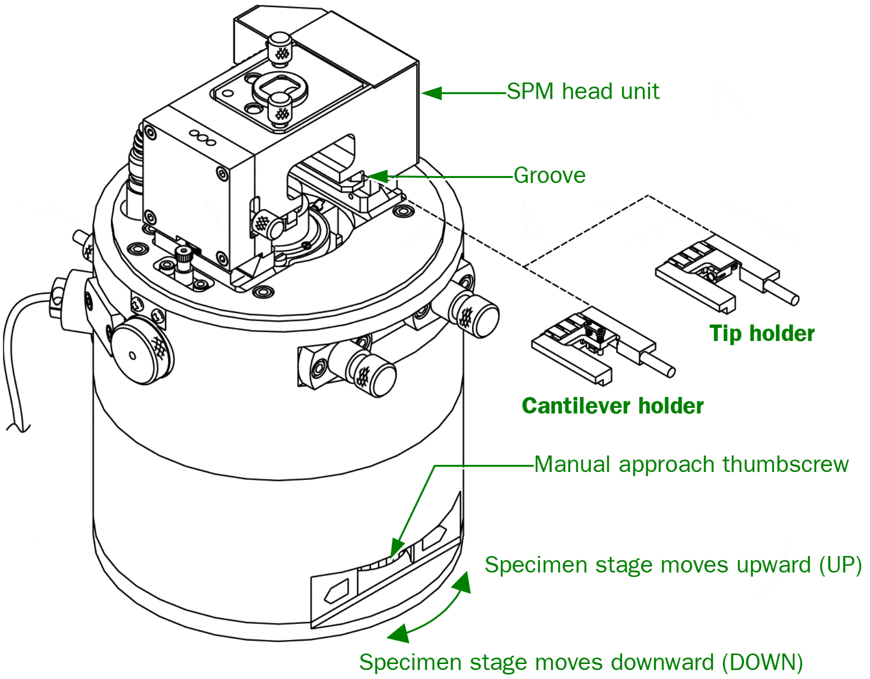
Below is the procedure for mounting the tip on the tip holder in order to perform STM observation.

To mount the tip on the tip holder, insert the tip into the plunger while pushing the plunger as shown in the figure below to align the external and internal tip-mounting holes. Make sure that the length from the top of the tip to the surface of the tip mounting base is 2 mm.



4.1.7 Inserting the Cantilever Holder or the Tip Holder into the SPM Head Unit

1. In order to prevent the cantilever or the tip from colliding with the scanner holder, confirm that the specimen stage is lowered to a low enough position. If it is not, move the specimen stage downward by turning the manual approach thumbscrew.



2. Insert the cantilever holder or the tip holder into the SPM head unit groove until it touches the innermost wall.

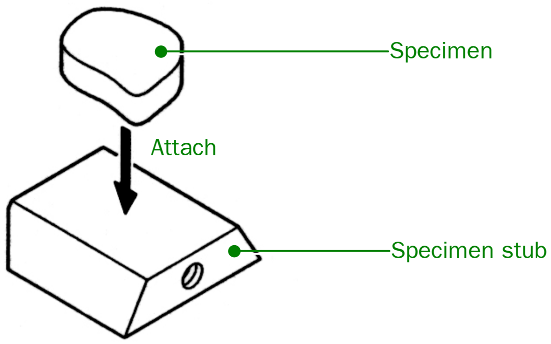
4.1.8 Mounting a Specimen

1. Attach a specimen to the specimen stub.

   Attach a specimen to the specimen stub with an appropriate material such as double-faced adhesive tape or conductive paint.

⚠ CAUTION

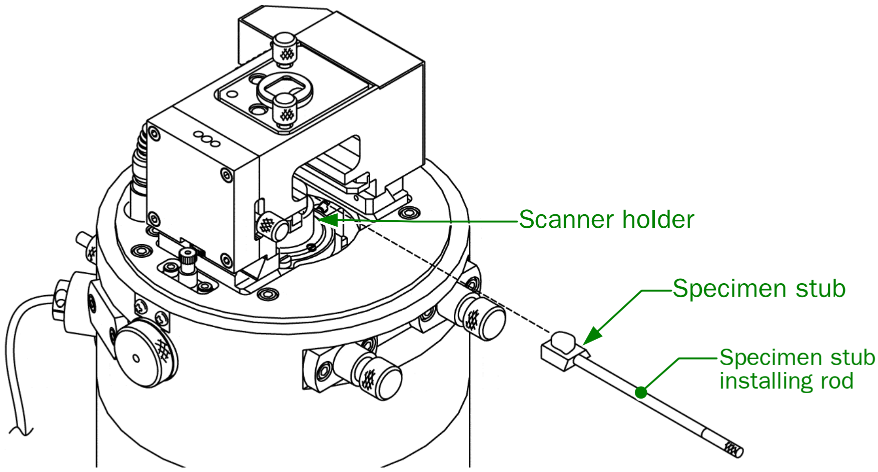
The specimen stub is gold-plated. Be careful not to scratch the stub surface.



2. In order to prevent the specimen or specimen stub from colliding with the cantilever or the tip, confirm that the specimen stage is set at a low enough position. If it is not, move the specimen stage downward by turning the manual approach thumbscrew as shown in Section 4.1.7, "Inserting the Cantilever Holder or the Tip Holder into the SPM Head Unit."
3. Insert the specimen exchange rod into the specimen stub and slide the specimen stub into the groove of the scanner holder until it clicks.

⚠ CAUTION

Insert or remove the specimen stub horizontally with care. If an excessive force is applied to the scanner holder, the scanner inside it might be damaged.



4.1.9 Specimen Exchange

When you replace the specimen just observed with a new specimen, you do not need to turn off the SPM CONTROL unit.

> ⚠ **WARNING**
>
> **Never exchange a specimen while a high bias voltage is being applied to the specimen. You might get an electric shock due to the high voltage applied to the specimen.**

1. Click on SPM Scan on the main menu of the WinSPM software and select Scan ··· from the pull-down menu. Then, select the Advanced tab. The SPM Parameters window will be displayed.
2. Select the Tip button, and the Tip window will be displayed.
3. Confirm that the High Bias check box ☐ located at the bottom left of the Tip window has not been checked.

   If the check box has been checked ☑ click on it to remove the check mark from the check box.

4.2 ADJUSTMENT FOR AFM OBSERVATION

Below are the procedures for adjusting the laser beam and the photodiode in the AFM head unit and for roughly approaching the specimen.

4.2.1 Adjusting the Laser Beam Position

Turn on the SPM CONTROL unit according to the procedure of Section 5.3.1, "Starting the System in Measurement Mode."

1. Turn on the LD-ON switch on the AFM amplifier unit.

   The switch lamp lights and the laser beam will be emitted.

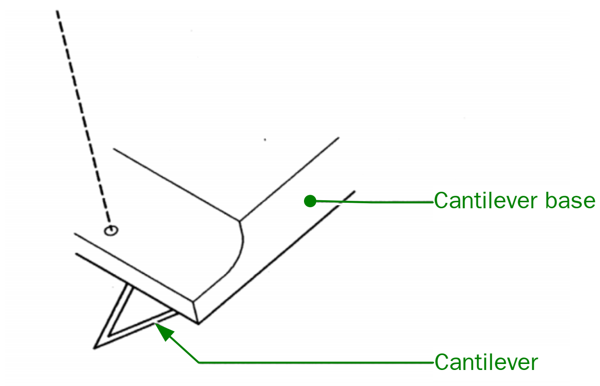
2. Adjust the laser illumination position adjusting knobs so that the laser beam illuminates correctly the tip of the cantilever while watching the illumination position through a CCD-mounted optical microscope.

> ⚠ **WARNING**
>
> **A Class 2 laser is used in this microscope. Do not look directly in the observation instruments such as the optical microscope. Look in the observation instrument indirectly by using a detecting device with CCD.**

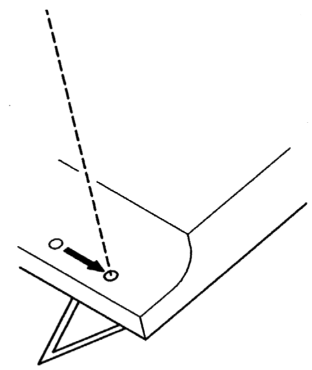
> ⚠ **WARNING**
>
> **Be careful not to get irradiation bombardment from the laser radiation aperture locating near the laser source position adjusting knobs.**

a. Adjustment procedure 1

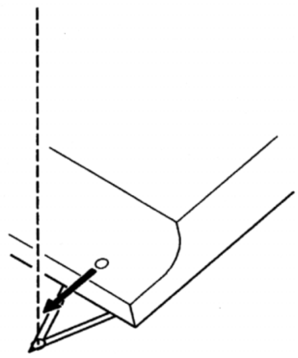
- Adjust the laser beam using the knobs so that the laser beam spot illuminates the edge of the cantilever base.



- Shift the laser beam spot so that it illuminates the edge of the cantilever base corresponding to the center of the cantilever, as shown below.

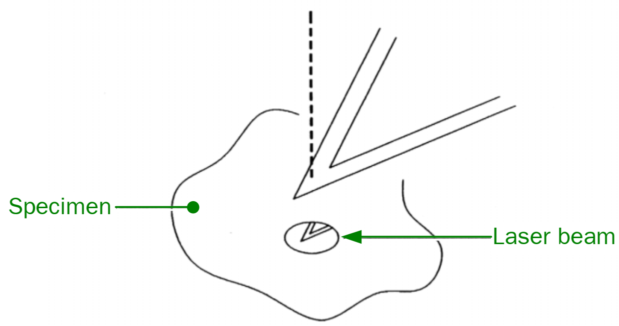


- Shift the laser beam spot so that it illuminates the tip of the cantilever, as shown below.



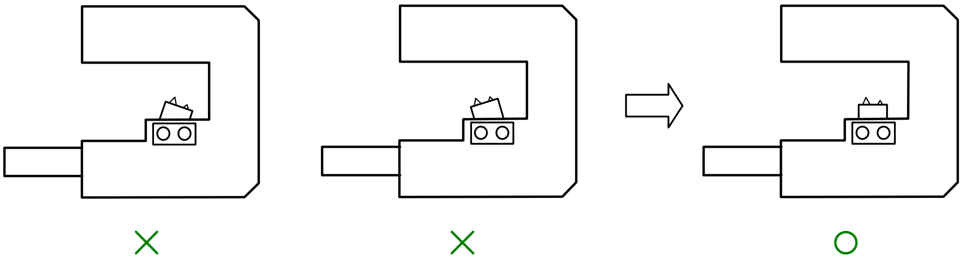
b. Adjustment procedure 2

- At this stage of adjustment, observe the laser beam spot on the specimen surface.



- Carry out fine adjustment of the laser beam spot position so that the laser beam spot on the specimen becomes as dark as possible.
  The range of the laser beam position adjustment is wide enough to handle almost all cantilevers. If the laser beam position fails to shift even though the laser beam illumination adjustment knobs are turned, the laser beam position may have shifted out of the beam position adjustment range. In such a case, check the following points.
  Is the cantilever holder inserted properly (does it touch the innermost wall) ?
- Especially in the case of the cantilever holder, its insertion becomes difficult due to the electrode on the holder when the holder gets near the innermost wall. Be sure that the holder touches the innermost wall.

• Is the cantilever set at a proper angle on the cantilever holder ?

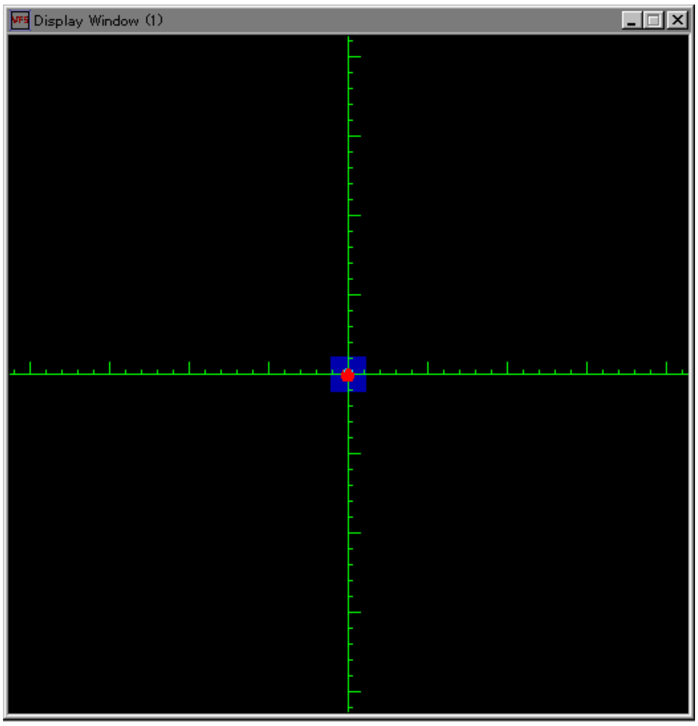


⚠ CAUTION

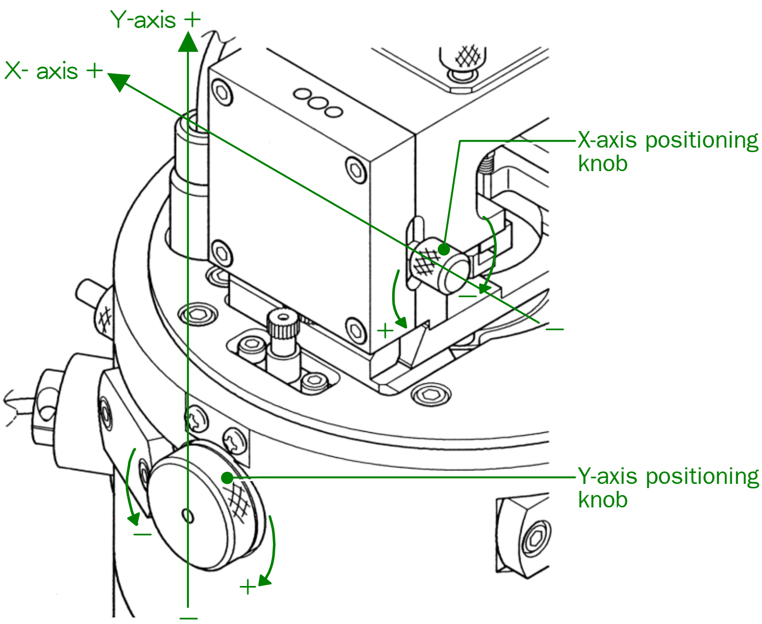
Although the focus of the laser beam has been adjusted in the factory before shipment, the beam may be out of focus for some reason. If so, readjust the beam focus referring to Chapter 7, "MAINTENANCE."

4.2.2 Adjusting the Photodiode Position

- Click on the Adjust PD button, and the Display Window shown below appears.



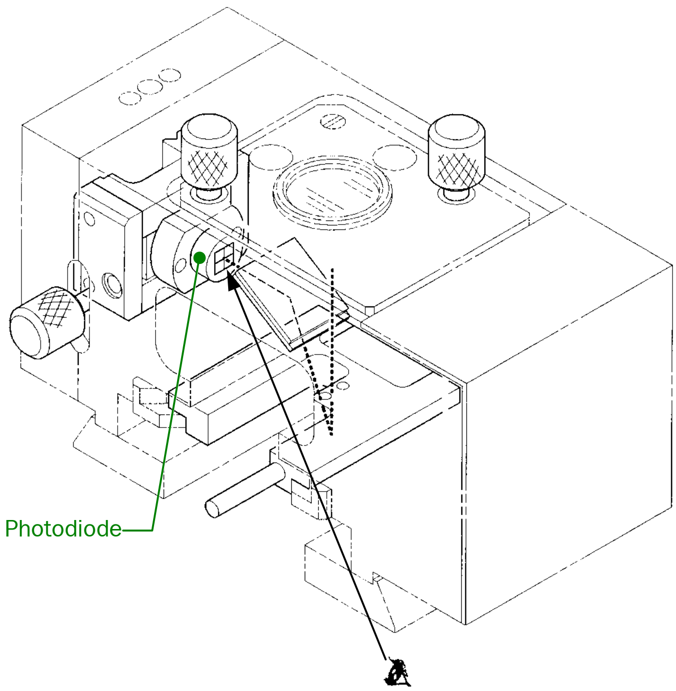
Adjust the position of the photodiode using the photodiode positioning knobs (for X-axis and Y-axis) so that the red spot enters the blue region in the center of the window.



Now, the laser beam illuminates the center of the photodiode.

☞ When the Si_3N_4 cantilever is used in this state, the SUM value is about –8.00 V to –10.0 V. When the Si cantilever for the AC mode is used, the SUM value is about –5.00 V. If the SUM value is small, it is conceivable that the laser beam position on the cantilever may have shifted from the correct position. Readjust the laser beam position according to Section 4.2.1, "Adjusting the Laser Beam Position."

● Photodiode adjustment procedure



1. To roughly adjust the photodiode position, watch the laser beam spot on the photodiode from the right side of the AFM head unit.
2. Adjust the photodiode position using the X- and Y-axis positioning knobs so that the center (▚) of the photodiode is positioned at the center of the laser beam.

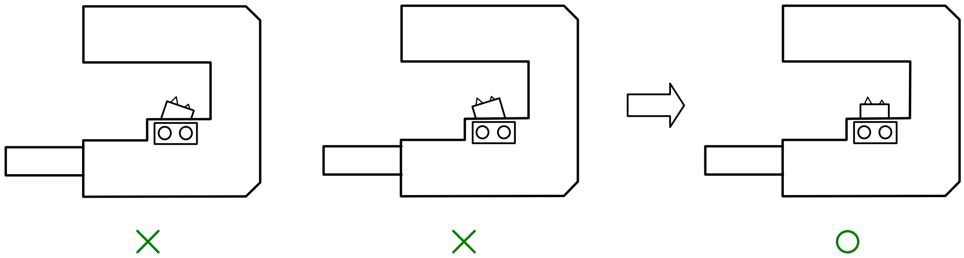
⚠ WARNING

Look in the AFM head more than 20 cm away from the AFM head since a Class 2 laser is provided in the AFM head.

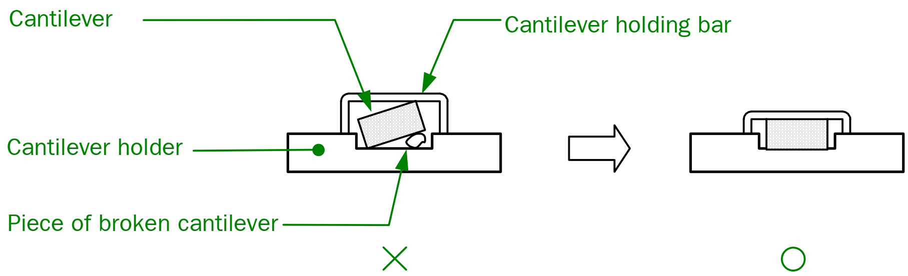
● The FFM value cannot be adjusted to 0.

Such a case probably occurs when the cantilever is not set correctly on the cantilever holder. Check the following four points.

- Is the cantilever set straight on the cantilever holder ?



- Is the cantilever inclined in the cantilever groove ?
  Such a case occurs mainly when burrs or broken pieces produced when the cantilever is cut out are inserted between the cantilever and the cantilever holder.

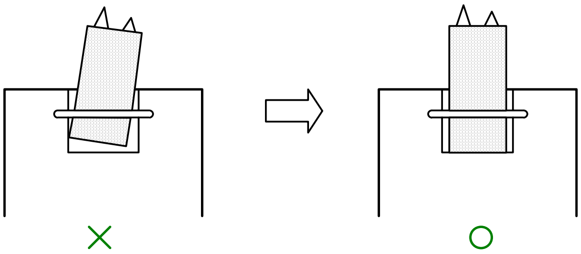


- Is the cantilever holder inserted properly (does it touch the innermost wall) ?
  Especially in the case of the cantilever holder, its insertion becomes difficult when the holder gets near the innermost wall due to the electrode on the holder. Be sure that the holder touches the wall.
- Is "External" 0 ?
  Confirm that the External value of Feedback/Filters Advanced in the Advanced tab on the SPM Parameters window in the WinSPM software is 0.0 V.

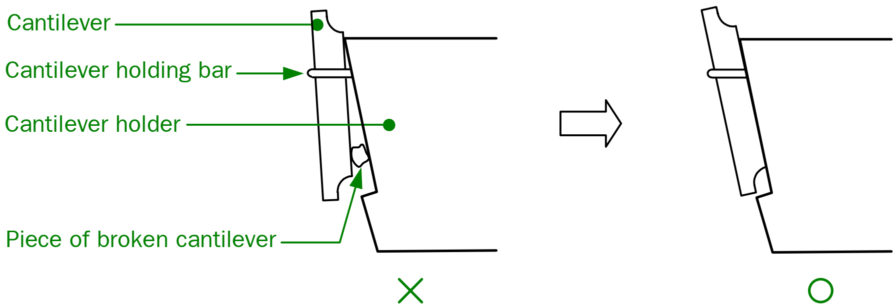
● The AFM value cannot be adjusted to zero, or the laser beam reflected by the cantilever does not illuminate the mirror.

Check the following two points.

- Is the cantilever inserted properly into the cantilever groove until it touches the innermost wall of the holder? Or, is there a piece of broken cantilever or something between the cantilever and the holder ?



- Is the cantilever holder inserted properly? Or, is there a piece of broken cantilever or something in the groove ?



If the AFM value still cannot be adjusted to 0 after the above checks, try to adjust the mirror position according to Chapter 8, "MAINTENANCE." If you cannot adjust it correctly, the cantilever itself may be bent or broken. Check the cantilever storage condition according to Chapter 8, "MAINTENANCE." If all these attempts are unsuccessful, replace the cantilever.

4.2.3 Rough Approaching

1. Using the Coarse Stage function of the SPM software, confirm that the stage is positioned within the range for approaching.
   ☞ For the confirmation procedure, refer to Section 5.3.5, “Checking the Stage Position.”
2. Watching the distance between the cantilever and the specimen using the optional optical microscope, turn the manual approach thumbscrew so that this distance becomes about 0.3 mm or less.

This completes the preparation for AFM observation.

5

MEASUREMENT OPERATION

5.1 BASIC USAGE OF WinSPM 5-1
  5.1.1 Before use 5-1
  5.1.2 Glossary 5-1
  5.1.3 Setting the User Name 5-4
5.2 STARTING THE SCAN (MEASUREMENT) MODE 5-7
  5.2.1 Selecting SPM Operation Mode 5-7
  5.2.2 SPM Parameters Window (Measurement Setting Window) 5-9
  5.2.3 Shortcut Icons 5-11
  5.2.4 Software Oscilloscope 5-12
  5.2.5 Lock-In Amplifier 5-13
  5.2.6 Specimen Temperature Controller (for JSPM-5200) 5-18
  5.2.7 CCD Camera 5-18
  5.2.8 Digital Control MFM unit 5-19
5.3 PREPARING FOR MEASUREMENT 5-20
  5.3.1 Starting the System in Measurement Mode 5-20
  5.3.2 Resetting the Controller 5-21
  5.3.3 Confirming Settings of the Device Setup Dialog Box 5-21
  5.3.4 Opening the SPM (Measurement) Parameters Window 5-21
  5.3.5 Checking the Stage Position 5-22
  5.3.6 Setting an Optional Oscilloscope 5-23
5.4 AC AFM MODE 5-25
  5.4.1 AC Mode Tab 5-25
  5.4.2 MFM Tab 5-36
  5.4.3 VE-AFM Tab 5-41
  5.4.4 SKPM Tab 5-45
  5.4.5 Advanced Tab 5-54
5.5 CONTACT AFM MODE 5-80
  5.5.1 Contact Mode Tab 5-80
  5.5.2 Viscoelasticity Tab 5-91
  5.5.3 Lateral Modulation FFM Tab 5-95
  5.5.4 Electrostatic Force Tab 5-99
  5.5.5 Advanced Tab 5-102

5.6 STM MODE 5-132
5.6.1 STM Tab 5-132
5.6.2 Advanced Tab 5-143
5.7 GENERAL PRECAUTIONS FOR IMAGE ACQUISITION 5-159
5.8 TERMINATING MEASUREMENT 5-165
5.9 TERMINATING OPERATION 5-166
5.10 REFERENCE 5-167
5.10.1 SPM Scan Menu 5-167
5.10.2 SPM Parameters (Simple) 5-177
5.10.3 SPM Parameters (Advanced) 5-202
5.10.4 Setting Lock-in Amplifier 5-253
5.10.5 Controlling Specimen Temperature 5-259
5.10.6 CCD Camera 5-263

5.1 BASIC USAGE OF WinSPM

5.1.1 Before use

Before using WinSPM, confirm that the system is properly set up and that the calibrated values of scanner sensitivity and motor drive position have been recorded. If and when it becomes necessary to re-install the WinSPM software, you must save these values in WinSPM once again.

☞ For details, refer to Sect. 7.2, "Setting Up the WinSPM Program."

5.1.2 Glossary

Basic terms used in discussing WinSPM are explained below.

● Administrator's privilege

In WinSPM, the name of a user (normally a system administrator) who has access privileges to windows relating to system maintenance is registered as "Admin". Once the name of the administrator has been registered, no other name can be registered as "Admin".

If you log into WinSPM as an "Admin", you can perform the following operations.

- Setting, altering or saving the calibrated values of the scanner
- Starting special measurement mode to calculate the calibrated values of the scanner
- Altering the power supply voltage
- Setting, altering or saving the calibrated values of the motor drive position

✍ Parameters such as measurement and display conditions saved with the (Admin) user name compose the basic parameters.

✍ The password for user name "Admin" is saved by default as JEOLSPM (with all characters in uppercase). Before using the instrument, be sure to change the password. We recommend that a password for the person responsible for the SPM system be used.

✍ The Administrator's privileges involve changing instrument conditions such as the power supply voltages and other important settings. If they were to be changed erroneously, malfunction of the instrument might occur. To avoid this, start up WinSPM with the user privilege described below.

● User's privilege

Users' names other than "Admin" are designated for enabling all measurement operations except those relating to maintenance. Use these privileges in routine operation.

● Multitasking

You can start WinSPM in either scan or process mode. You may start the system in both modes simultaneously, thereby enabling you to perform image processing while performing measurements.

● Main menu

This is the menu bar stretching across the top of the window, opened when WinSPM is in operation, containing the names of available pull-down menus, the contents of which differ depending upon operation mode—namely, scan mode or process mode.

● Pull-down menu

This menu appears below a button  selected from the main menu or from a window. To select a menu item from this pull-down menu, move the cursor to the menu item that you wish to select, using the mouse so that the menu item is highlighted, then click on the highlighted menu item.

● Clicking a mouse

This is an operation in which you move the mouse cursor to a selected point, and then click the left button once.

● Double-clicking a mouse

This is an operation in which you move the mouse cursor to a selected point, and then click on the left button twice in rapid succession.

● Dragging a mouse

This is an operation in which you move the cursor while you hold down the mouse button.

● Input window

This is an area for entering text and numerical values using the keyboard. By moving the mouse cursor to the position of the input window and double-clicking, you can highlight previously entered text and numerical values. Directly type new text and values using the keyboard. Simply typing text and values does not automatically finalize the entered data. To do this, you must either press the Tab key or select another item using the mouse.

● Check box

A box ☑ containing a tick mark means that the corresponding item has been selected. A box ☐ that does not contain a tick mark means that the item has not been selected. To select an item, move the mouse cursor to the ☐ mark and click on it. Likewise, to cancel selection of an item, move the mouse cursor to the selected ☑ mark and click on it.

● Radio button

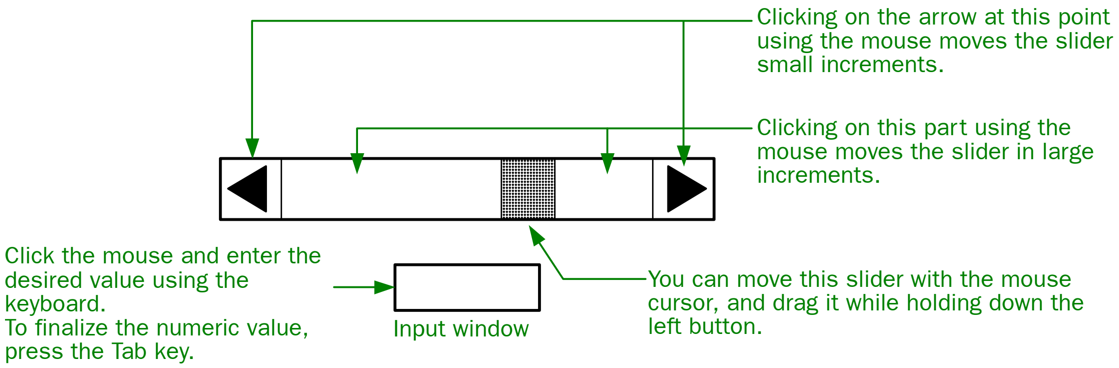
A button marked ⊙ means that the corresponding item has been selected. A button marked “○” means that the corresponding item has not been selected. A radio button is used to select one item from among two or more items. To select an item, move the mouse cursor to the ○ mark, and click on it. To cancel selection of an item, simply select another item. In so doing, selection of the first item will be canceled automatically.

● Gray display

If a check box, radio button, input box, or the like is displayed in gray, it indicates that you cannot select it.

● Slider

You can change the parameter values in the parameter setting slider shown below using either the keyboard or the mouse.



5.1.3 Setting the User Name

The WinSPM system enables you to set your user name and store parameters such as measurement and display conditions in separate personal files. The method of setting the user name is as follows.

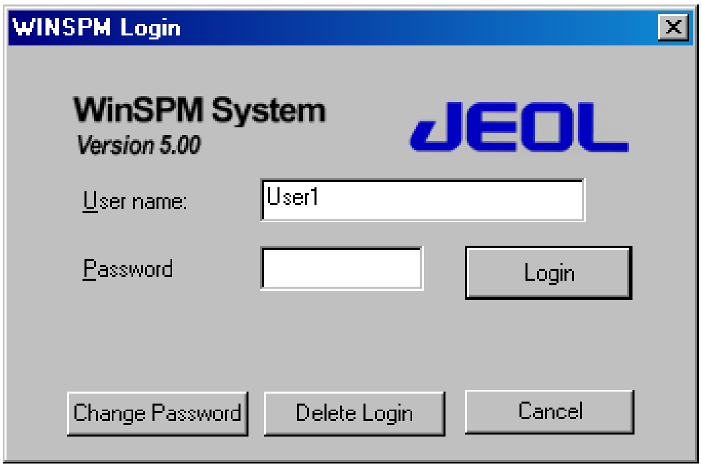
✍ No user name other than the name “Admin”— which belongs only to the user who has the authority of an administrator—is stored in the initial state of WinSPM. Be sure to store a new user name before you begin to use the system.

● Creating a new user name

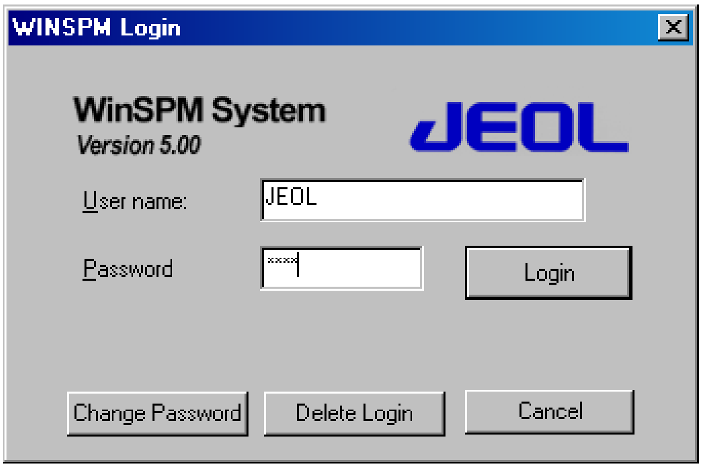
The procedure for storing a new user name is as follows:

1. Start the WinSPM system.

The WINSPM Login dialog box will open as shown below:



2. Enter the desired new user name; then also enter the password using the keyboard; then click on the Login button.



In the above example, JEOL is entered as User name and “test” is entered as Password.

✍ All entered characters will be displayed as the “*” marks.

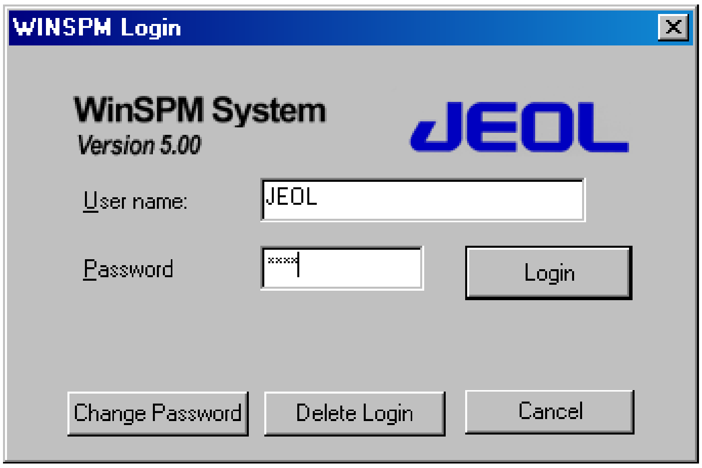
3. When the Create new login dialog box opens as shown below, click on the OK button.

The new user name will be stored.

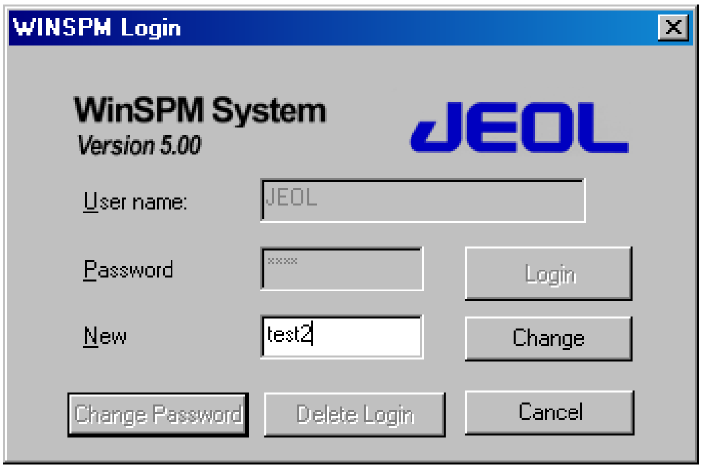
● Changing a password

An already stored password can be changed as follows:

1. Start the WinSPM system, and enter the user name and password.



2. Click on the Change Password button. The dialog box changes as shown below if the user name and the password are correct. Enter the desired password in the New box.



In the above example, “test2” is entered as the new password.

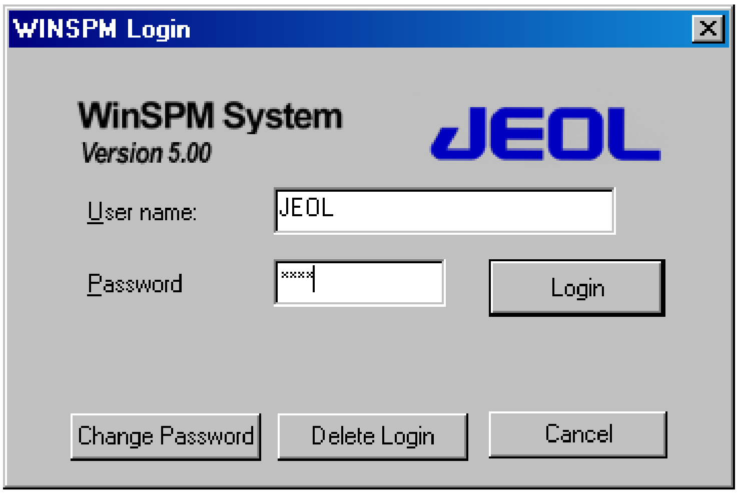
3. Click on the Change button. The Change Password dialog box opens as shown below.

Clicking on the Yes button changes the password.
The new user name will be stored.

- **Deleting a user name**

The procedure to delete a user name which is already stored is as follows:

1. Start the WinSPM system, and enter the user name and the password.



2. Click on the Delete Login button.
   If the user name and password were entered correctly, the Winspm dialog box opens.

3. Click on the Yes button.
   The user name will be deleted.

5.2 STARTING THE SCAN (MEASUREMENT) MODE

WinSPM has two modes, a scan mode and a process mode, which function independently of each other. Here, operation of the scan mode is explained.

5.2.1 Selecting SPM Operation Mode

The operation control window differs depending on the SPM operation mode selected from the dialog box that opens when the system starts.

The functions of the radio buttons in the dialog box are detailed below:

- **AC AFM**

AFM measurements are possible in AC (slope), phase, or frequency detection mode.
In SPM measurement, you can perform the following measurements:
Shape measurement
SPS (Scanning probe spectroscopy) measurement
SPS mapping measurement
MFM (Magnetic forth microscope) measurement
Viscoelasticity measurement
Kelvin probe measurement.

The optional lock-in amplifier is needed for viscoelasticity and Kelvin probe measurement.

- **Contact AFM**

In this mode, you can perform the following measurements:
Shape measurement
SPS (Scanning probe spectroscopy) measurement
SPS mapping measurement
MFM (Magnetic forth microscope) measurement
Viscoelasticity measurement
Lateral modulation friction force microscopy measurement
Electrostatic force microscopy measurement.

✍ The optional lock-in amplifier is needed for measurement of viscoelasticity, lateral modulation friction force microscopy and electrostatic force microscopy.

- **STM**

The following measurements are possible:
Shape measurement
SPS (Scanning probe spectroscopy) measurement
SPS mapping measurement
✍ No optional measurement is available in the standard system configuration.

- **All SPM Mode**

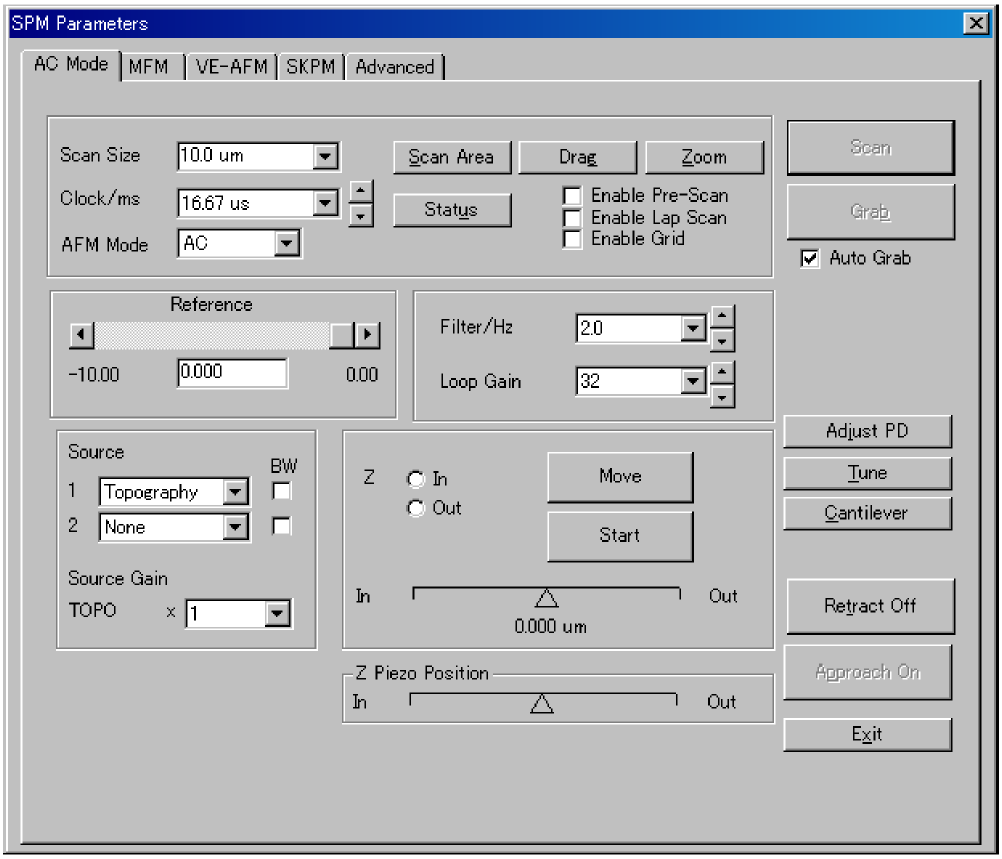
In this mode, the above three modes (AC AFM, Contact AFM, and STM) can run simultaneously. Since neither restriction nor protection on the control of SPM measurement is provided, it is mandatory that you thoroughly understand the system and nature of the measurement.

5.2.2 SPM Parameters Window (Measurement Setting Window)

The SPM Parameters window is the most fundamental window in the SPM system. It contains the tabs that open windows to control each independent operational mode and the tab (Advanced) that opens the tab window containing controls for detailed items of each operational mode.

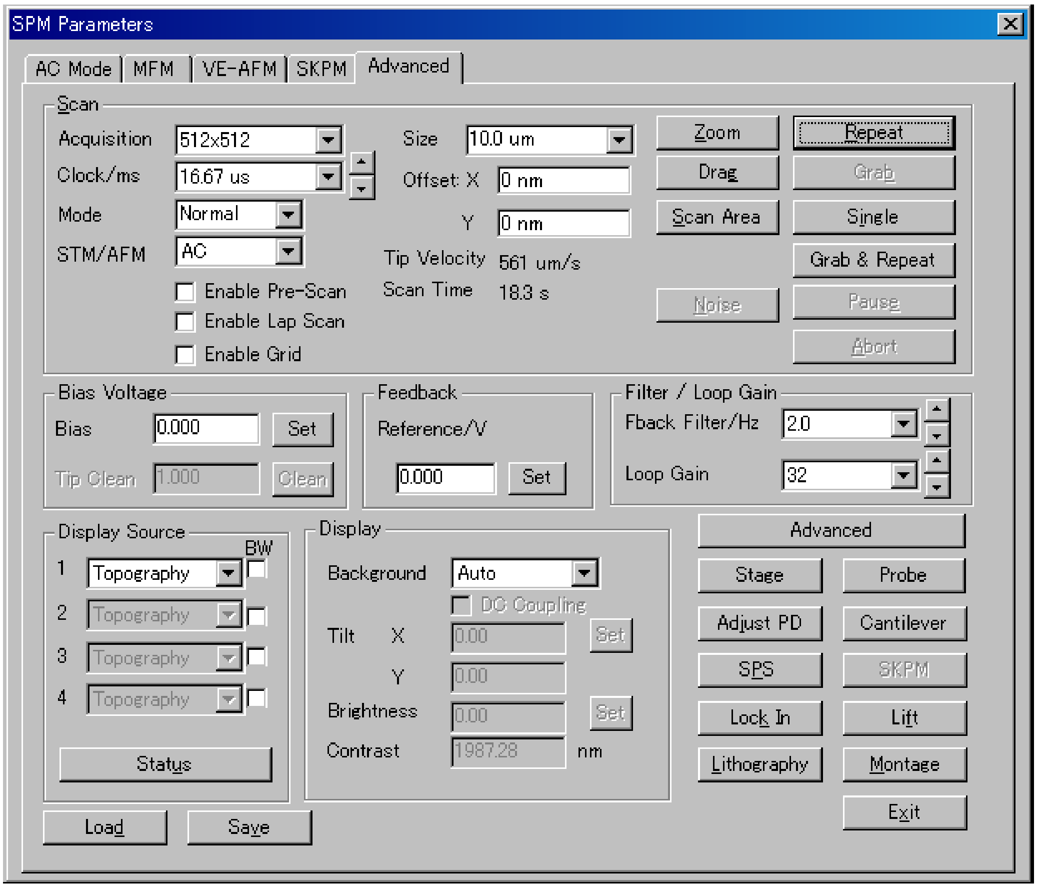
● AC Mode, MFM, VE-AFM, and SKPM tab windows

These windows automatically set parameters required for each operational mode allowing the operator to perform the measurement with ease. Although this method to set the parameters is most suitable for SPM measurement under atmospheric pressure, it is not so ideal for UHV SPM measurement which requires additional adjustments.



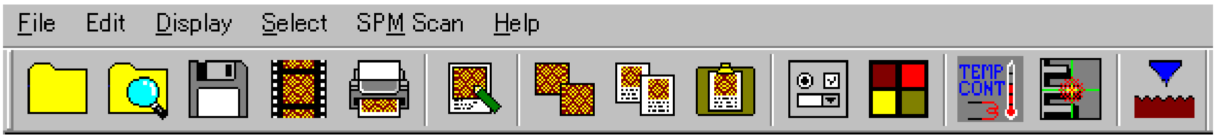
● Advanced tab window

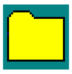
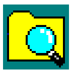
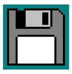
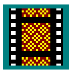
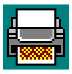
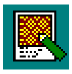
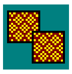
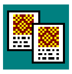
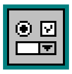
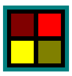
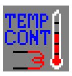
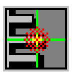
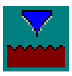
This window is used mainly for UHV SPM measurement. All of the parameters should be set by the user. This enables you to make more detailed settings. When all of the SPM operational modes are selected, only the Advanced tab window is open.



5.2.3 Shortcut Icons

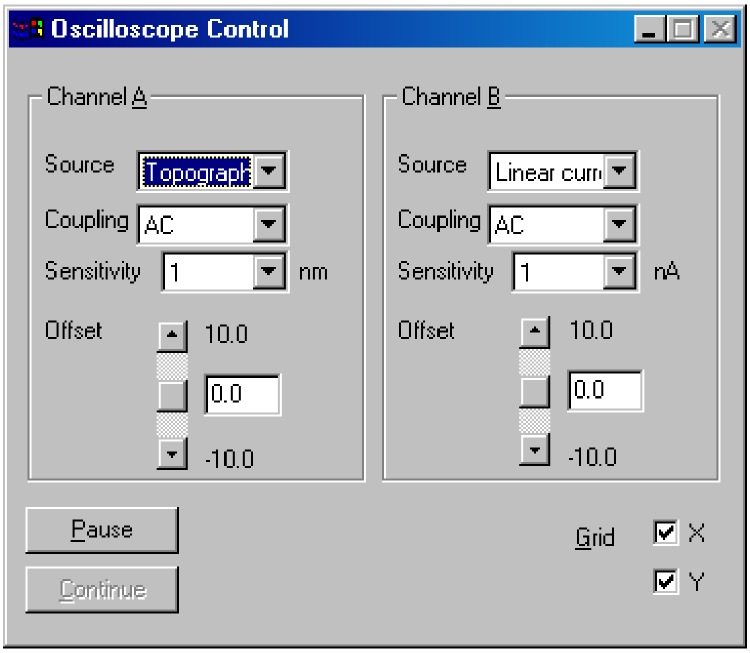
Shortcut icons are placed just under the main menu.

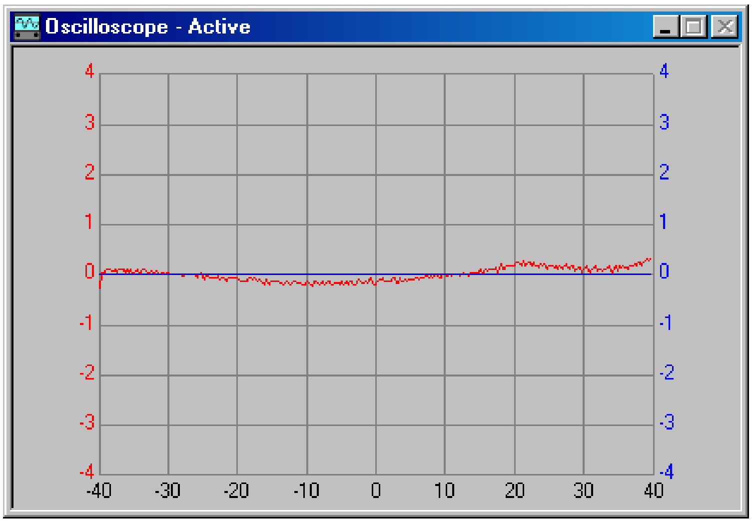


	Open	Reads file data from the disk.
	Search	Searches file data from the list.
	Save	Saves data to a disk.
	Replay	Replays images obtained by continuous measurement as quasi movies.
	Print	Prints the data.
	Report	Creates the report.
	Copy	Transfers a displayed image to the clipboard.
	Data copy	Transfers data to the clipboard.
	Data paste	Transfers data from the clipboard.
	Display settings	Opens the display settings dialog box.
	Color settings	Opens the color settings dialog box.
	Temperature control	Opens the specimen temperature control dialog box. (Optional)
	CCD	Opens the top observation CCD dialog box. (Optional)
	Measurement	Opens the measurement settings dialog box.

5.2.4 Software Oscilloscope

You can use the oscilloscope on the software. Clicking on the Oscilloscope Control and Oscilloscope (🗗) buttons on the WinSPM window opens the Oscilloscope Control and Oscilloscope windows as shown below, enabling you to monitor the state of signals under measurement.





■ Setting Channel A

This software oscilloscope enables you to acquire and display data from two channels at the same time. Channel A is displayed in red, and Channel B in blue. Normally, set Channel A to Topography (motion in the Z direction of the scanner). The setting of Channel B differs depending upon the scanning mode (Contact mode, AC Mode, STM, etc.), so refer to the respective operation methods.

The procedure for setting Channel A is as follows:

1. Click on the Source button, and select Topography from the pull-down menu.
2. Click on the Coupling button, and select DC from the pull-down menu.
3. Click on the Sensitivity button, and select sensitivity from the pull-down menu.

   The numerical value of the sensitivity displayed in the pull-down menu automatically changes according to the sensitivity of Z of the presently selected scanner.
4. Double-click on the Offset numerical value input box, and enter 0.0 using the keyboard.
5. Once you have completed settings, select File from the main menu, and then select Store Configuration from the pull-down menu to save the set values.

   If you skip Step 5 above, the system will revert to the initial settings the next time it is started.

5.2.5 Lock-In Amplifier

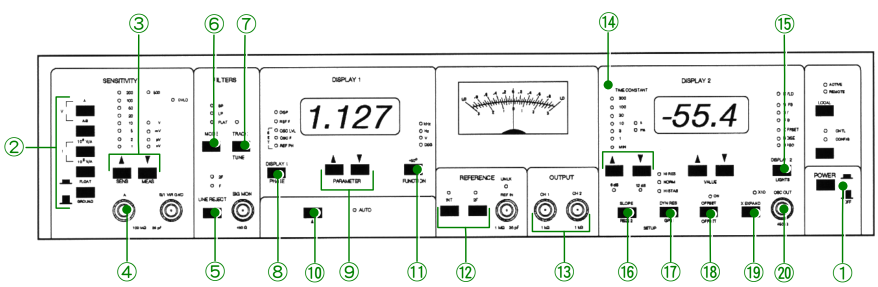
This optional lock-in amplifier expands the application of the system, enabling you to perform the following measurements:

- Viscoeleasticity measurement
- Lateral modulation friction force measurement
- SKPM (Scanning Kelvin Probe Microscopy) measurement
- Electrostatic force measurement

The Model 7265 lock-in amplifier is needed when you perform electrostatic force measurement.

■ Model 5110 lock-in amplifier

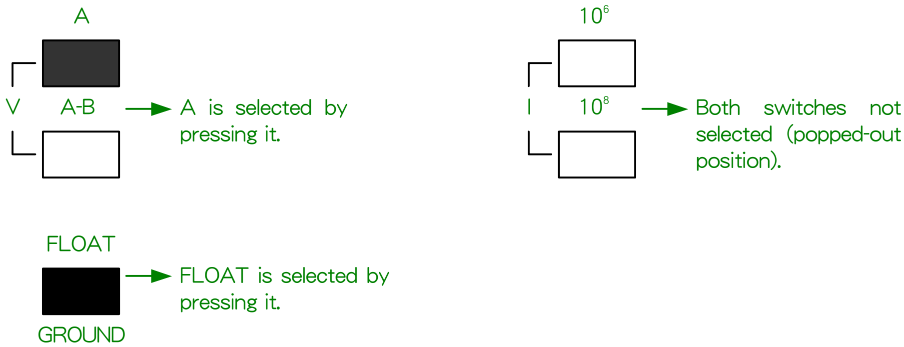
● Front operation panel



The functions of the switches and indications are detailed below.

① POWER — This switch turns on or off the power.

② Input selection switches — These switches select input signals. When using the Lock-in Amplifier, set the switches as follows:



③ SENSITIVITY setting keys — These keys set input sensitivity. Set the highest sensitivity so that the OVLD indicator does not light.

④ “A” (INPUT) terminal — This is a signal input terminal.

⑤ LINE REJECT key — If this key is on, the frequency of the power (AC100V) that enters the input signal will be filtered. You do not usually use this key.

⑥ FILTERS MODE key — If this key is on, the input signal will be filtered. Usually, you select “BP”.

⑦ FILTERS TRACK key — This key decides whether the frequency range for filtering is changed or not, according to the reference signal. You usually select TRACK.

⑧ DISPLAY1 key — This key selects which value to display out of the set value and the CH1 output value. The presently displayed value corresponds to the one for which the LED is lit.

⑨ PARAMETER keys — These keys change the set value selected by the DISPLAY1 key ⑧.

⑩ AUTO key — If this key is on, parameters such as phase will be set automatically.

⑪ +90/FUNCTION key — Every time you press this key, the phase will be changed by 90°.

⑫ REFERENCE keys — These keys are used for selecting reference signal and components ($\omega/2\omega$) of detected signal for the Lock-in Amplifier. Turn the INT LED on, and turn the F LED off.

⑬ OUTPUT terminals — These are the signal output terminals. Change the type of signals to output to CH1 and CH2 by using the output selection key ⑮.

⑭ TIME CONSTANT setting keys — These keys set the time constant of the lock-in amplifier. You can change the time constant according to the scan speed of the SPM. Usually, you select MIN.

⑮ Output selection key — You can change the Acosϕ (CH1) and Asinϕ (CH2) outputs, or the amplitude (CH1) and phase (CH2) outputs.

⑯ SLOPE key — This key specifies the filtering of output signals. Usually, you select 6dB.

⑰ DYNRES (dynamic reserve) setting key — You usually select NORM or H1 RES when using the lock-in amplifier.

⑱ OFFSET key — You usually select OFF when using the lock-in amplifier.

⑲ X EXPAND setting key — You usually select OFF when using the lock-in amplifier.

⑳ OSC OUT terminal — This terminal is used for the modulation oscillator.

● Setting (Model 5110) RS-232C of lock-in amplifier

The RS–232C is adjusted and set before factory shipment. However, if an error should occur when you are operating the lock-in amplifier, perform the following procedure.

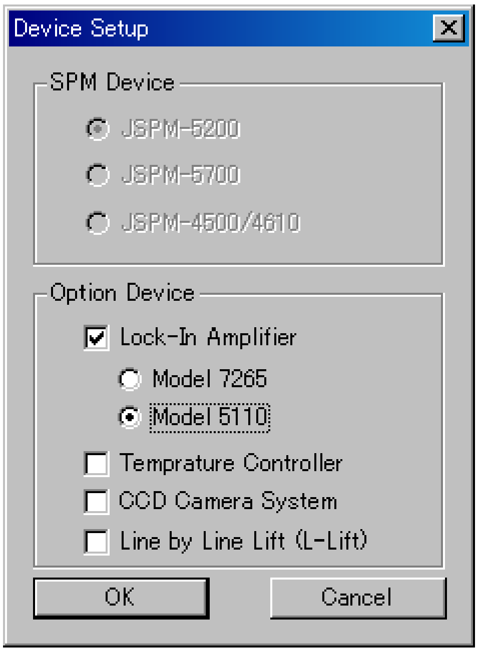
1. Press the CONFIG key at the right end of the Lock-in Amplifier panel, and then press the RS232 key.
2. Confirm that 0 is displayed on the digital panel of the DISPLAY1 frame, and that 11 is displayed on the digital panel of the DISPLAY2 frame. If 11 is not displayed, press the VALUE ▲, ▼ keys until 11 is displayed.
3. Press the PARAMETER ▲ key until 1 is displayed on the digital panel of the DISPLAY1 frame; then confirm that 16 is displayed on the digital panel of the DISPLAY2 frame. If 16 is not displayed, press the VALUE ▲, ▼ keys until 16 is displayed.
4. Press the CONFIG key again.

Then the settings will be as follows:

BAUD RATE	9600
DATA BITS	7
PARITY	Enabled and even
STOP BITS	1
RS232 ECHO	Enabled
PROMPT	Enabled

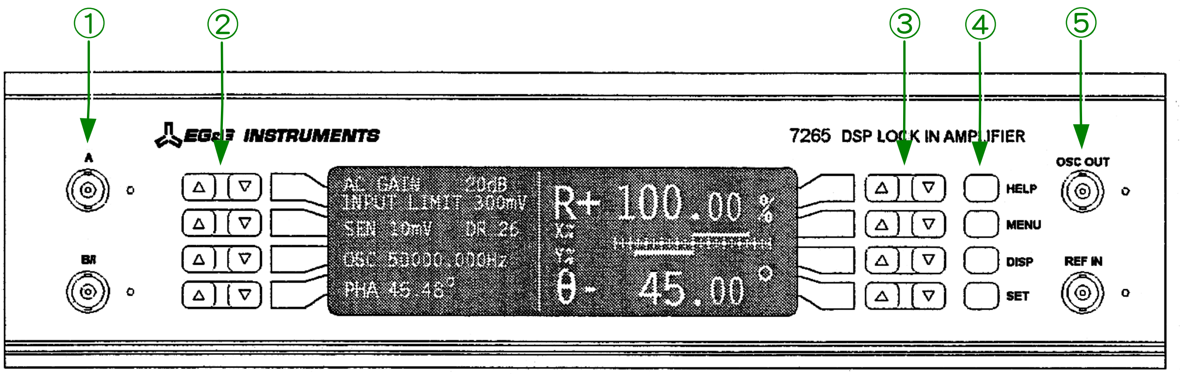
- **Setting software (Model 5110)**

  1. Click on SPM Scan in the main menu bar to open the pull-down menu; then click on Device Setup to open the Device Setup dialog box.
  2. Check the Lock-in Amplifier box and click on the Model 51110 radio button.



Description of the lock-in amplifier (Model 7265)

- **Layout of the front operation panel**



①	"A" terminals	Signal input terminals
②	Cursor keys	Cursor keys to set parameters
③	Cursor keys	Cursor keys to set parameters
④	Function keys	Keys to select the set parameters
⑤	OSC OUT terminals	Modulation oscillator output terminals

- **Setting (Model 7265) RS-232C of Lock-in Amplifier**

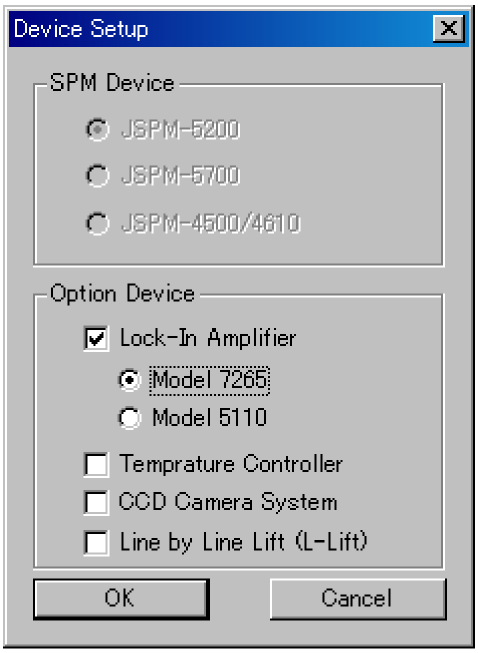
  The RS–232C is adjusted and set before shipment from the factory. However, if an error should occur when you are operating the lock-in amplifier, perform the following procedure:

1. Press the MENU key (④) on the front operation panel.
2. Confirm that MAIN MENU 1 is displayed on the display panel; then select CONFIGURATION.
3. Confirm that the CONFIGURATION menu is displayed; then select COMMUNICATIONS.
4. Confirm that the COMMUNICATIONS menu is displayed; then select RS232 SETTINGS.
5. Confirm that the RS232 SETTINGS menu is displayed and then set the parameters in accordance with the list below.

BAUD RATE	19200 bps
DATA BITS	7 + 1 PARITY
DELIMITER	, (044)
RS232 ADDRESS	1
ECHO	ON
PARITY	EVEN PARITY
PROMPT	ON

- **Setting software (Model 7265)**

1. Click on SPM Scan in the main menu bar to open the pull-down menu; then click on Device Setup to open the Device Setup dialog box.
2. Check the Lock-in Amplifier box; then click on the Model 7265 radio button.



Normal AFM/STM observation

When performing normal AFM/STM observation, it is recommended that you shut down the lock-in amplifier, although there may be no effect one way or another on the observation.

5.2.6 Specimen Temperature Controller (for JSPM-5200)

With the aid of the optional specimen temperature controller (TM-24090), specimen temperature can be controlled. When the controller is connected to a PC using RS-232C, specimen temperature can be controlled via WinSPM.

■ Setting the software

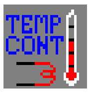
- ◆ When WinSPM controls the specimen temperature, click on SPM Scan in the main menu bar to open the pull-down menu. Click on Device Setup to open the Device Setup dialog box; then check the Temperature Controller box.

■ Sample Temperature Control dialog box

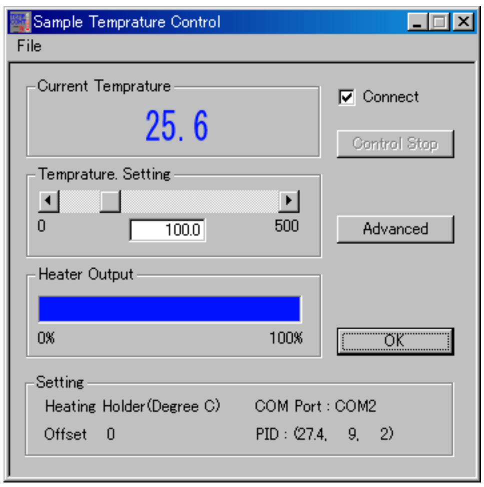
The sample temperature is controlled using the Sample Temperature Control dialog box.

- ◆ Click on SPM Scan in the main menu bar to open the pull-down menu. Click on Device Setup to open the Device Setup dialog box. Check the Temperature Controller box, and then click on the OK button. The Sample Temperature Control dialog box will appear.

✍ The Sample Temperature Control dialog box can also be opened either by pressing the T key while holding down the Ctrl key on the keyboard, or by clicking on the temperature control icon.



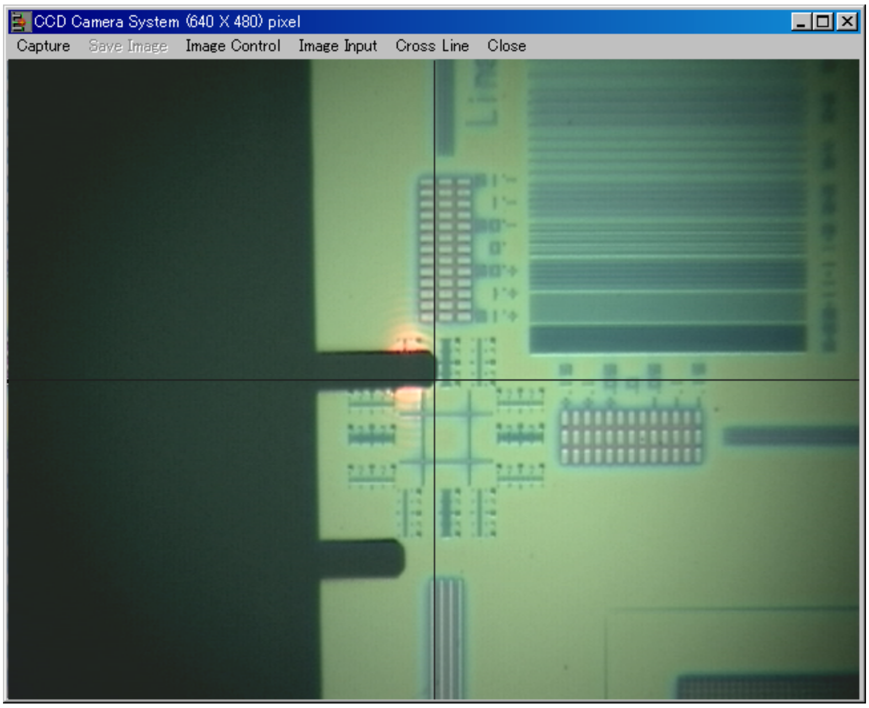
(Temperature control icon)



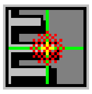
5.2.7 CCD Camera

The CCD camera image is displayed in the CCD Camera window.

- ◆ Click on SPM Scan in the main menu bar to open the pull-down menu. Click on Device Setup to open the Device Setup dialog box. Check the CCD Camera System box, and then click on the OK button. The CCD Camera System window will appear.



✍ The CCD Camera System window can also be opened either by Pressing the V key while holding down the Ctrl key on the keyboard or by clicking on the CCD camera icon.


(CCD camera icon)

5.2.8 Digital Control MFM unit

Connect the optional digital MFM unit (TM-26060) to the SPM controller. You can use the “line by line lift” mode, thus enabling MFM measurement to be implemented under a vacuum in a stable manner. In the line-by-line lift mode, the surface topography obtained by the first line scan is recorded. The topography should be traced with the probe lifted up. The digital MFM unit is used for this purpose.

When the digital MFM unit is in use (in the line-by-line lift mode), signal feedback is performed using the digital signal processor (DSP). In this case, feedback signal is in the digital form.

✍ In the modes other than line-by-line lift mode, however, feedback signal is dealt with in the analog form even if the digital MFM unit is incorporated.

■ Setting the software

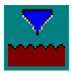
◆ To open the CCD Camera System window, click on SPM Scan in the main menu bar to open the pull-down menu; click on Device Setup to open the Device Setup dialog box; then check the Line by Line Lift (L-Lift) box.

5.3 PREPARING FOR MEASUREMENT

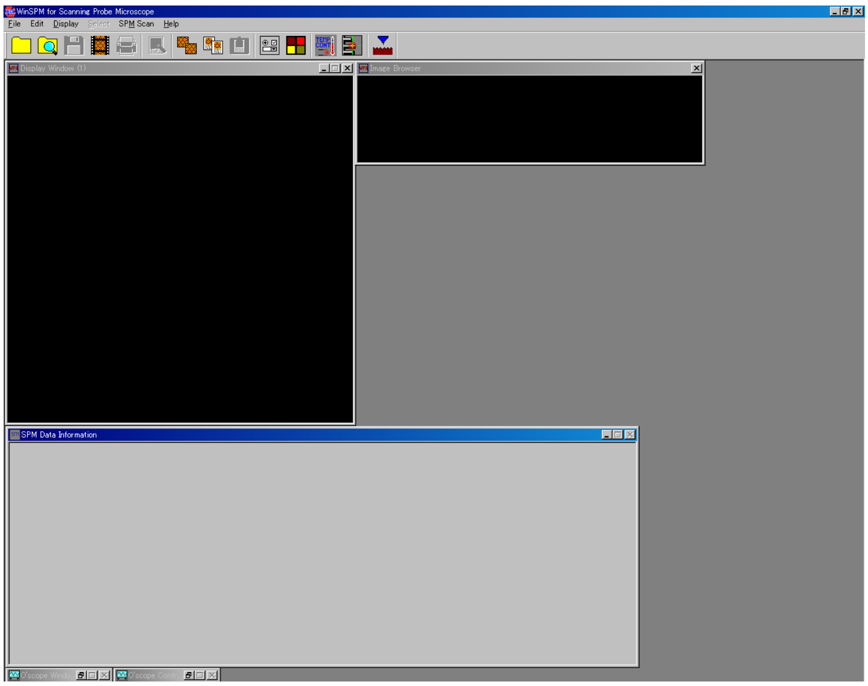
The term “approach” means moving the cantilever probe toward the specimen to the point where inter-atomic forces come into play or a tunnel current flows. Before starting measurement, carry out the following procedures and perform the approach.

5.3.1 Starting the System in Measurement Mode

1. Make sure that the specimen is mounted and that the cantilever probe is fastened in place, and that they are in position before starting the approach.
2. Turn on the SPM controller and the computer. Doing this starts Windows.
   ✍ The computer does not turn on even if the SPM controller is turned on. The computer must be turned on independently.
   ✍ When any of the optional units are connected, similarly turn them on.
3. Double-click the measurement icon. WinSPM starts in measurement mode and the login dialog will appear.


(Measurement icon)

4. Enter the user name and password and click on the Login button.
   The measurement mode window that appears during startup opens.



5.3.2 Resetting the Controller

The SPM controller is initialized by signals from the software when the WinSPM software is started. Before starting the software, it is necessary to ensure that the SPM controller is on. If you switch on the SPM controller after starting the software, or switch off the SPM controller then switch it on again after replacing the scanner, for example, you must reset the system from the software.

To reset the SPM controller, carry out the following procedure:

1. Select SPM Scan from the main menu, and select Reset SPM from the pull-down menu.
   The “Reset SPM?” window appears.
2. Confirm that the SPM controller is switched on; then click on the OK button.

5.3.3 Confirming Settings of the Device Setup Dialog Box

◆ Click on SPM Scan in the main menu bar to open the pull-down menu. Click on Device Setup to open the Device Setup dialog box. Then make sure that the models of the instrument, unit and attachments are correctly selected.

✍ The basic settings of WinSPM vary according to the instrument selected. There may be times when the system malfunctions, unless they are correctly selected. Likewise, the piezo-element power supply voltage depends on the instrument—±150 V or ±200 V. If you ignore the confirmation, there is the possibility of damaging the system.

✍ The settings of the Device Setup Dialog Box are preset in the factory. Should you change the setting, you must enter WinSPM using the “Admin” password.

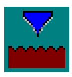
✍ If any of the settings are incorrect, terminate the software once, correct them and reboot the software using the “Admin” password.

5.3.4 Opening the SPM (Measurement) Parameters Window

Prepare for measurement as follows:

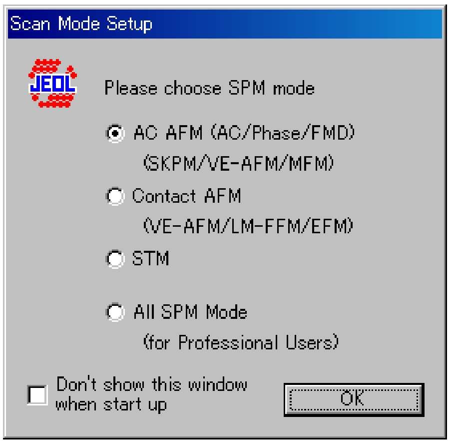
1. Click on SPM Scan in the main menu bar to open the pull-down menu. Click on Scan to open the Scan Mode Setup dialog box.

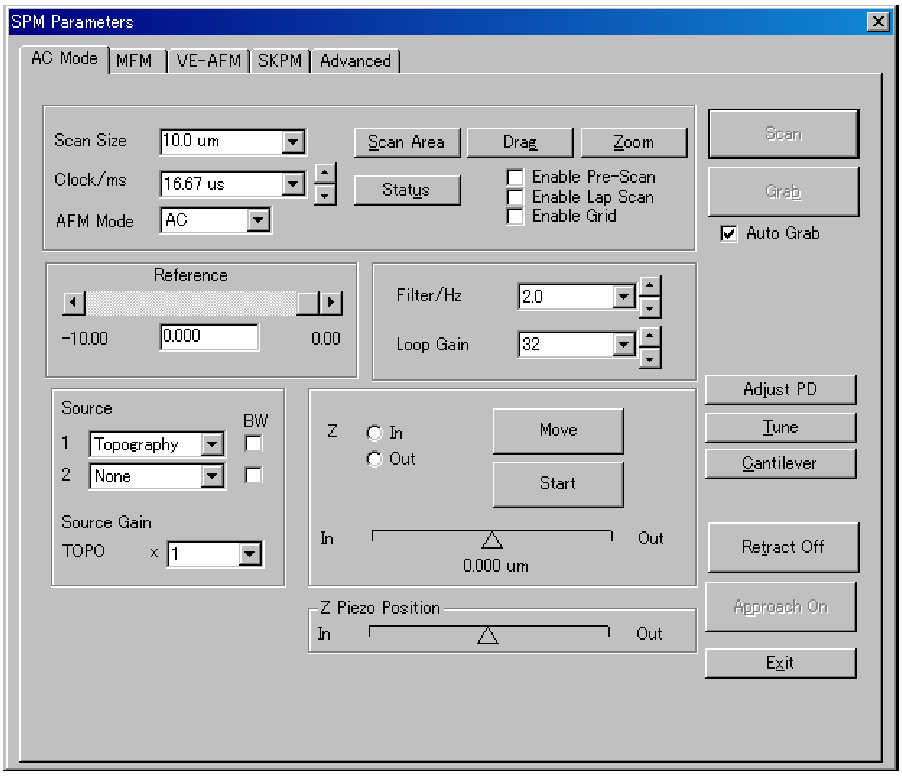
✍ The Scan Mode Setup dialog box can also be opened either by pressing the S key while holding down the Ctrl key on the keyboard, or by clicking on the measurement icon.


(Measurement icon)

2. Click on the radio button that corresponds to the desired mode, and then click on the OK button. The selected mode starts and the SPM Parameters window opens.

   ✍ Check the box for “Don’t show this window when start up” and the Scan Mode Setup dialog box will not appear the next time you start WinSPM. The selected mode automatically starts. It is therefore expedient to check the box when the mode you use is limited to a particular one.



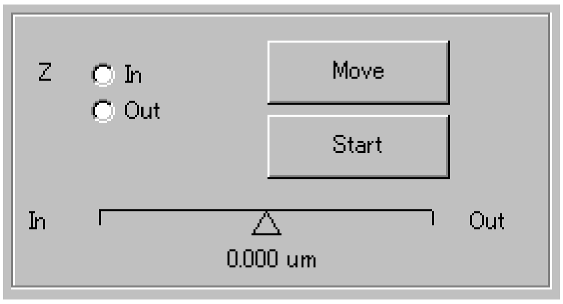


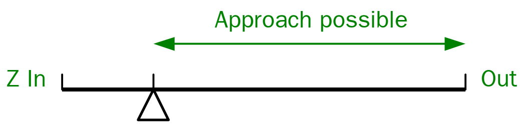
5.3.5 Checking the Stage Position

In the WinSPM system, the approach operation is done automatically by a motor. An approach cannot be performed when the Z stage has already risen to the top position.

Before performing an approach, confirm that the position of the Z stage is in the approachable range by means of the following procedure.

◆ Observe the Z stage position indicator (△) in the lower section of the SPM Parameters window. Make sure that the position of the stage is 1/4 of the distance between In and Out.





- If the Z stage position indicator (△) is too close to the In position, move the stage to the Out position as follows:

1. Click on the Out radio button. (The probe moves away from the sample.)
2. Click on the Start button.
   The Start button changes to the Stop button. The Z stage moves toward the OUT direction.
3. Click on the Stop button when the (△) mark enters the approachable range.

5.3.6 Setting an Optional Oscilloscope

You can install an optional oscilloscope on this system. By using an oscilloscope, you can measure faster events than those that can be measured with the software oscilloscope and also perform real-time measurement of waveforms during observation. You can also use an oscilloscope to check the scanning waveform, bias voltage, and so on.

Set the oscilloscope using the procedure below. If you carry out the procedure below, you can monitor the applied voltage in CH1 in the Z direction of the scanner and also the waveforms of signals specified using the software in CH2.

■ Correction of tilt due to the geomagnetism effect

1. Turn on the oscilloscope power.
2. Adjust the INTENSITY and FOCUS knobs so that the trace can be better seen.
3. Set the MODE switch to CH1 and the AC, GND, DC switch of CH1 to GND.
4. Adjust TRACE ROTATION with a screwdriver so that the trace becomes horizontal to the scale axis on the display.

■ Input adjustment

1. Set the MODE switch to CH1 and the AC, GND, DC switch of CH1 to GND.
2. Adjust the vertical position control knob (⇕) of CH1 so that the trace is positioned at the center of the display.
3. Set the MODE switch to CH2 and the AC, GND, DC switch of CH2 to GND.

4. Adjust the vertical position control knob (⇕) of CH2 so that the trace is positioned at the center of the display.

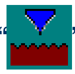
■ Other settings

CH1, CH2			
VOLTS/DIV:	5 V/div	VARIABLE:	Push in, CAL
AC, GND, DC:	DC		
Mode:	CHOP		

TIME/DIV:	2 ms/div	NORM, AUTO:	AUTO
Trigger coupling:	AC	Trigger source:	INT
VARIABLE:	CAL	Internal trigger source:	VERT
HOLD OFF:	NORM	LEVEL:	FIX

■ Setting the software

You can select the signals that you want to monitor in CH2 using the software as follows:

1. Click on the measurement icon "".

The SPM Parameters window will appear.

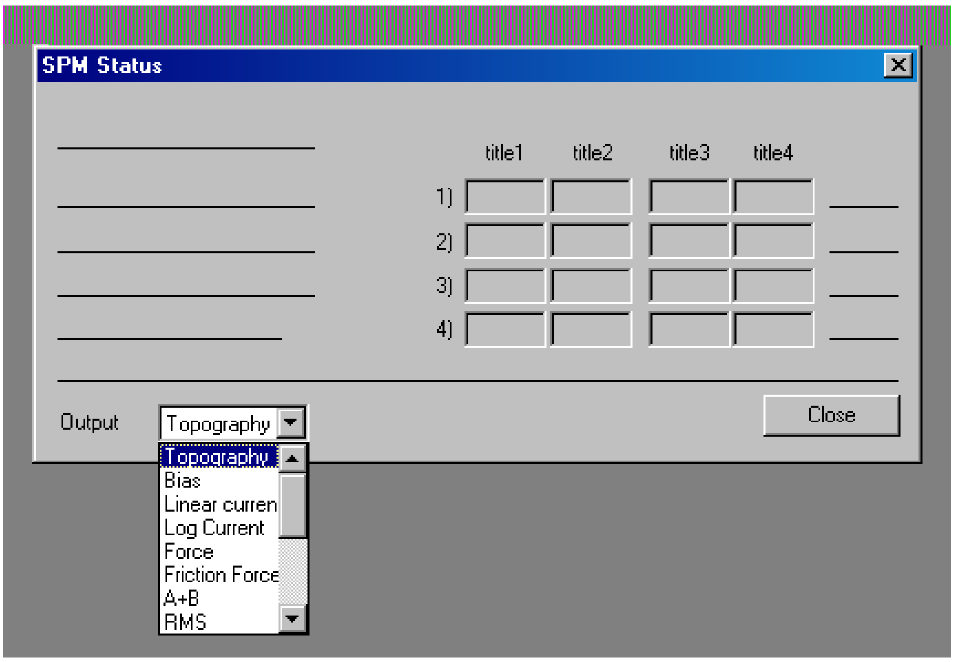
2. Click on the Advanced tab at the top of the SPM Parameters window.

The Advanced mode tab window appears.

3. Click on the Status button at the lower left of the tab window.

The SPM Status window appears.

4. Click on the Output [▼] button; then select the desired signal for monitoring.

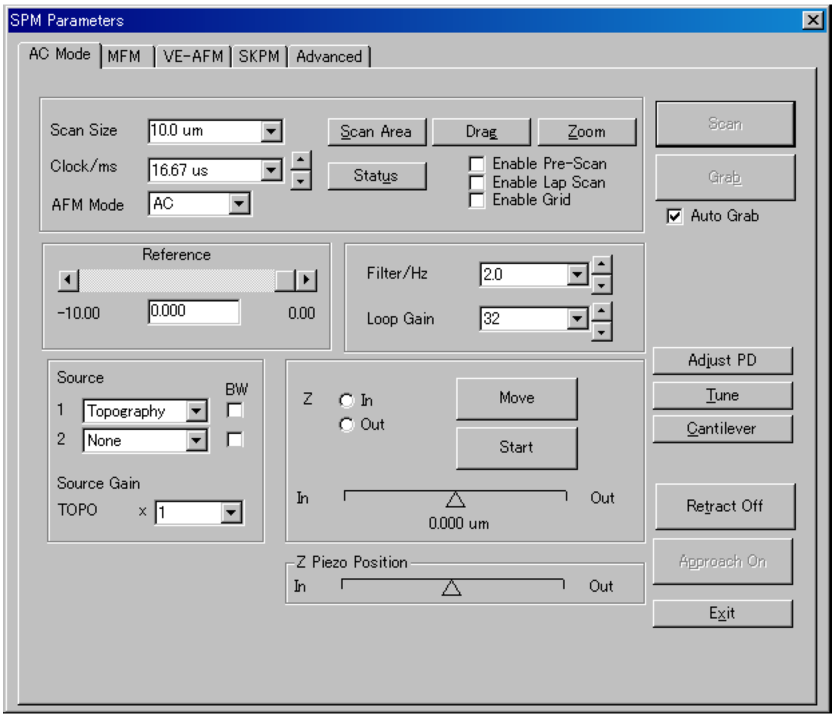


5.4 AC AFM MODE

This mode is selected from the Scan Mode Setup dialog (Sect. 5.3.4). In AC AFM mode, a cantilever probe vibrates in the vicinity of its characteristic frequency and scans the specimen in such a way that the amplitude of vibration of the cantilever remains constant. The AC, MFM, VE-AFM, SKPM, and Advanced tab windows belong to the AC AFM mode and can be opened by clicking on each tab in the SPM Parameters window.

5.4.1 AC Mode Tab

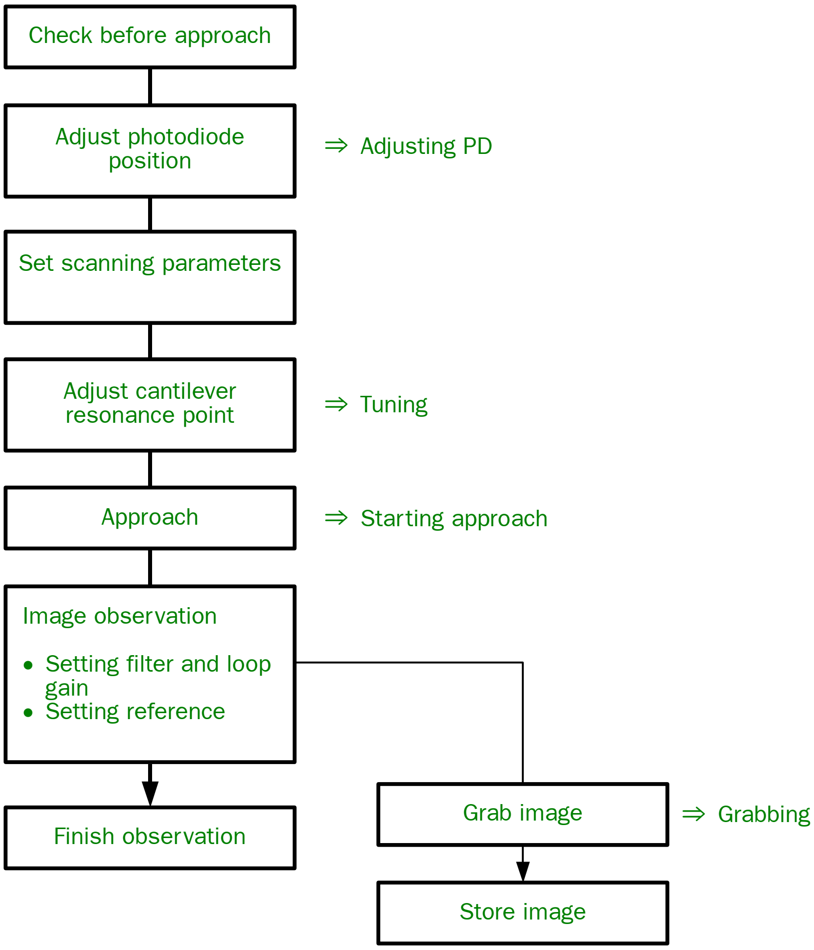
Topographic observation in AC AMF mode can be performed using the AC Mode tab window that is opened by clicking on the AC Mode tab in the SPM Parameters window.



AC Mode tab window

■ Operation flow chart

The following is the flow chart showing operation in the AC mode.



■ Checking before an approach

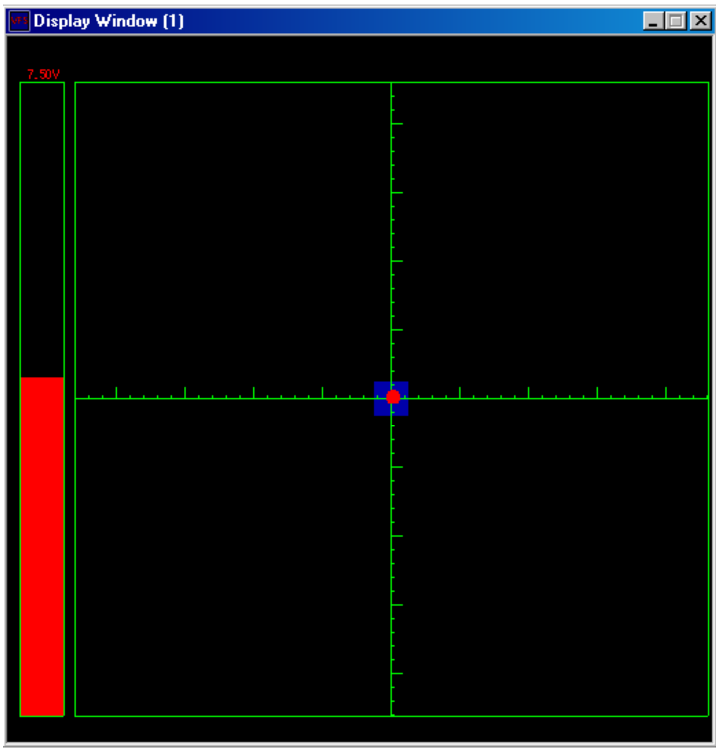
◆ Before performing an approach, make sure that preparation has been completed according to the procedure in Sect. 5.3, “Preparing for Measurement.”

- Is the cantilever for the AC mode properly mounted on the cantilever holder?
- Has coarse approach been executed in such a way that the distance between the cantilever tip and the specimen surface is 0.3 mm or less?
- Is the Z stage position within the approachable range?
- Is the SUM value of the AFM amplifier unit as negative as possible (–1.0 V to –9.0 V: where the value depends upon the cantilever used)?

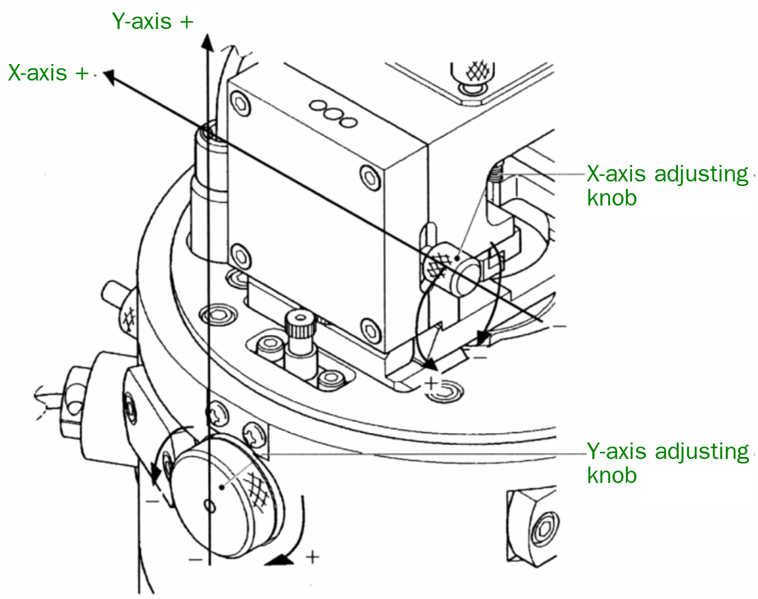
✍ After checking these points, set the indicator selection knob on the AFM amplifier unit to RMS in the AC mode, and to FMD in the FMD mode.

■ Adjusting the photodiode position

1. Click on the Adjust PD button on the right side of the AC Mode tab window box. The Display Window will appear.



2. Adjust the photodiode position adjustment knobs so that the red spot enters the blue zone at the center. Also confirm that the SUM value of the AFM amplifier unit is as large as possible.



The example illustrated above shows the photodiode position adjustment knobs for the JSPM-5200.

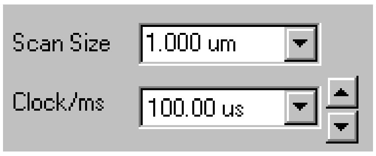
■ Setting scanning parameters

Before carrying out an approach, set the scanning parameters required for observation. Although these parameters differ depending upon the specimen and the purpose of observation, you usually set the parameters as follows.

● Scan Size

◆ Click on the Scan Size selection box. When the numerical value is highlighted, enter 1.000 (1 um) using the keyboard and press the Tab key to finalize the input. Or, click on the button in the Scan Size selection box and select a numerical value near 1 000 nm.

The maximum scanning range depends on the scanner installed. In actual practice, the scanning area should be changed to the region you want to observe.



● Clock/ms

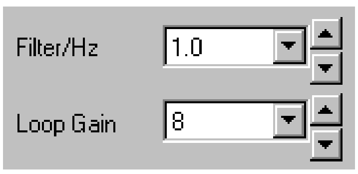
◆ Click on the button in the Clock/ms selection box and select 100.00 us.

This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen surface.

● Filter/Hz

◆ Click on the button in the Filter/Hz selection box and select 1.0 from the pull-down menu.

Filter/Hz is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image. But the feedback circuit easily oscillates. As a general rule to follow, set the highest speed at which the feedback circuit does not oscillate while watching the image during scanning.



● Loop Gain

◆ Click on the button in the Loop Gain selection box and select 8 from the pull-down menu.

The setting determines the gain of the feedback circuit. The larger the set value is, the higher the response gain becomes, thus obtaining a good image from an uneven specimen surface, but the feedback circuit easily oscillates.

● Topography and phase images

• Topographic image observation

AFM topographic images are obtained with the cantilever being vibrated in the vicinity of its characteristic frequency and with the amplitude of vibration of the cantilever remaining constant during scanning.

1. Click on the ▼ button in the Source 1 selection box and select Topography.
2. Click on the ▼ button in the Source 2 selection box and select None.
3. Click on the Source Gain TOPO ▼ button and select 1.

• Phase image observation

Phase images can be obtained by imaging phase variation in the vicinity of the cantilever characteristic frequency.

1. Click on the ▼ button in the Source 1 selection box and select Phase from the pull-down menu.
2. Click on the ▼ button in the Source 2 selection box and select None.

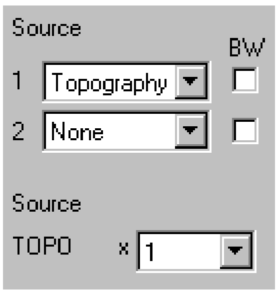
✍ The setting of Source Gain is available only for Topography.

• Simultaneous observation of topographical and phase images

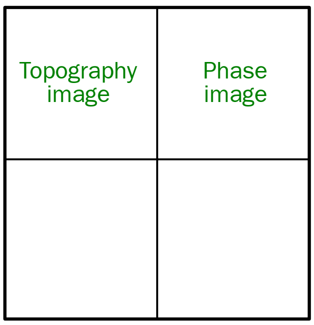
Both images can be observed at a time as follows:

1. Click on the ▼ button in the Source 1 selection box and select Topography.
2. Click on the ▼ button in the Source 2 selection box and select Phase from the pull-down menu.
3. Click on the Source Gain TOPO ▼ button and select 1.

✍ Now you have completed the parameter settings for observing a topographical image in the AC mode.



4. Click on the Scan button to start observation. The topographical image and phase image appear.



■ Adjusting a cantilever resonance point

1. Select either AC or FMD from the AFM Mode selection box in the AC Mode window.

✍ Either of the detection modes, AC (amplitude detection) or FMD (frequency detection) can be used under atmospheric pressure. However, FMD is better suited for high-resolution observation under vacuum. In general, FMD provides higher sensitivity under vacuum, as compared with AC, in detecting topographical change in the specimen.

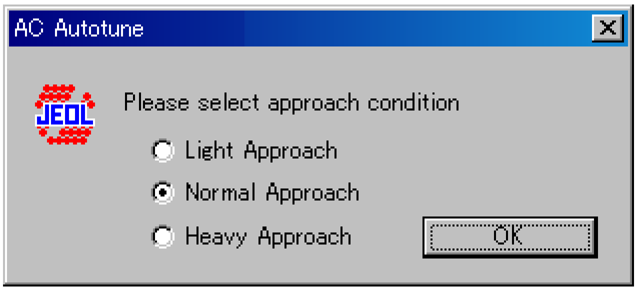
2. Click on the Adjust PD button to open the Display Window. A caret symbol (^) appears and a message window opens, asking whether or not PD adjustment is complete.

3. Adjust the photodiode position adjustment knobs so that the red spot enters the blue zone at the center (☞ Sect. 5.4.1d). Then click on the OK button.

4. Click on the Tune button in the AC Mode window to open the AC/FMD Autotune dialog box.

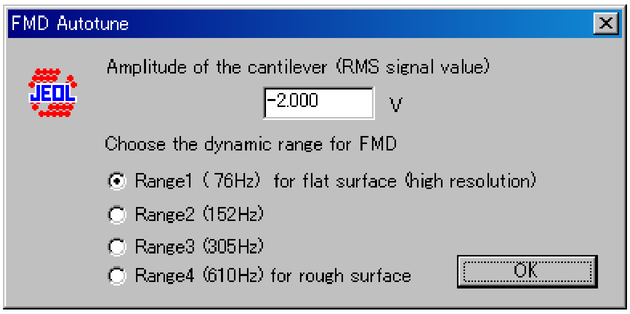
a. AC mode

Select the approach conditions (Reference value) to be used after implementing adjustment of the cantilever resonance point. When the Light Approach radio button from the AC Autotune dialog box is selected, a comparatively large reference value may be set, causing the distance between the probe and the specimen to be longer than is the case in selecting the Normal Approach radio button. But when the Heavy Approach radio button is selected, the distance becomes longer. The selection should be made in accordance with the softness of the specimen, absorption, or any surface condition of the specimen.



b. FMD mode

When FMD mode is selected, the FMD Autotune dialog box appears. Select the amplitude (RMS value) and the width of FM detection (dynamic range) to be used after adjusting the cantilever resonance point. Doing this determines the resolution and the width of the detectable dynamic range. To resolve a finer topographical specimen, like an image of atoms, you may also select Range1 or Range2. When the scan size is large and the surface of the specimen is rough, choose Range3 or Range4.



5. Click on the OK button.

Adjustment of the cantilever resonance point takes place and the excitation frequency, voltage, and reference value are set automatically.

● Considerations in using the tuning function

• Excitation voltage to be applied to the cantilever

In this system there is a switch that changes the voltage to be applied to the cantilever to “high” or “low”. When “high” is selected, up to 10 V is applied to the cantilever. Use this “high” setting for in-liquid observation, or when a cantilever in use does not easily resonate. On the other hand, if, in observing a specimen under vacuum, you set the voltage to “high,” the cantilever might break. To avoid this, you should use the “low” setting.

• Usable cantilever resonance frequency

The range of cantilever resonance frequencies that can be adjusted by using the tuning function is 1 kHz to 1 MHz.

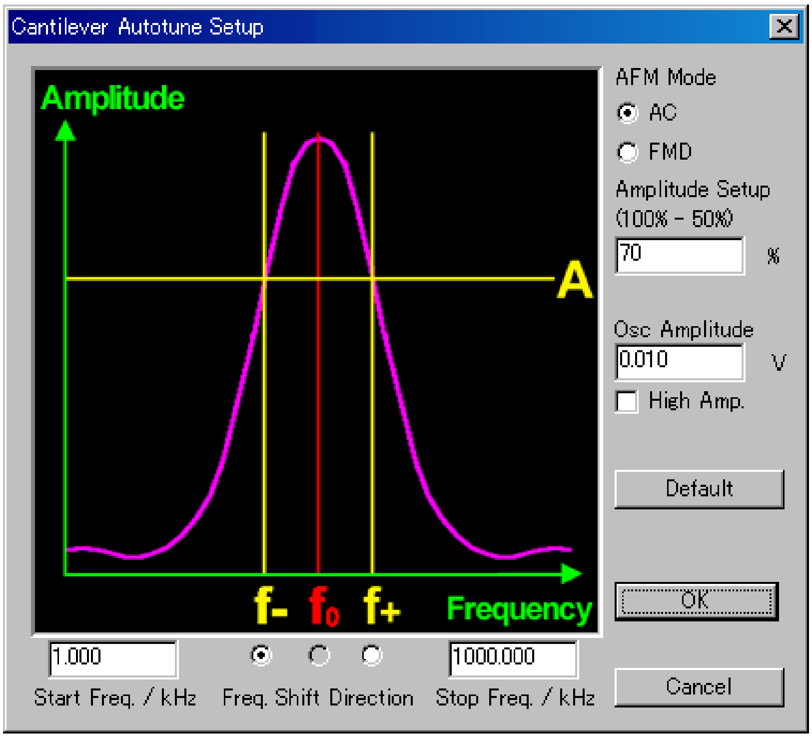
• If tuning fails

If the message “Auto Tune Failed” is displayed, carry out the operations described in Sect. 5.4.1, “Checking before approach” and in Sect. 5.4.1, “Adjusting the photodiode position.” If the “Auto Tune Failed” message still does not disappear, adjust the resonance frequency manually, referring to Sect. 5.10.3,”■ Cantilever.”

● Tuning

Adjust the cantilever resonance point using the Cantilever Autotune Setup dialog that is opened by clicking on Cantilever Autotune Setup in the SPM Scan pull-down menu.

✍ For further details, refer to Section 5.10.1, “SPM Scan Menu.”

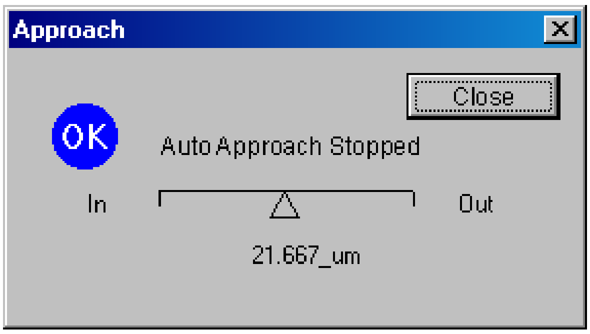


■ Approach

1. Click on the “Approach On” button.

Approach starts automatically. When approach finishes, the Approach window containing the message “Auto Approach Stopped” is displayed in the center of the screen.

2. Click on the Close button.



● Considerations in using the Approach On button

• When the Approach On button is displayed in gray:

◆ Click on the Retract Off button.

✍ Unless you click on the Retract Off button, the Z-scanner shrinks the most and the Approach On button does not function.

• Speed of approach

◆ Specify the speed of approach in the Advanced tab window. You cannot specify the speed of approach in the AC Mode tab window. You cannot modify the speed of approach in any SPM instrument other than ultra-high vacuum SPM instruments.

- Judgment of approach conditions
  Whether approach has finished or not is judged by measuring the voltage applied to the Z scanner. The voltage is set to ±0 V at the time of shipment from the factory. Specify approach conditions in the Advanced tab window. You cannot specify approach conditions in the AC Mode tab window.
- Halt of approach
  When approach starts. the Approach window appears. If you click on Stop, approach stops.

■ Observation

◆ To observe an image, click on Scan in the SPM Scan pull-down menu.
Scanning will start and an image will be displayed in the display window.

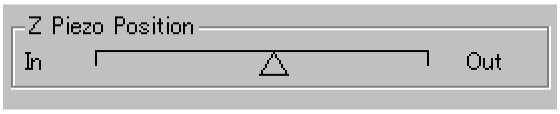
■ Capturing an image

- When Auto Grab (in the AC Mode tab window) is checked
  Each time measurement ends, an image is captured automatically.
- When Auto Grab (AC Mode tab window) is deselected
  To capture an image, click on Grab during image scan. The image is recorded in memory immediately after a frame is scanned, then automatically stored in the specified folder as a temporary file. Unless the Grab button is clicked, the measurement repeats and the image is not captured.
- The offset to the input signal for image display is calculated automatically.
  Offset is controlled in the Advanced window.

■ Considerations in image observation

- In the AC mode, an important factor for obtaining a quality image is the distance between the specimen and the cantilever tip. If this setting is inappropriate, not only can a quality image not be obtained, but also damage to specimen and the cantilever may result.
- You can set the distance between the specimen and the cantilever tip using the Reference function. If the RMS value is –5.6 V, provided that it is set to –1.6 V initially when the cantilever is away from the specimen, this may indicate that the cantilever tip is too far from the specimen. An RMS value of 0 V, means that the cantilever tip has collided with the specimen surface.
- Normally, while observing an image from a separated position, gradually move the cantilever tip toward the 0 V side (the direction toward the specimen), and set it in the optimum position so that the best image can be photographed.
- You can visually confirm the distance between the specimen and the cantilever at Z Piezo Position. It appears in gray during scanning. Adjust it before starting to scan.

Condition in which the specimen and cantilever tip are completely separated (condition prior to approach)



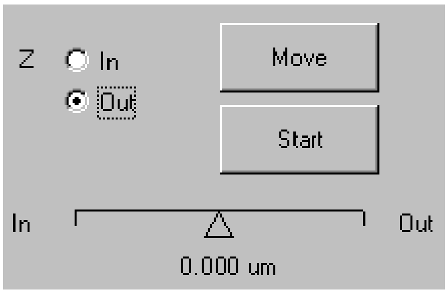
Neutral position (condition at the end of approach)

Condition in which the cantilever tip is in contact with the specimen

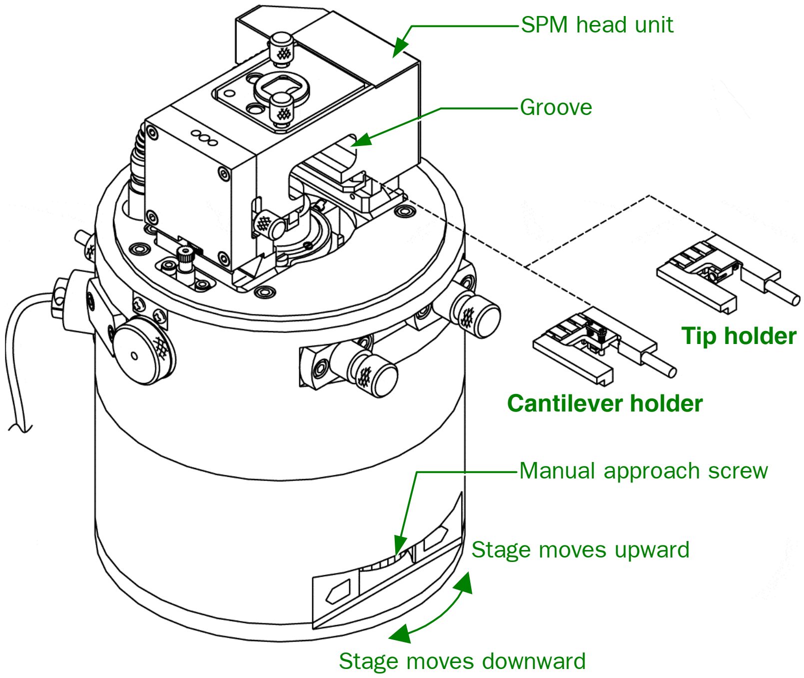
■ Terminating observation

Terminate observation according to the following procedure:

1. Stop scanning.
2. Click on the Retract On button to retract the cantilever tip.
3. Click on the Out radio button for Z and click on the Start button.



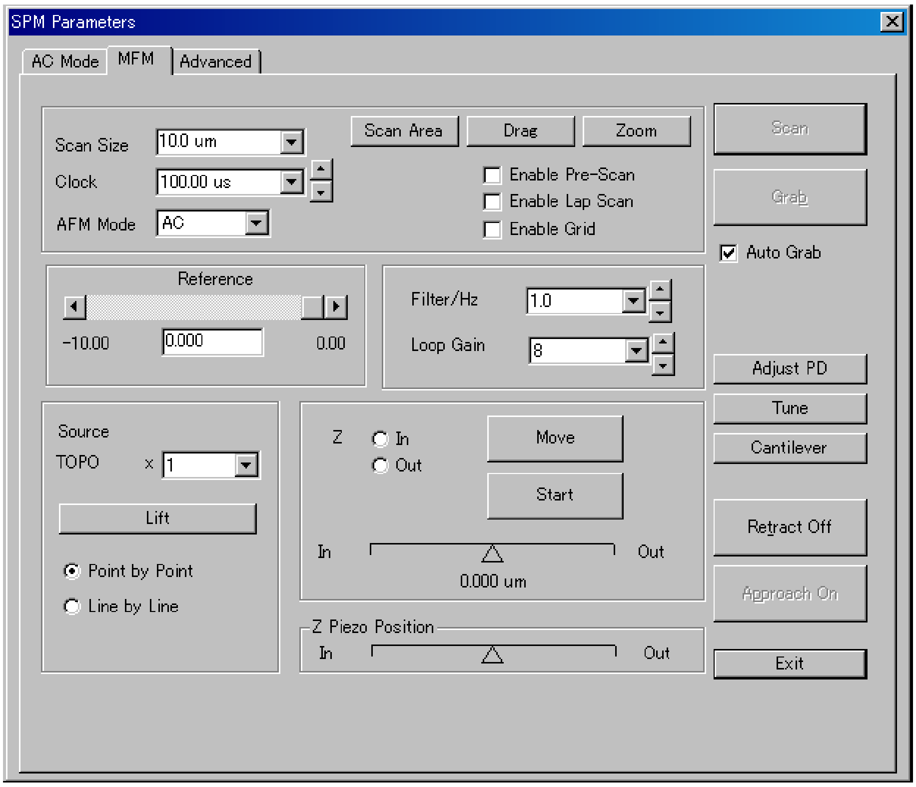
4. When the cantilever has moved 0.1 to 0.2 mm away from the specimen, click on the Stop button to stop the movement.
5. Turn the manual approach screw to move the specimen stage down.



The example illustrated above show the manual approach screw for the JSPM-5200.

5.4.2 MFM Tab

MFM (Magnetic Force Microscopy) measurements in AC AMF mode can be performed using the MFM tab window that is opened by clicking on the MFM tab in the SPM Parameters window. To do this, however, an optional MFM cantilever is required. The point-by-point lifting function (lifting at every picture element) is included as standard and the line-by-line lifting function (lifting at every line) is optionally available.

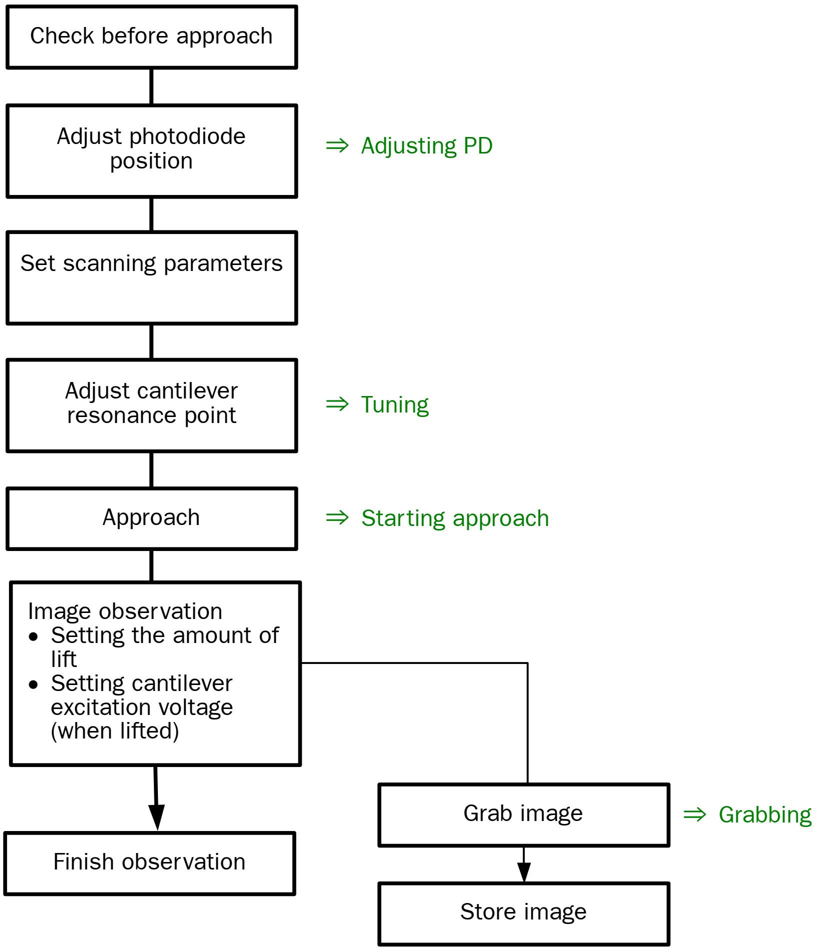


■ MFM image observation

In general, MFM observations are performed in AC AFM mode. To differentiate the topographical image of the sample from the MFM image, the topographical image is first observed at a point and then the cantilever is lifted for observation of the MFM image formed by the difference of the cantilever phase. The procedure for observing an MFM image is given below.

■ Operation flow chart

The following is the flow chart showing MFM observation.



■ Checking before an approach

Before performing an approach, make sure that preparation has been completed according to the procedure in Sect. 5.3, “Preparing for Measurement.”

- Is the MFM cantilever properly mounted on the cantilever holder?
- Has coarse approach been executed in such a way that the distance between the cantilever tip and the specimen surface is within 0.3 mm or less?
- Is the Z stage position within the approachable range?
- Is the SUM value of the AFM amplifier unit at its maximum (–5.0 V)?

■ Adjusting the photodiode position

Carry out the procedure in Section 5.4.1, “Adjusting the photodiode position.”

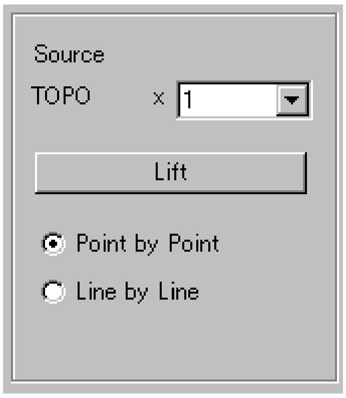
■ Setting scanning parameters

Before you carry out an approach, set the scanning parameters required for observation using the MFM tab window. Although these parameters differ depending upon the specimen and the purpose of observation, you can usually set the parameters as follows:

● Lifting

◆ Click on the radio button that corresponds to the desired lift mode.

✍ The standard is the point by point lift mode. The optional line by line lift mode can be used by incorporating the DSP MFM board into the controller.



● Scan Size

◆ Click on the Scan Size selection box in the MFM tab window. When the numerical value is highlighted, enter 5.000 (5 um) using the keyboard and pressing the Tab key to finalize the input. Or, click on the ▼ button in the Scan Size selection box and select a numerical value near 5 000 nm.

The maximum scanning range depends on the scanner installed. In actual practice, the scanning area should be changed to the region you want to observe.

● Clock/ms

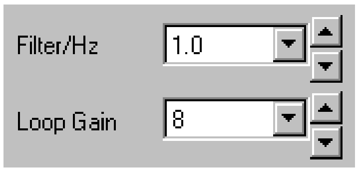
◆ Click on the ▼ button in the Clock/ms selection box and select 1.67 ms.

This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen surface.

● Filter/Hz

◆ Click on the ▼ button in the Filter/Hz selection box and select 1.0 from the pull-down menu.

Filter/Hz is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, set the highest speed at which the feedback circuit does not oscillate while watching the image during scanning.



- **Loop Gain**
  - ◆ Click on the button in the Loop Gain selection box and select 8 from the pull-down menu.

    The setting determines the gain of the feedback circuit. The larger the set value, the higher the response gain, letting you obtain a good image from an uneven specimen surface. In this case, however, the feedback circuit readily oscillates.

- **Source Gain**
  - ◆ Click on the Source Gain TOPO button and select 1.

    ✍ Now you have completed the parameter settings for observing an MFM image in AC mode.

■ Adjusting a cantilever resonance point

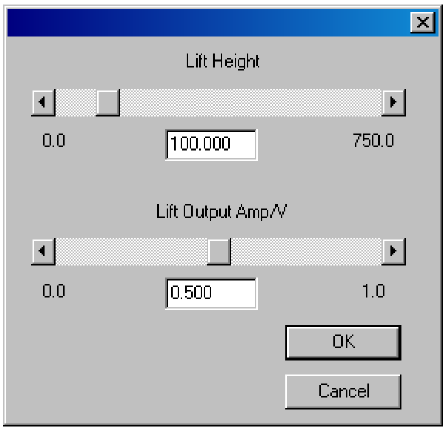
◆ Carry out the procedure in Section 5.4.1, " Adjusting a cantilever resonance point."

■ Approach

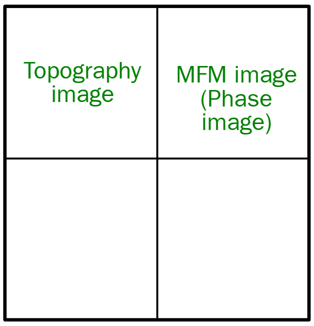
◆ Carry out the procedure in Section 5.4.1, “Approach.”

■ Observing an image and lift setting

1. Click on the Lift button in the MFM tab window to open the lift control window.



2. Double-click on the lift height entry box; input 100.000 (nm) using the keyboard; then press the Tab key.
3. Click on the Scan button to start scanning. The topographical image and MFM image appear.



4. Gradually reduce the excitation voltage to the cantilever so that the sharpest MFM image is obtained.

■ Capturing an image

Carry out the procedure in Section 5.4.1, “Capturing an image.”

■ Considerations in observing an image

In MFM image observation, it is essential that the topographical image of a sample can be observed clearly and sharply in AC mode. Observe the image in AC mode in advance to establish the best observation parameters. Then, carry out the same procedure as in Section 5.4.2, “Image observation and lift setting.”
Better results might be obtained if you magnetize the MFM cantilever beforehand using a permanent magnet.

■ Terminating observation

Carry out the procedure in Section 5.4.1, “Terminating observation.”

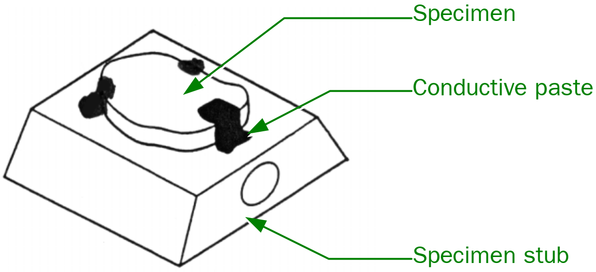
5.4.3 VE-AFM Tab

Viscoelasticity image observation is an optional function that requires a lock-in amplifier supplied to order. Connect the lock-in amplifier to the SPM controller and set the software in accordance with the procedure in Section 5.2.5, "Lock-in amplifier."

Usually you observe a viscoelasticity image using Contact mode. Depending on the sample, however, you may not be able to obtain a good image. You can obtain only perturbed images due to the adhesion of the cantilever to the sample. To avoid this problem, use AC mode. Then you can obtain good results. Viscoelasticity observation in AC mode will be performed through use of the difference between the resonance frequency (about 300 kHz) of the cantilever and the modulation frequency (several tens of kHz) for viscoelasticity observation.

■ Mounting a sample

In order to observe a viscoelasticity image correctly, it is essential to affix the sample firmly to the specimen stub using conductive paste instead of double-faced tape.



■ Confirmation before an approach

Affix the specimen, adjust the laser and photodiode, and then perform the coarse approach according to the procedure in Section 5.4.1, "Approach."

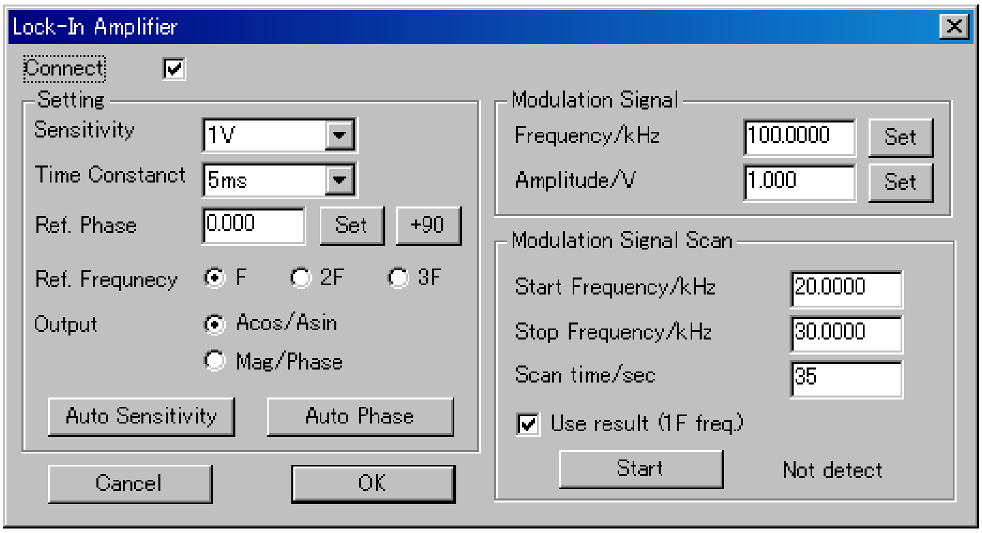
■ Observing a topographical image

Observe the topographical image of a sample; make sure that the image is satisfactory; then click on the Retract On button to retract the tip.

■ Setting the lock-in amplifier

● Model 7265

1. Click on the Lock-In button to open the Lock-In Amplifier window.



2. Check the Connect box to connect the amplifier to the SPM controller. The system waits about a second for the parameters to be initialized.

✍ If an error message appears, be sure that the power supply is on, the cables are connected securely and the Device Setup window is properly set.

3. Specify the parameters according to the following table:

Sensitivity	1 mV
Time Constant	5 ms
Ref. Phase	0.000
Ref. Frequency	F
Output	Acos･Asin
Frequency/kHz	20.000
Amplitude/V	0.200

4. Click on the Retract Off button in the VE-AFM tab window.

5. Click on Auto Sensitivity in the Lock-In Amplifier window.

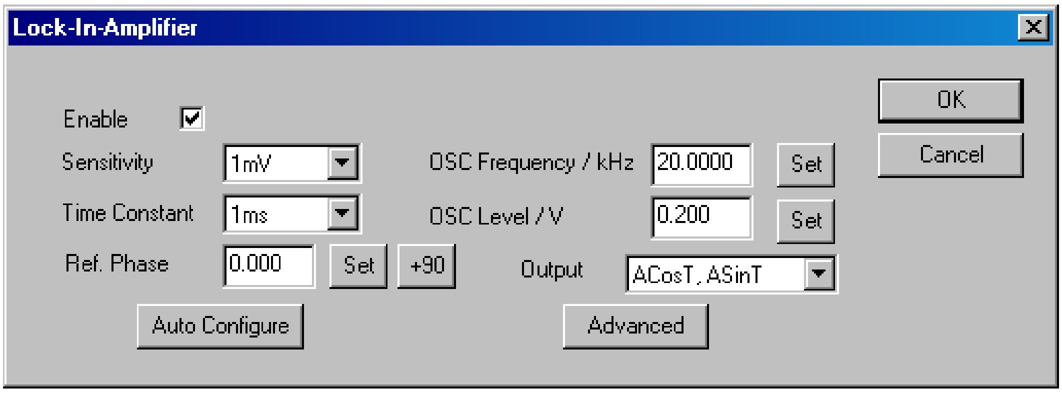
The lock-in amplifier automatically adjusts its gain.

6. Click on Auto Phase in the Lock-In Amplifier window.

The lock-in amplifier automatically adjusts its phase.

● Model 5110

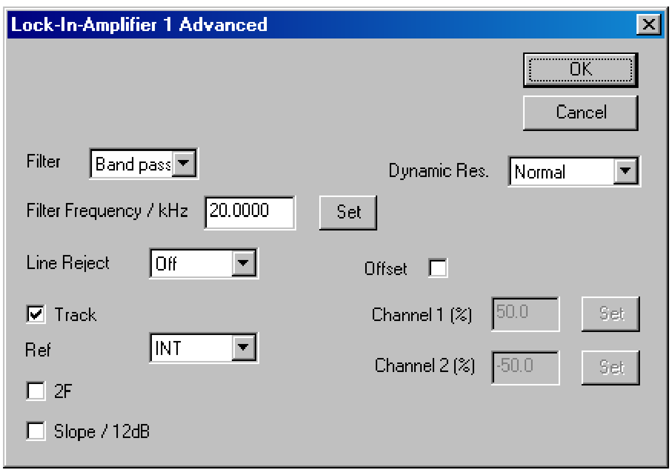
1. Turn on the POWER switch of the lock-in amplifier (see Section 5.2.5, “Lock-In Amplifier”).
2. Set the lock-in amplifier as follows:
   a. Press the A button of the Input selection switches.
   b. To put the Amplifier into the FLOAT state, press the FLOAT/GROUND button of the Input selection switches.
   c. To deselect the 10^8 and 10^6 buttons of the Input selection switches, put the buttons into the popped-out state.
3. Click on the Lock-in button to open the Lock-in Amplifier window.



4. Check the Enable check box to activate the lock-in amplifier.
   It will take about one second until the amplifier starts, initializing parameters. If an error occurs, confirm the connections and the software settings.
5. Specify the parameters according to the following table:

Sensitivity	1 mV	OSC Frequency	20.000
Time Constant	1 ms	OSC Level	0.200
Ref. Phase	0.000	Output	ACosT, ASinT

6. Click on the Advanced button.
   The lock-in amplifier 1 Advanced window opens.



7. Specify the parameters according to the following table:

Filter	Band pass	Dynamic Res.	High Resolution
Filter Frequency/kHz	20.000	Offset	☐
Line Reject	Off		
Track	☑		
Ref	INT		
2F	☐		
Slope/12dB	☐		

8. Click on the Retract Off button in the VE-AFM tab window.
9. Click on the Auto Configure button in the Lock-in-Amplifier window.
   The Lock-in-Amplifier will adjust the phase and gain automatically.

■ Observation

1. Click on the Scan button in the VE-AFM tab window.
   The following images will be obtained.

Topography (Topography image)	Acosϕ (Elasticity image)
Asinϕ (Viscosity image)	

   An oscillating noise might sound depending upon the characteristic frequency of the scanner that you use. If it happens, reduce the oscillation level (OSC Level/V), or shift the present oscillation frequency (OSC Frequency/kHz) setting position until the sounding stops.
2. Increase the input sensitivity of the lock-in amplifier using the SENSITIVITY setting key in the range in which the OLVD LED does not light up (from 1 mV to 100 nV direction).
   The region where both Acosϕ (elasticity) and Asinϕ (viscocity) images become bright is the region where elasticity and viscosity are high.
3. Specify the SPM parameters for usual operation so that you can obtain an optimal topographical image.
4. Change the following parameters so that you can obtain an optimal elasticity image as well as an optimal viscosity image.

- Oscillation frequency (OSC Frequency/kHz)
  If the difference between elasticity and viscosity of the specimen is small, for example, in composite plastics composed of the same kinds of materials, it is expedient to increase the oscillation frequency. Doing so might provide better images.

- Oscillation level (OSC Level/V)

  When you use hard cantilevers such as an Si cantilever, it is recommended that you use a low oscillation level to observe the image. If the oscillation level is too high, the cantilever may be broken. When you use soft cantilevers, however, increase the oscillation level accordingly. Generally, the harder the cantilever, the better the results for viscoelasticity image observation.

5.4.4 SKPM Tab

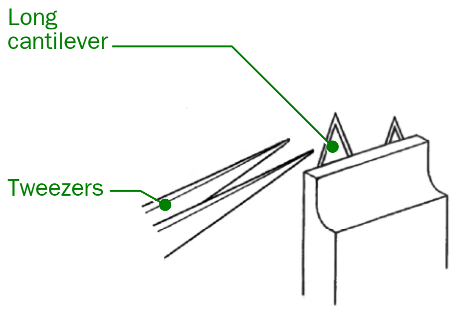
SKPM (Scanning Kelvin probe Microscopy) is an optional function that requires a lock-in amplifier supplied to order. Connect the lock-in amplifier to the SPM controller and set the software in accordance with the procedure in Section 5.2.5, “Lock-in amplifier.”

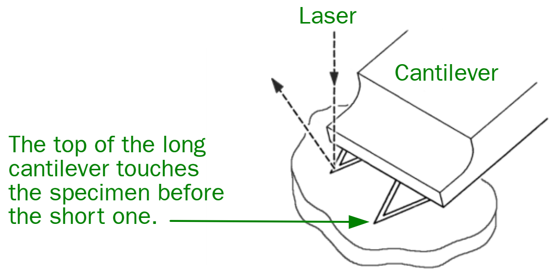
■ Preparation for SKPM image observation

A conductive cantilever is used for SKPM image observation. A current-detection amplifier (operational amplifier) is incorporated in the SPM head. The cantilever is grounded via this amplifier.

■ Selecting a cantilever

If a cantilever has a long and short cantilever tips, as shown in the figure below, and you want to use the short cantilever for image observation, be sure to break and remove the long one using a pair of tweezers. For this, use a conductive cantilever whose resonance frequency is 100 to 300 kHz.



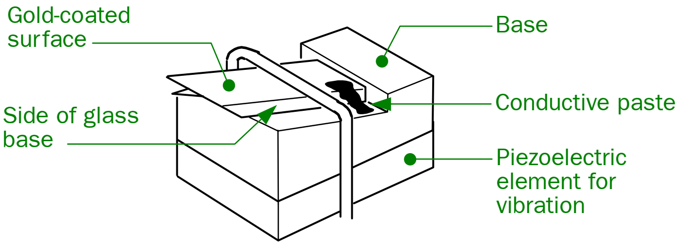


— **CAUTION** —

When you use a short cantilever, be sure to remove the long one with a pair of tweezers. Otherwise, the top of the long cantilever touches the specimen before the short one does.

■ Affixing the cantilever

Use a conductive cantilever such as a conductive Si cantilever or a cantilever with both sides coated with gold. Affix the cantilever on a cantilever holder. Make sure that good conductivity is kept between the cantilever and the cantilever holder. Use conductive paste such as Conductive paste especially for a gold-coated cantilever since the conductivity between the front face and the rear face is not so good.



— CAUTION —

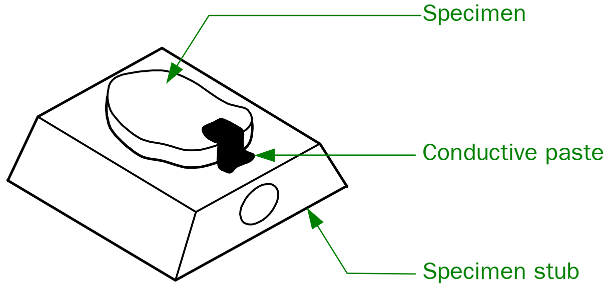
When applying conductive paste to the cantilever and the cantilever holder, be sure not to apply the conductive paste to the cantilever piezoelectric element. When replacing a cantilever, be sure to confirm that no previously used conductive paste remains on the holder. Otherwise, the cantilever will tilt, causing the reflected laser beam not to irradiate the right position.

■ Inserting the cantilever holder

After attaching a cantilever to the cantilever holder, insert the cantilever holder into the SPM head until it stops.

■ Affixing the specimen

To properly observe a surface potential image, it is essential that the specimen be tightly secured to the specimen stub. Affix the specimen to the specimen stub with conductive paste such as Dotite instead of conductive tape.



■ Preparation before an approach

Before performing an approach, affix the specimen. Adjust the laser and photodiode; then perform a coarse approach according to the procedure in Section 5.4.1, "Approach."

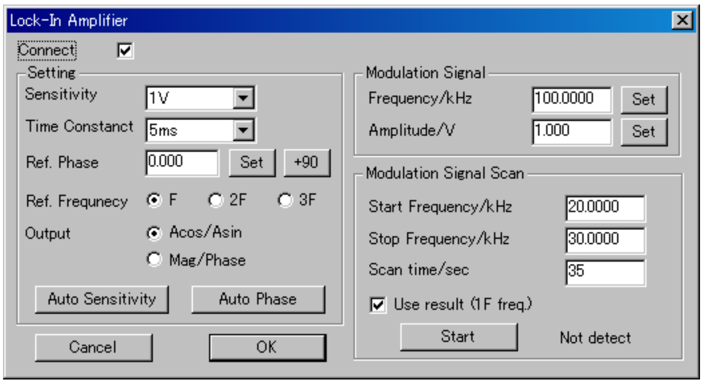
■ Topographical image observation using AC mode

Observe the topographical image of a specimen surface using the AC mode, and confirm that you can obtain a good image. Then retract the tip by clicking on Retract On.

■ Setting the lock-in amplifier

● Model 7265

1. Click on the Lock-In button to open the Lock-In Amplifier window.



2. Check the Connect box to connect the amplifier to the SPM controller. The system waits about a second for the parameters to be initialized.

✍ If an error message appears, be sure that the power supply is on, the cables are connected securely and the Device Setup window is properly set.

3. Specify the parameters according to the following table:

Sensitivity	10 mV
Time Constant	5 ms
Ref. Phase	0.000
Ref. Frequency	F
Output	Acos・Asin
Frequency/kHz	40.000
Amplitude/V	1.000

4. Click on the Retract Off button.

5. Click on Auto Sensitivity in the Lock-In Amplifier window.

Doing this automatically adjusts the gain of the lock-in amplifier.

6. Click on Auto Phase in the Lock-In Amplifier window.

Doing this adjusts automatically the phase of the lock-in amplifier.

● Model 5110

1. Turn on the POWER switch of the lock-in amplifier (see Section 5.2.5, “Lock-In Amplifier”).

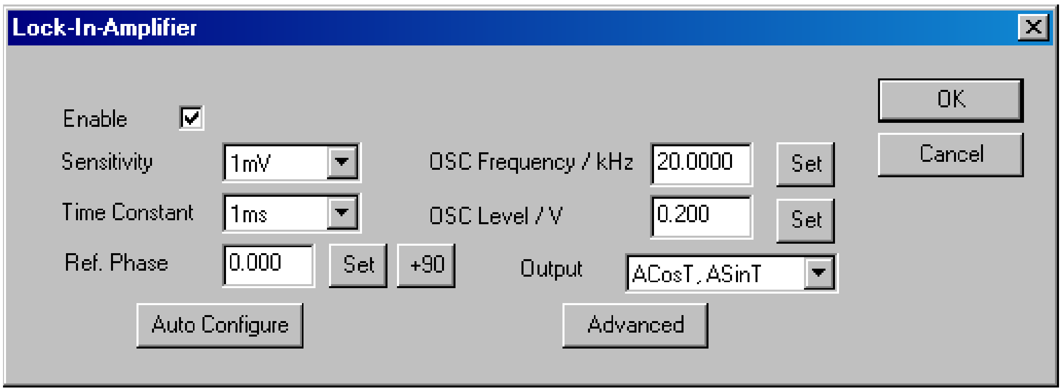
2. Set the lock-in amplifier as follows:

a. Press the A button of the Input selection switches.

b. To put the Amplifier into the FLOAT state, press the FLOAT/GROUND button of the Input selection switches.

c. To deselect the 10^8 and 10^6 buttons of the Input selection switches, put the buttons into the popped-out state.

3. Click on the Lock-in button to open the Lock-in Amplifier window.



4. Check the Enable check box to activate the lock-in amplifier.

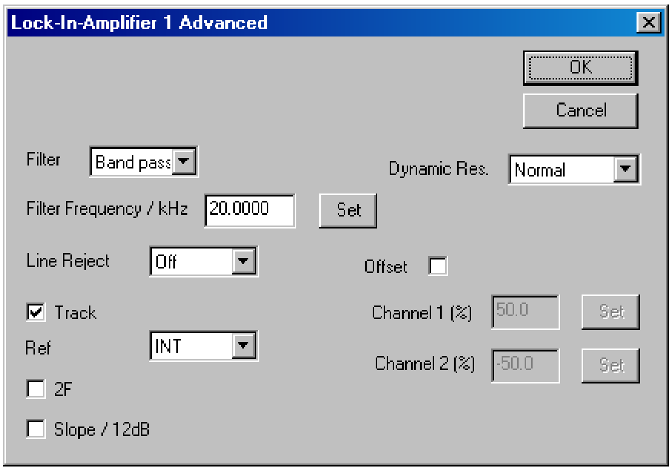
✍ It will take about one second until the amplifier starts, initializing parameters. If an error occurs, confirm connections and software settings.

5. Specify the parameters according to the following table:

Sensitivity	10 mV	OSC Frequency	40.000
Time Constant	1 ms	OSC Level	1.000
Ref. Phase	0.000	Output	ACosT, ASinT

6. Click on the Advanced button.

The lock-in amplifier 1 Advanced window opens.



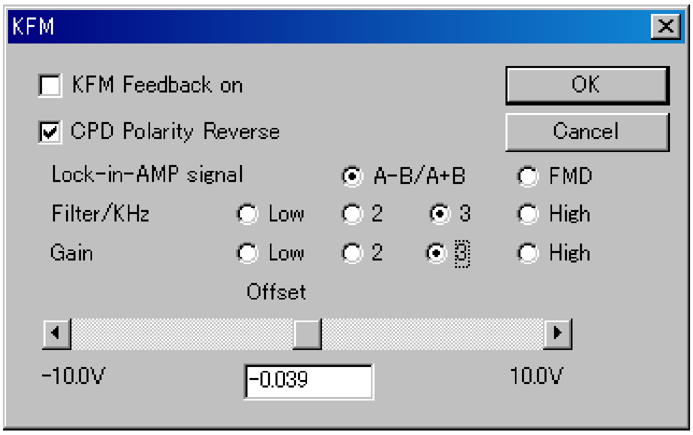
7. Specify the parameters according to the following table:

Filter	Band pass	Dynamic Res.	High Resolution
Filter Frequency/kHz	40.000	Offset	☐
Line Reject	Off		
Track	☑		
Ref	INT		
2F	☐		
Slope/12dB	☐		

■ Setting the KFM parameters

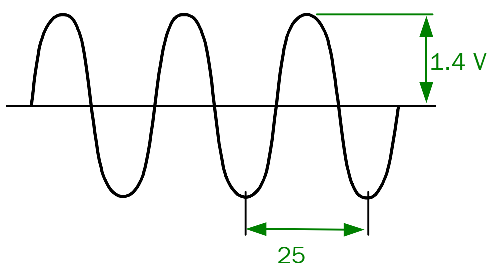
1. Click on the KFM button in the SKPM tab window to open the KFM window; then specify the following items.

KFM Feedback on	☐
CPD Polarity Reverse	☑ (when the sample is biased)
	☐ (when the probe is biased)
Lock-in-AMP signal	A–B/A+B
Filter/KHz	3
Gain	3
Offset	Center position



2. Set CH2 of the optional oscilloscope to BIAS and monitor the CH2.

You can observe the waveform set in the lock-in amplifier as shown below:

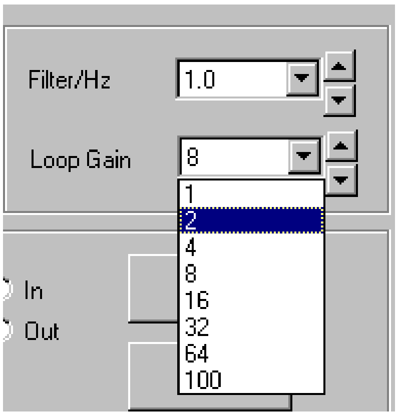


Adjust the Offset slider of the KFM window so that the DC component of the bias voltage becomes 0 V (so that the waveform of the bias voltage can be generated with 0 V as the center line).

3. Click on the Retract Off button and set the cantilever to an approach state.

Monitor Z/20 using oscilloscope CH1 and confirm that the Z voltage is in the vicinity of 0 V. If the Z voltage is extremely far either above or below 0 V, adjust it.

4. Select 1 or 2 from the Loop Gain box of the SPM Parameters window.



5. Move the Offset slider button to the plus side, and click on the Auto Configure button in the Lock-in Amplifier window to make an automatic phase adjustment.

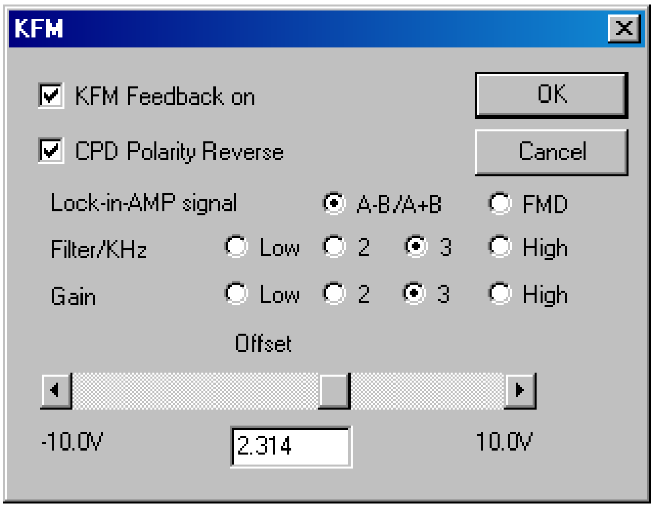
✍ Judge whether or not automatic phase adjustment has been properly carried out. To do this, click on the +90 button in the Lock-in-Amplifier window. If the reading of the lock-in amplifier analog meter changes from 0 → negative → 0 → positive each time the phase is changed 90° by clicking on the +90 button, phase adjustment is normal. Stop clicking on the button when the analog meter registers positive. If it does not indicate 0 when the phase is +90°, or +270°, carry out the automatic phase adjustment again.

6. Confirm that the reading of the analog meter on the lock-in amplifier changes toward the plus direction when you drag the Offset slider button in the KFM window to the plus side (the bias voltage changes to the plus side).

✍ This polarity results from the fact that the automatic phase adjustment was performed after changing the bias voltage to the plus side. If the polarity is reversed, click on the +90 button twice to rotate the phase by 180°.

7. Click on the Retract On button to retract the tip from the specimen; check the KFM Feedback on check box; then set Time Constant in the Lock-in-Amplifier window to MIN.

✍ If the lock-in amplifier meter needle swings beyond the scale (or in the case of Model 5110, the OVLD LED lights up), lower its sensitivity using the Lock-In Amplifier window.



8. Click on the Retract Off button and set the cantilever into an approach state again.

✍ At this stage, feedback will be executed to set the ω component (one cycle) to zero.

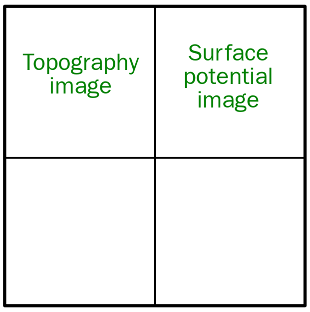
✍ If the lock-in amplifier meter needle swings out of scale (or in the case of Model 5110, the OVLD LED lights up), raise its sensitivity using the Lock-In Amplifier window.

9. Set oscilloscope (optional) CH2 to AUX1 to monitor CH2; then reset Filter and Gain in the KFM window according to the potential resolution.

■ Observation

◆ Click on the Scan button in the SKPM tab window.

The topographical image is displayed on the left side of the screen, and the surface potential image is displayed on the right side.



Set Clock/ms to 3.3333 ms or more and set Filter/Hz to 0.1 Hz. If the sample is comparatively flat, set its Loop Gain to 2. If the sample is uneven, set its Loop Gain to 8. If the topographical image does not become stable (the tip catches), increase the Clock setting. If that does not help improve the situation, increase the Loop Gain. To increase the Loop Gain, first click on the Retract On button to retract the cantilever from the sample, then change the Gain. After changing Reference in the SKPM tab window to minus, click on Retract Off and change Reference to plus. Then perform the approach slowly.

The higher the modulation frequency of the bias voltage applied across the specimen and the cantilever, the higher the resolving power. So you must keep in mind the fact that the excitation frequency is set so as not to exceed the characteristic frequency of the cantilever.

The captured surface potential image directly shows the surface potential of the sample (the vertical axis value relating to the surface potential image profile).

■ Principles of SKPM operation

Kelvin Force Microscopy (KFM) is a special technique used to observe the surface-potential image of a specimen by detecting the electrostatic force generated between a cantilever and the specimen using an AC-mode atomic force microscope (AFM) and controlling the bias potential of the specimen so that the electrostatic force is minimized.

If U is the potential difference between a cantilever and a specimen, the electrostatic force generated between them is given by the following equation:

$$F = -\frac{1}{2} \cdot U^2 \cdot \frac{\partial C}{\partial z}$$

where, z is the distance between the cantilever and the specimen, and C is the electrostatic capacitance. An AC voltage with amplitude V_{AC} and angular frequency ω, superimposed on a DC voltage $V_{DC,}$ is given by the following equation:

$$V_t = V_{DC} + V_{AC} \cdot \sin \omega t$$

This superposed voltage is applied between the cantilever and the specimen. If the contact potential difference is Δϕ/q*, the potential difference U_t is :

$$U_t = V_t - \Delta\phi / q$$

$$V_{DC} - \Delta\phi / q + V_{AC} \cdot \sin \omega t$$

From the above equation, the electrostatic force F is given as follows:

$$F = -\frac{1}{2} \cdot \left(V_{DC} - \Delta\phi / q + V_{AC} \cdot \sin \omega t\right)^2 \cdot \frac{\partial C}{\partial z}$$

This equation can be expanded as follows:

$$F = -\frac{1}{2} \cdot \left[\left(V_{DC} - \Delta\phi / q\right)^2 + \frac{1}{2} V_{AC}{}^2\right] \cdot \frac{\partial C}{\partial z}$$

$$- \frac{\partial C}{\partial z} \cdot \left(V_{DC} - \Delta\phi / q\right) \cdot V_{AC} \cdot \sin \omega t$$

$$+ \frac{1}{4} \cdot \frac{\partial C}{\partial z} \cdot V_{AC}{}^2 \cdot \cos 2\omega t \quad \cdots\cdots (1)$$

The Electrostatic force F has both a static component and components at angular frequencies ω and 2ω, as shown in equation (1). These components are detected as the change of the vibration amplitude (F: Force) of the cantilever and the characteristic frequency ($\frac{\partial F}{\partial z}$: Z-component of the Force gradient). The ω component is removed using the Lock-in Amplifier. In the case of Force, the ω component corresponds to $\frac{\partial C}{\partial z} \cdot \left(V_{DC} - \Delta\phi / q\right) \cdot V_{AC}$, as shown in the second term of equation (1).
In the case of the Force gradient the ω component corresponds to $\frac{\partial^2 C}{\partial z^2} \cdot \left(V_{DC} - \Delta\phi / q\right) \cdot V_{AC}$.
The specimen surface potential is measured by controlling V_{DC} so that this value becomes zero.

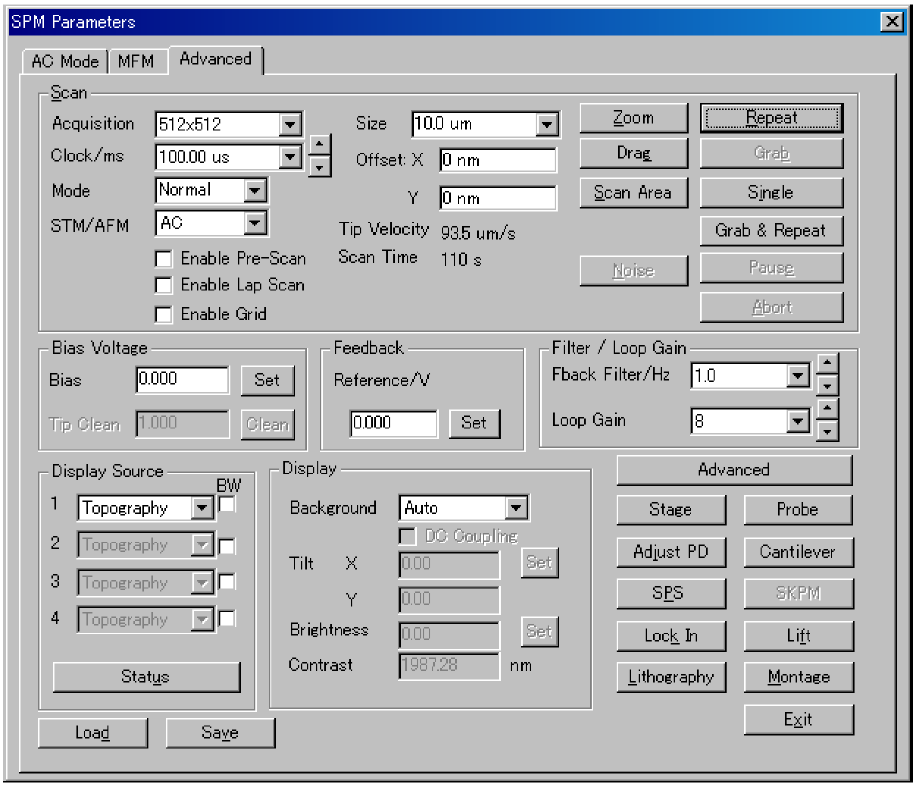
- REFERENCE:

Hiroshi Yokoyama, et al., Journal of The Physical Society of Japan, 49, 281 (1994)
T. Hochwitz, et al., Journal of Vacuum Science Technology, B14, 457 (1996)

* Δϕ(units: eV) is the Work Function Difference (WFD) and Δϕ/q(units: V) is the Contact Potential Difference(CPD).

5.4.5 Advanced Tab

The Advanced tab window is used to set parameters in detail. All of the parameters in this window must be specified.



■ Checking before an approach

Before performing an approach, check whether the preparation has been completed according to the procedure in Sect. 5.3, "Preparing for Measurement".

- Is the cantilever for the AC mode properly mounted on the cantilever holder?
- Has coarse approach been executed in such a way that the distance between the cantilever tip and the specimen surface is 0.3 mm or less?
- Is the Z stage position in the approach-possible range?
- Is the AFM value of the AFM amplifier unit about 0 V?
- Is the FFM value of the AFM amplifier unit about 0 V?

✍ After checking these points, set the indicator selection knob on the AFM amplifier unit to "RMS".

■ Setting the advanced mode parameters

Below is the procedure for setting parameters for topography observation. Specify each parameter according to the following procedure.

1. Click on the ▼ button in the Acquisition selection box and select 512×512 from the pull-down menu.

2. Click on the ▼ button in the Clock/ms selection box and select 100.00 us from the pull-down menu.

This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen. Here, set it to 100.00 us provisionally.

3. Click on the ▼ button in the Mode selection box and select Normal from the pull-down menu.

The AC AFM observation mode (Normal, MFM, VE-AFM, or SKPM) can be selected from this selection box. Selectable modes depend on the attachments connected. Selecting Normal sets the system to topography mode.

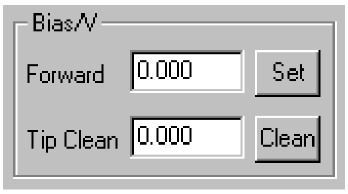
4. Click on the ▼ button in the STM/AFM selection box and select AC from the pull-down menu.

Doing so sets the system to the AC/Phase/FMD feedback detection mode.

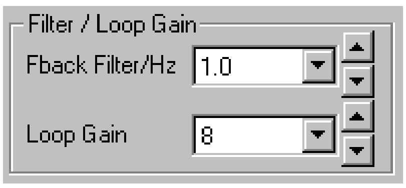
5. Click on the Size box. When the numerical value is highlighted, enter 1 um using the keyboard and finalize the numerical value by pressing the Tab key. Or, click on the ▼ button in the Size selection box and select a numerical value close to 1.000 um.

✍ The size to be set depends on the scanner used. Specify an appropriate value according to the observation area you want to observe.

6. Click on the Bias/V box. When the numerical value is highlighted, enter 0 using the keyboard and finalize the numerical value by pressing the Tab key.



7. Click on the ▼ button in the Fback Filter/Hz selection box and select 1.0 from the pull-down menu.

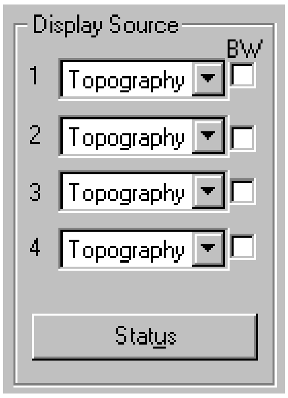


Fback Filter/Hz is the parameter that determines the response speed of the feedback circuit. The larger the specified value, the faster the response speed, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, select the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.

8. Click on the ▼ button in the Loop Gain selection box and select 8 from the pull-down menu.

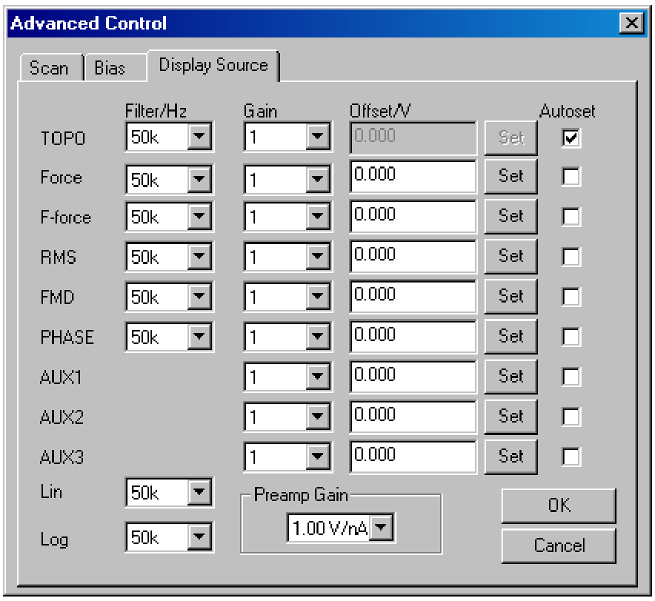
Loop Gain is the parameter that determines the gain of the feedback circuit. The larger the specified value, the higher the gain and the better the image of a specimen which has irregularities. In this case, however, the feedback circuit easily oscillates.

9. Click on the ▼ button in the Display Source 1 selection box and select Topography from the pull-down menu.



10. Click on the Advanced button in the Advanced tab window.

The Advanced Control window is displayed.



The ☐ or ☑ check box is a toggle switch. Every time you click on it, it changes alternately between ☐ and ☑. The ☑ check box means that it is selected.

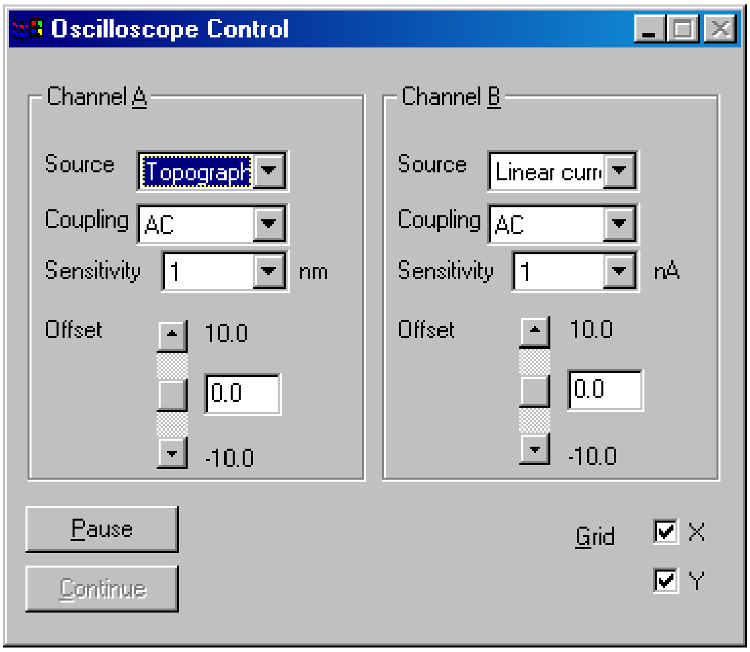
11. Click on the Display Source tab, and then check the TOPO–Autoset box.

■ Setting the software oscilloscope

Set the software oscilloscope for Channel B as follows:

1. Click on the 🗗 button of the Oscilloscope Control window.

The Oscilloscope Control window will open.



2. Click on the ▼ button in the Source selection box in the Channel B frame; then select Force from the pull-down menu.

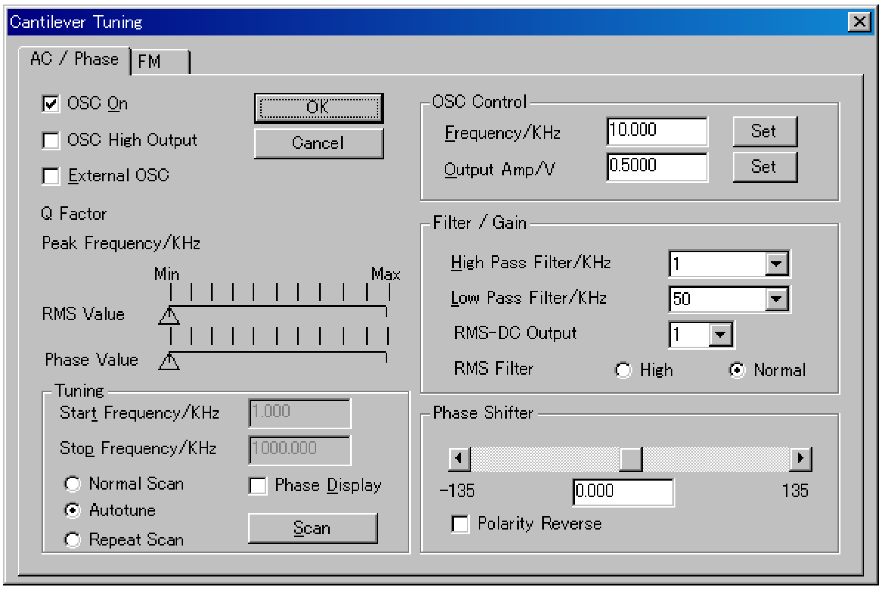
3. Click on the ▼ button in the Sensitivity selection box in the Channel B frame; then select 5 from the pull-down menu.

■ Cantilever automatic tuning (AC)

Specify the frequency and excitation voltage at which to vibrate the cantilever. If you use it under an ultra-high vacuum, the Q value of the cantilever becomes high; the cantilever amplitude becomes large even with a small excitation voltage. Therefore, if you carelessly apply a large excitation voltage to the cantilever, the cantilever might break. In the ultra-high vacuum AFM, use the instrument without checking the OSC High Output check box (☐).

1. Click on the Cantilever button in the Advanced tab window (SPM Parameters window).

The Cantilever Tuning window will open.



2. Click on the AC/Phase tab of the Cantilever Tuning window; click on the Autotune radio button in the Tuning frame.

3. Click on the Scan button in the Tuning frame.

Cantilever tuning takes place automatically as in the case of the AC AFC mode. (Section 1.4.1, "Adjusting a cantilever resonance point.")

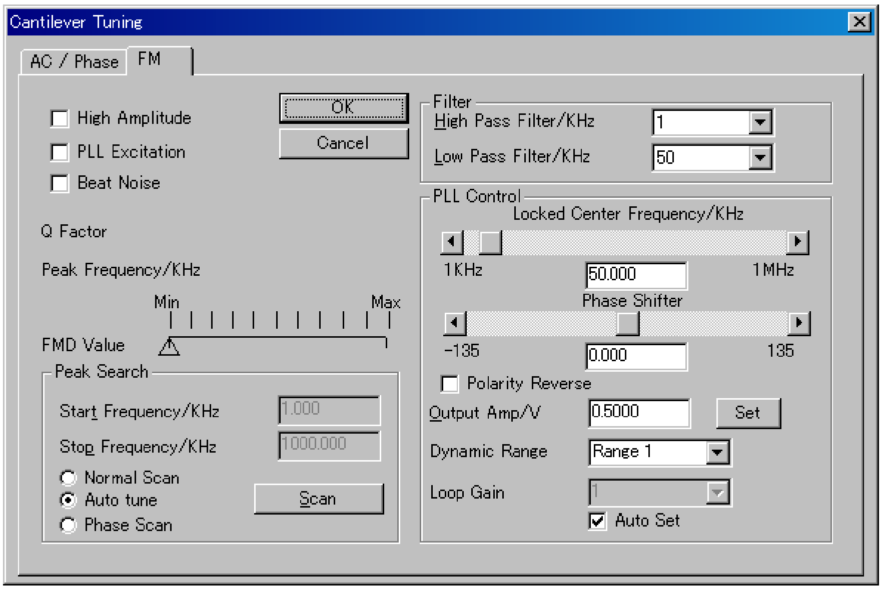
The procedure above completes automatic cantilever tuning. If, however, you have failed to do so, you should also carry out the procedure for manual tuning.

■ Cantilever automatic tuning (FMD)

In AC mode observation under ultra-high vacuum, not only the Slope detection method (RMS-DC) but also the FM detection method is applicable. Since the Q value of the cantilever under a vacuum is high, positive feedback oscillation is possible. FM detection is well suited for flat samples with small observation areas, providing higher sensitivity and resolution than Slope detection. The disadvantage of FM detection is that stability is comparatively poor.

1. Click on the Cantilever button in the Advanced tab window (SPM Parameters window).

The Cantilever Tuning window will open.



2. Click on the FM tab of the Cantilever Tuning window; click on the Autotune radio button in the Tuning frame.
3. Click on the Scan button in the Tuning frame.
   Cantilever tuning takes place automatically as in the case of the AC AFC mode. (Section 5.4.1, "Adjusting a cantilever resonance point.")

The above completes automatic cantilever tuning. If, however, you have failed to do so, you should also carry out the procedure for manual tuning.

■ Cantilever manual tuning (AC)

This section presents the procedure for tuning the cantilever manually, assuming that an Si cantilever whose resonance frequency is 300 kHz is employed. Carry out the procedure, for instance, when the tuning cannot be accomplished automatically.

● To sweep the frequency and find the resonance frequency

1. Click on the Normal Scan radio button in the Peak Search frame.
2. Double-click on the Start Frequency/KHz input box and enter 250 using the keyboard.
3. Double-click on the Stop Frequency/KHz input box and enter 350 using the keyboard.
   This sets the frequency sweep range to 250 - 350 kHz.
4. Click on the ▼ button in the High Pass Filter/KHz selection box and select 200 from the pull-down menu.
5. Click on the ▼ button in the Low Pass Filter/KHz selection box; then select 400 from the pull-down menu.
   The Low and High Pass Filter/KHz selection boxes are used to cut off other frequency components which interfere with the A–B signal. Enter a frequency lower than the start frequency in the Low Pass Filter/KHz selection box and a frequency higher than the stop frequency in High Pass Filter/KHz selection box.
6. Click on the ▼ button in the RMC-DC Output selection box; then select 10 from the pull-down menu.

7. Double-click on the Output Amp/V input box; then enter 0.2 using the keyboard.

8. Double-click on the Frequency/KHz input box; then enter 250 using the keyboard.

The reason why you enter 250 is that, if this Frequency/KHz is in the vicinity of the resonance point when you begin the frequency sweep, the effect of the resonance might still remain even though the frequency is set to the same value as Start Frequency/KHz, meaning that the resonance point might not be measured correctly. Set Frequency/KHz to the same value as Start Frequency/KHz.

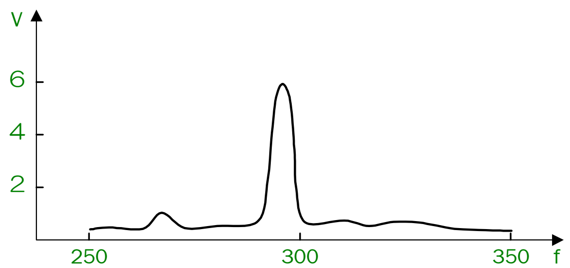
9. Click on the OSC On check box.

The box changes to ☑ and the cantilever starts vibrating.

10. Click on the Scan button in the Tuning frame.

The frequency sweep takes place and the frequency sweep data is displayed in the Display Window. Since the Enter image title window will appear, click on the OK button if you want to save the data. However, you usually click on the Cancel button.

The frequency sweep data roughly looks like the figure shown below.



The peak frequency is indicated as Peak Frequency/KHz in the Cantilever Tuning window. If no correct data is obtained, confirm that the following points are set.

- STM/AFM in the Scan frame in the Advanced tab window is set to AC.
- High Pass Filter/KHz and Low Pass Filter/KHz in the Cantilever Tuning window are set to the correct values.
- OSC On is checked ("☑").
- SUM for the AFM AMP unit is set to within a range of –1.0 to –9.0 V, and AFM and FFM are both set to somewhere near 0 V.
- When the Force waveform is observed while increasing the CH2 gain of the optional oscilloscope, the waveform is a sine curve.

● To sweep the frequency in a narrower frequency range

◆ Perform frequency sweep in the frequency range of ±10 kHz of the obtained Peak Frequency/KHz value.

For example, if the obtained Peak Frequency/kHz value is 290 kHz, perform the frequency sweep again by setting Start Frequency and Stop Frequency to 280 kHz and 300 kHz, respectively.

● To set the excitation frequency of the cantilever

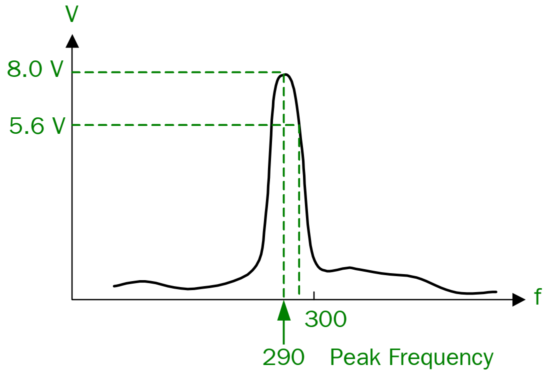
1. Click on the Set button for Frequency/KHz in the Cantilever Tuning window.

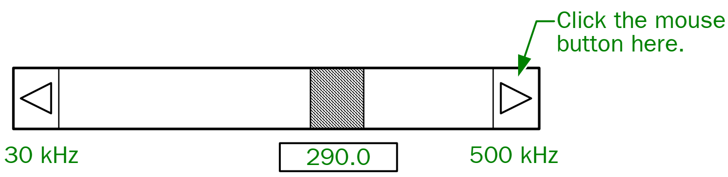
The VCO Frequency/kHz window will appear.

2. Enter the frequency displayed in Peak Frequency/KHz in the input box in the VCO Frequency/kHz window using the keyboard.

3. Adjust the frequency toward the higher frequency allowance, using the VCO Frequency/kHz window, so as to obtain close to 70% of the maximum output voltage at the Peak Frequency value obtained in the frequency sweep.

For example, if the following data is obtained, set the RMS Value to 8.0 V × 0.7 = 5.6 V, and shift the frequency from the peak value to a slightly higher value. If instead you set the frequency toward the lower frequency reading, shift the frequency from the peak value to a slightly lower value.





Click on the increase button (arrow mark to the right) while watching the RMS Value until it reaches –5.6 V; then click on the OK button to close the VCO Frequency /kHz window.

■ Cantilever manual tuning (FMD)

This section presents the procedure for manually tuning the cantilever. The procedure is useful when you are unable to tune the cantilever automatically.

● Cantilever characteristic frequency peak search

You can check the cantilever resonance frequency for the FM detection method and specify the center frequency for the FM detection method by doing the following:

1. Click on the ▾ button in the STM/AFM selection box in the Scan frame in the Advanced tab window; then select FM from the pull-down menu.

2. Click on the Cantilever button at the lower right in the Advanced tab window.

The Cantilever Tuning window opens.

3. Click on the FM tab to open the FM tab window; then type 0.1 in the Output Amp/V input box.

4. Enter 10 in the High Pass Filter/KHz input box and 600 in the Low Pass Filter/KHz input box.
5. Click on the Normal Scan radio button.
6. Specify Start Frequency/KHz and Stop Frequency/KHz in the Peak Search frame.

   ✍ A span of about 100 kHz centering on the characteristic frequency of the cantilever is an appropriate range to input.
7. Click on the Scan button in the FM tab window.

   The frequency-dependence curve of cantilever vibration amplitude created by forced oscillation will be displayed, and the peak frequency and Q factor will be displayed.

You can check the cantilever resonance frequency for the FM detection method and specify the center frequency for the FM detection method, using the curve and the peak value obtained through the operations explained above. Moreover, you can determine the forced frequency for the FMD mode.

● Adjustment of Positive Feedback Oscillation (FM Detection Method)

In the case of image observation by the FM detection method, if you already know the characteristic frequency of the cantilever, you can omit the above operation, "Cantilever characteristic frequency peak search" and can proceed directly to the following operation:

1. Select RMS from AFM ALIGNMENT on the AFM AMP unit.
2. Click on the ▼ button in the STM/AFM selection box in the Scan frame on the Advanced tab window; then select FM from the pull-down menu.
3. Click on the Cantilever button at the lower right in the Advanced tab window to open the Cantilever Tuning window; then click on the FM tab to open the FM window.
4. Specify High Pass Filter/KHz and Low Pass Filter/KHz according to the characteristic frequency of the cantilever.

   ✍ If you set High Pass Filter to 10 kHz and Low Pass Filter to 600 kHz, there will be no inconvenience in routine measurement.
5. Specify Dynamic Range and Loop Gain according to measurement conditions.

   When measuring a very uneven surfaced specimen, select Range 3 or Range 4 for Dynamic Range, and select a number from 2 to 10 for Loop Gain. When measuring a not so uneven surfaced specimen, select Range 1 or Range 2 for Dynamic Range, and select a number from 10 to 30 for Loop Gain.

	Frequency Dynamic Range	Optimum Loop Gain
Range 1	76 Hz	20, 30
Range 2	152 Hz	10, 20
Range 3	305 Hz	5, 10
Range 4	610 Hz	2, 5

6. Enter the characteristic frequency of the cantilever in the Locked Center Frequency/KHz input box.

If you do not know the characteristic frequency of the cantilever, perform the above operation, “Cantilever characteristic frequency peak search.” If the characteristic frequency is known, the frequency to be input is given by:

Locked center frequency = Peak frequency – Dynamic range/2

7. Set Output Amp/V to 0.1 V.

8. Click on the Phase Scan radio button and on the Scan button in the FM window.

The phase is automatically adjusted so that the RMS value displayed in AFM ALIGNMENT of the AFM AMP unit becomes the largest. The RMS value should not exceed 2. If it seems likely to exceed it, diminish the Output Amp/V value.

There may be times when the RMS value exceeds 2 even if the output voltage is near 0 V. If this occurs, proceed to the next step as it is.

9. Set the indicator selection knob on the AFM AMP unit to FMD, then set the AFM ALIGNMENT display to FMD.

10. Adjust the Locked Center Frequency/KHz bar chart so that the FMD value becomes about –5 (V).

11. Change the locked center frequency to the higher frequency using the □ button of the Locked Center Frequency/KHz bar chart.

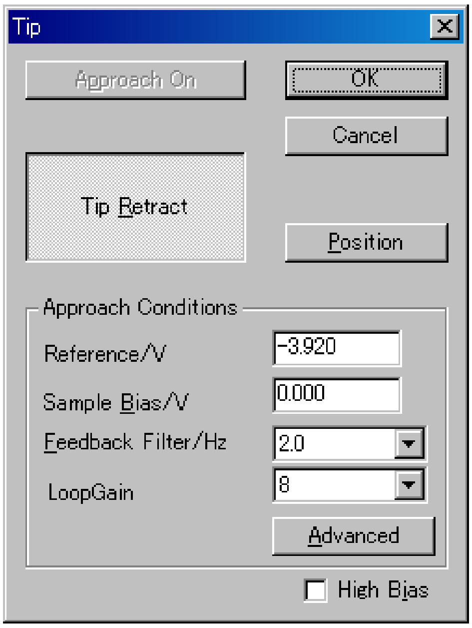
If the locked center frequency is not appropriate, the display of FMD value will be about –5 (V). It does not change any more. If the locked center frequency is appropriate, you can set the FMD value between 0 and 10 (V) according to the appropriately locked center frequency.

■ Approach

Move the cantilever closer to the specimen until the RMS value becomes the voltage specified in Reference/V. The cantilever movement automatically stops when the RMS value reaches the Reference/V voltage. The following is the procedure used for this approach.

1. Click on the Probe button in the Advanced tab window.

The Tip window will appear.



2. Specify each parameter according to the following procedure:

a. Double-click on the Reference/V input box. When the value in the box is highlighted, enter the desired value using the keyboard. Press the Tab key on the keyboard to finalize the value.

Set Reference/V to a figure close to 70% of the RMS value in the AC feedback mode. Subtract a value of 0.2 from the FMD value in FMD feedback mode.

b. Click on the ▼ button in the Feedback Filter/Hz selection box; then select 2.0 from the pull-down menu.

Now, the Reference/V voltage and the response speed of the feedback circuit, which are used for approach, have been determined. To prevent the cantilever from colliding with the specimen, set Feedback Filter/Hz to a value higher than that for image observation.

c. Click on Tip Retract to deselect it.

3. Before performing an approach, make sure that the voltage applied to the Z scanner is at the maximum (+150 V - 200 V).

If the voltage applied to the Z scanner does not reach +150 V, it is judged that the approach has already been completed. So, the approach will not start even if you click on the Approach On button in the Tip window.

In such a case, check the following points:
- Make sure that Loop Gain is not so low.
  If Loop Gain is set to a low number, the gain of the feedback circuit is so small that the feedback voltage is not applied up to +150 V.
- Make sure that the RMS value displayed in RMS Value is not too close to the value given in the Reference/V input box.
  If the RMS value is close to that given in Reference/V, this indicates that the approach has already been completed.

  The following two reasons can be considered:
  1. The amplitude of the cantilever vibration has become small.
     If the cantilever tip is fairly close to the specimen surface, the cantilever amplitude could become small due to the attracting force of the specimen or the electrostatic force acting between the specimen surface and the cantilever tip, thus resulting in decreasing the RMS value close to the Reference/V value. In such a case, change the Reference/V value to an even smaller value (nearly 0 V), or repeat the adjustment.
  2. The approach has already been completed, or the cantilever tip has collided with the specimen.
     Retract the cantilever tip from the specimen. Then, try to readjust it.

4. Click on the Approach On button in the Tip window.

The motor for the approach starts to rotate and automatically stops when the RMS value becomes the same as the value given in Reference/V. Confirm that the approach has been completed, using the indicator of the AFM AMP unit, the oscilloscope or the software oscilloscope.

- When confirming the completion of an approach using the indicator of the AFM AMP unit, check whether the RMS value is close to the Reference/V value (the RMS value does not necessarily have to be exactly the same as the Reference/V value).
- When confirming the completion of an approach using the oscilloscope or the software oscilloscope, confirm that the Z voltage (CH1 or Channel A (red)) has come closer to 0 V than the position it had when approach started. Also confirm, using the software oscilloscope, that the RMS voltage (Channel B (blue)) approaches the Reference/V value.

■ Topographical image observation

When approach has been completed, carry out the scan.

● Starting scanning

◆ Click on the Repeat button on the Advanced control panel. The scanning will start and an image will appear in the Display Window.

✍ In the AC mode, an important factor for obtaining a high-quality image is the distance between the specimen surface and the cantilever tip. If this setting is inappropriate, not only can a quality image not be obtained, but also the specimen and the cantilever may be damaged. You may set the distance between the specimen and the cantilever tip using Reference/V. Generally, the scanning speed for the AC mode is one step slower than that for the contact mode, even for the same scanning range.

● Setting Reference/V

◆ Set the distance between the specimen and the cantilever tip using Reference/V. Normally, while observing an image from a separated position, gradually move the cantilever tip toward the 0 V side (the direction toward the specimen), and set it in the optimum position so that the best image can be photographed.

✍ If the RMS value reads –5.6 V (the preset voltage setting at which the cantilever separates completely), this indicates that the cantilever tip is too far from the specimen. If the RMS value reads 0 V, this indicates that the cantilever tip has collided with the specimen surface.

■ Observing an MFM image

You can carry out MFM (Magnetic Force Microscope) measurement using a dedicated cantilever for MFM measurement. It should be noted that better results might be obtained if you magnetize the MFM cantilever beforehand using a permanent magnet. You can usually perform MFM observation using the AC mode. To separate a topographic image from an MFM image, lift the cantilever from the specimen in the position where a topographic image is acquired. Then the phase difference of the cantilever will be displayed as an MFM image. The standard system provides point-by-point lifting (lifting at every picture element); line-by-line lifting (lifting at every line) is also optionally available.

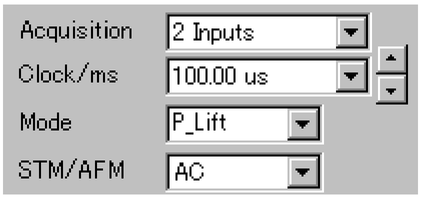
- Point by Point Lift Mode (P_Lift)
  In this mode, the cantilever is lifted at every point where measurement has been performed. If, however, you want to carry out the measurement under vacuum using this mode, you can carry out measurement only with a loss of the stability in the topographical image, and in the MFM image since the cantilever frequently moves up and down.
- Line by Line Lift Mode (L_Lift)
  In this mode, the cantilever is lifted each time a line has been scanned for measurement. Since the movement of the cantilever is less frequent in this mode, comparatively stable images can be obtained.

● Topographical image

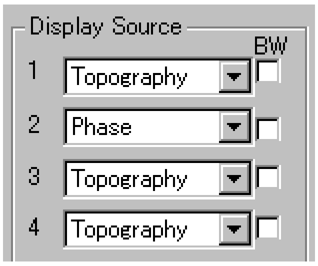
In MFM image observation, it is essential that the topographical image of a sample can be observed clearly and sharply in AC mode. Observe the topographical image in the AC mode in advance to find out the best observation condition. To do this, click on the Retract On button and then carry out the same procedure as in Section 5.4.2, “Image observation and lift setting.”

● MFM image

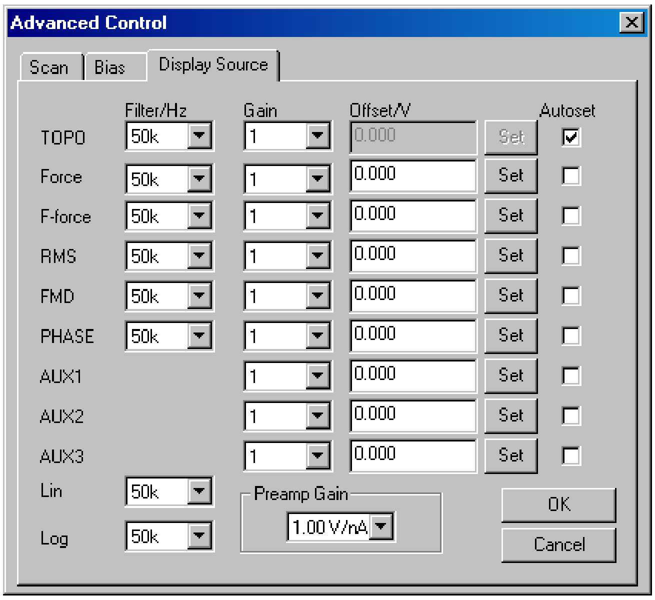
1. Obtain a desirable topographical image (see Section 5.4.2).
2. Stop scanning and enter the parameters as follows;
   a. Select 2 Inputs from the Acquisition selection pull-down menu in the Scan frame of the Advanced tab window.
   b. Select P_Lift or L_Lift from the Mode selection pull-down menu.



c. Enter information in the Display Source frame as follows:

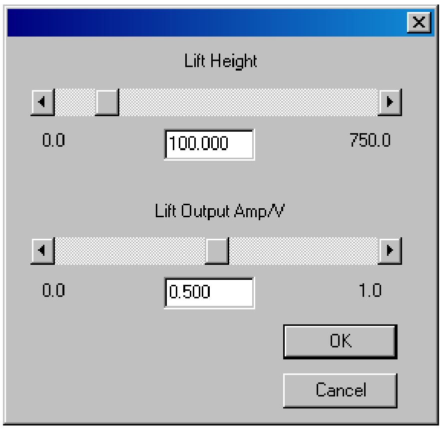


3. Click on the Advanced button (in the lower right section) in the Advanced tab window to open the Advance Control window; click on the Display Source tab to open the Display Source window; then enter data in the manner shown below.



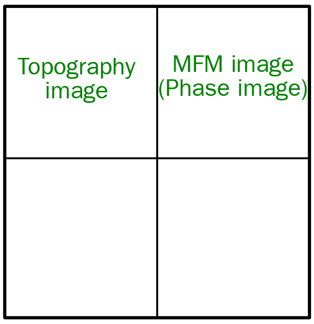
4. Click on the Retract Off button.

5. Click on the Lift button in the Advanced tab window to open the Lift window.



6. Double-click on the Lift Height input box; then enter 100 nm using the keyboard. Press the TAB key to finalize the value.
7. Click on the Repeat button to scan the specimen.

   The following display will appear.



8. Decrease the Lift Output Amp/V value gradually so that you can obtain the best possible MFM image.

■ Observing a VE-AFM image (optional)

Viscoelasticity image observation is an optional function that requires a lock-in amplifier supplied to order. Connect the lock-in amplifier to the SPM controller and set the software in accordance with the procedure in Section 5.2.5, “Lock-in amplifier.”

Usually, you will observe a viscoelasticity image using the Contact mode. Depending on the sample, however, you may not be able to obtain any good image. At times you obtain only perturbed images due to the adhesion of the cantilever to the sample. To avoid this problem, use the AC mode. Then you can obtain good results. Viscoelasticity observation in the AC mode will be performed through use of the difference between the resonance frequency (about 300 kHz) of the cantilever and the modulation frequency (several tens of kHz) for viscoelasticity observation.

● Topographical image

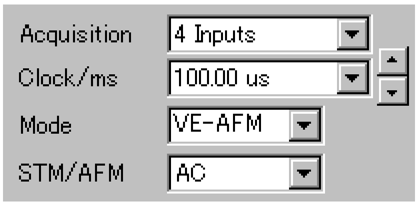
◆ Observe the topographical image of a sample; make sure that the image is satisfactory; then click on the Retract On button to retract the tip.

● Setting the lock-in amplifier

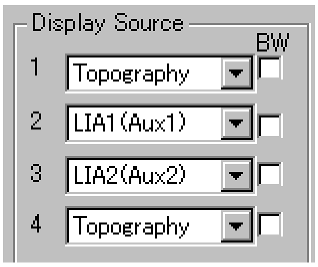
◆ Carry out the same procedure as in Section 5.4.3, “Setting the lock-in amplifier.”

● MFM Image

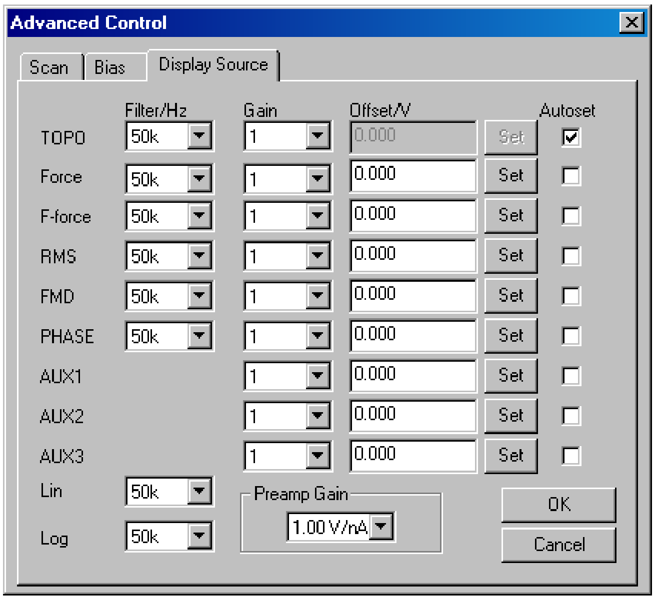
1. Obtain a desirable topographical image (see Section 5.4.2).
2. Stop scanning and enter the following parameters:
   a. Select 4 Inputs from the Acquisition selection pull-down menu in the Scan frame of the Advanced tab window.
   b. Select VE-AFM from the Mode selection pull-down menu.



   c. Enter information in the Display Source frame as follows:

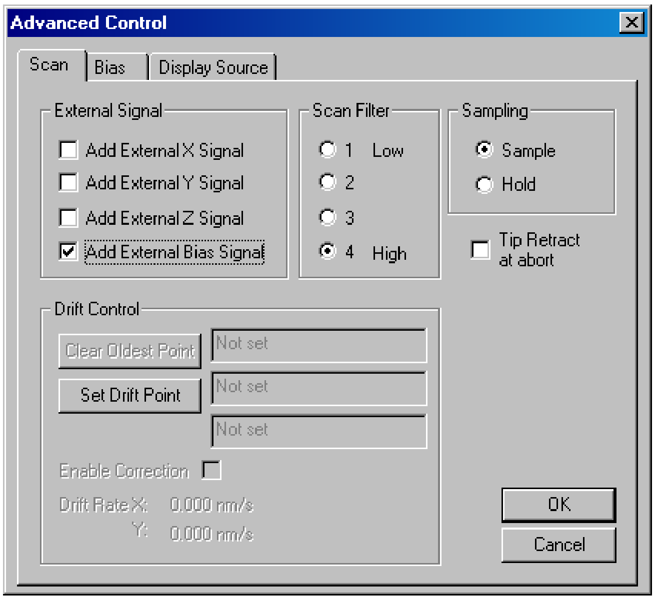


3. Click on the Advanced button (in the lower right section) in the Advanced tab window to open the Advance Control window. Click on the Display Source tab to open the Display Source window; then enter data in the manner shown below.



4. Click on the Scan tab in the Advanced Control window to open the Scan tab window and check the Add External Z signal checkbox. (Note that in the illustration below, Add External Bias Signal is checked. In this step, however, check the Add External Z signal checkbox.)

An oscillating noise might sound depending upon the characteristic frequency of the scanner you use. If it happens, reduce the oscillation level (OSC Level/V), or shift the present oscillation frequency (OSC Frequency/kHz) setting the position until sounding stops.



5. Click on Probe in the Advance tab window to open the Tip window (see Section 5.4.5). Then click on Tip Retract to release retraction of the tip.

6. Set the sensitivity and phase of the lock-in amplifier using the Lock-In Amplifier window (see Section 5.4.4, “Setting the lock-in amplifier”).

Click on Auto Configure in the Lock-In Amplifier window in the case of Model 5110, and on Auto Sensitivity and Auto Phase in the case of Model 7265. Doing so adjusts the sensitivity and phase of the lock-in amplifier automatically.

7. Increase the input sensitivity of the lock-in amplifier using the SENSITIVITY setting key in the range in which the OLVD LED does not light up (from 1 mV to 100 nV direction).

8. Click on the Repeat button to scan the specimen.

The following display will appear:

Topography (Topography image)	Acosϕ (Elasticity image)
Asinϕ (Viscosity image)	

The region where both Acosϕ (elasticity) and Asinϕ (viscocity) images become bright is the region where elasticity and viscosity are high.

9. Specify the SPM parameters for usual operation so that you can obtain an optimum topographical image.

10. Change the following parameters so that you can obtain an optimum elasticity image as well as an optimum viscosity image.

- Oscillation frequency (OSC Frequency/kHz)
  If the difference between elasticity and viscosity of the specimen is small as in, for example, composite plastics composed of related materials, it is expedient to increase the oscillation frequency. Doing so might provide better images.
- Oscillation level (OSC Level/V)
  When you use hard cantilevers such as an Si cantilever, it is recommended that you use a low oscillation level to observe the image. If the oscillation level is too high, the cantilever may be broken. When you use soft cantilevers, however, increase the oscillation level accordingly. Generally, there is a tendency that the harder the cantilever, the better the results for viscoelasticity image observation.

■ Surface potential observation (SKPM)(optional)

SKPM (Scanning Kelvin Probe Microscopy) is an optional function that requires a lock-in amplifier supplied to order. Connect the lock-in amplifier to the SPM controller and set the software in accordance with the procedure in Section 5.2.5, "Lock-in amplifier."

● Topographical image

◆ Observe the topographical image of a sample; make sure that the image is satisfactory; then click on the Retract On button to retract the tip.

● Setting the lock-in amplifier

◆ Carry out the same procedure as in Section 5.4.4, "Setting the lock-in amplifier."

● Setting the bias voltage

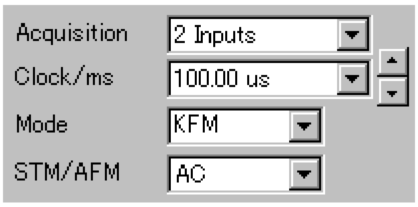
1. Input 0.000 in the Bias input box in the Bias Voltage frame of the Advanced tab window.
2. Click on the Advanced button to open the Advanced Control window.
3. Click on the Scan tab in the Advanced Control window.
4. Check the Add External Bias signal checkbox.

● Setting the SKPM parameters

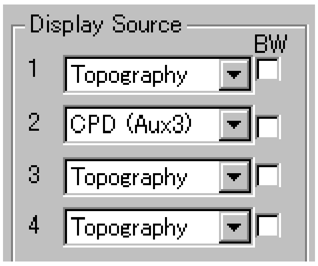
◆ Carry out the same procedure as in Section 5.4.4, "Setting the KFM parameters."

● SKPM image

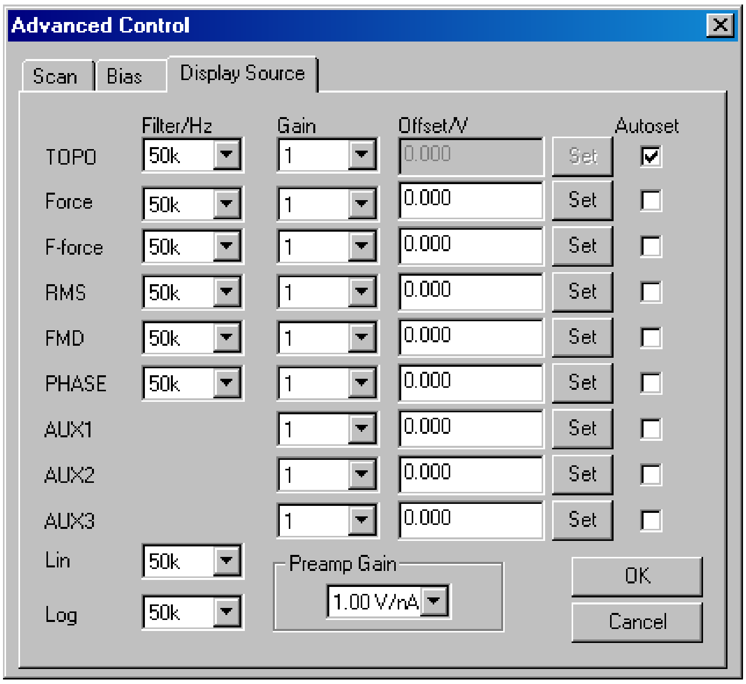
1. Obtain a desirable topographical image (see Section 5.4.2).
2. Stop scanning and enter the following parameters
   a. Select 2 Inputs from the Acquisition selection pull-down menu in the Scan frame of the Advanced tab window.
   b. Select SKPM from the Mode selection pull-down menu.



   c. Enter information in the Display Source frame as follows:

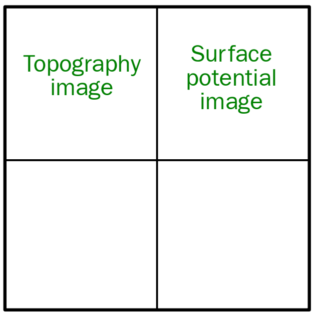


3. Click on the Advanced button (in the lower right section) in the Advanced tab window to open the Advance Control window. Click on the Display Source tab to open the Display Source window. Then enter data in the manner shown below.



4. Click on the Repeat button to scan the specimen.

The topographical image is displayed on the left side of the screen, the surface potential image on the right side.



✍ Set Clock/ms to 3.3333 ms or more and set Filter/Hz to 0.1 Hz. If the sample is comparatively flat, set Loop Gain to 2. If the sample is uneven, set Loop Gain to 8. If the topographical image does not become stable (the tip catches), increase the

Clock setting. If that does not help improve the situation, increase Loop Gain. To increase Loop Gain, first click on the Retract On button to retract the cantilever from the sample, then change Gain. After changing Reference in the SKPM tab window to minus, click on Retract Off and change Reference in the plus direction. Then slowly perform approach.

✍ Although the higher the modulation frequency of the bias voltage applied across the specimen and the cantilever, the higher the resolving power, you must keep in mind the fact that the excitation frequency is set so as not to exceed the characteristic frequency of the cantilever.

✍ The captured surface potential image directly shows the surface potential of the sample (the vertical axis value relating to the surface potential image profile).

■ Principle of SKPM operation

Kelvin Force Microscopy (KFM) is designed to observe a surface-potential image of a specimen by detecting the electrostatic force generated between a cantilever and a specimen using an AC-mode atomic force microscope (AFM) and controlling the bias potential of the specimen so that the electrostatic force becomes a minimum.
The following states the principle of KFM.
If U is the potential difference between a cantilever and a specimen, the electrostatic force generated between them is given by the following equation:

$$F = -\frac{1}{2}\cdot U^2 \cdot \frac{\partial C}{\partial z}$$

Here, z is the distance between the cantilever and the specimen, and C is the electrostatic capacitance. An AC voltage with amplitude V_{AC} and angular frequency ω, superimposed on DC voltage $V_{DC,}$ is given by the following equation:

$$V_t = V_{DC} + V_{AC} \cdot \sin \omega t$$

This superposed voltage is applied between the cantilever and the specimen. If the contact potential difference is Δϕ/q*, the potential difference U_t is :

$$U_t = V_t - \Delta\phi / q$$
$$V_{DC} - \Delta\phi / q + V_{AC} \cdot \sin \omega t$$

From the above equation, the electrostatic force F is given as follows:

$$F = -\frac{1}{2}\cdot \left(V_{DC} - \Delta\phi / q + V_{AC} \cdot \sin \omega t\right)^2 \cdot \frac{\partial C}{\partial z}$$

This equation can be expanded as follows:

$$F = -\frac{1}{2}\cdot \left[\left(V_{DC} - \Delta\phi / q\right)^2 + \frac{1}{2} {V_{AC}}^2\right] \cdot \frac{\partial C}{\partial z}$$
$$-\frac{\partial C}{\partial z}\cdot \left(V_{DC} - \Delta\phi / q\right)\cdot V_{AC} \cdot \sin \omega t$$
$$+\frac{1}{4}\cdot\frac{\partial C}{\partial z}\cdot {V_{AC}}^2 \cdot \cos 2\omega t \quad \cdots\cdots\cdots (1)$$

The Electrostatic force F has both a static component and components at angular frequencies ω and 2ω, as shown in equation (1). These components are detected as the change of the vibration amplitude (F: Force) of the cantilever and the characteristic frequency ($\frac{\partial F}{\partial z}$: Z-component of Force gradient). The ω component is removed using the Lock-in Amplifier. In the case of Force, the ω component corresponds to $\frac{\partial C}{\partial z}\cdot\left(V_{DC} - \Delta\phi / q\right)\cdot V_{AC}$, as shown in the second term of equation (1).
In the case of Force gradient the ω component corresponds to $\frac{\partial^2 C}{\partial z^2}\cdot\left(V_{DC} - \Delta\phi / q\right)\cdot V_{AC}$.
The specimen surface potential is measured by controlling V_{DC} so that this value becomes zero.

- REFERENCE:

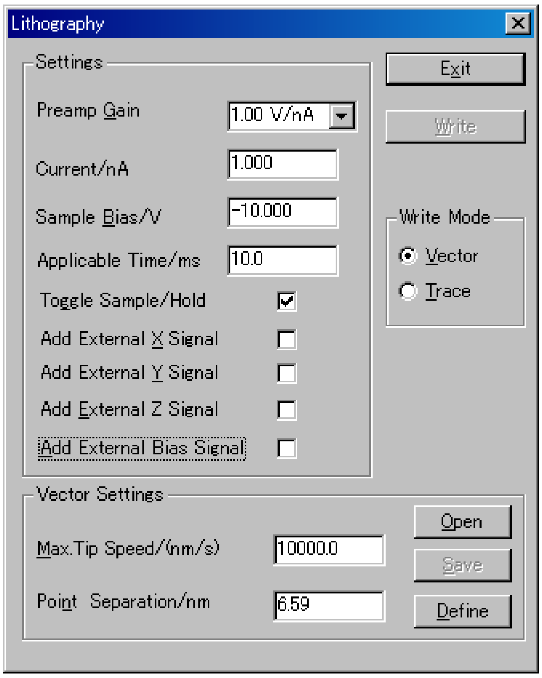
Hiroshi Yokoyama, et al., Journal of The Physical Society of Japan, 49, 281 (1994)
T. Hochwitz, et al., Journal of Vacuum Science Technology, B14, 457 (1996)

---

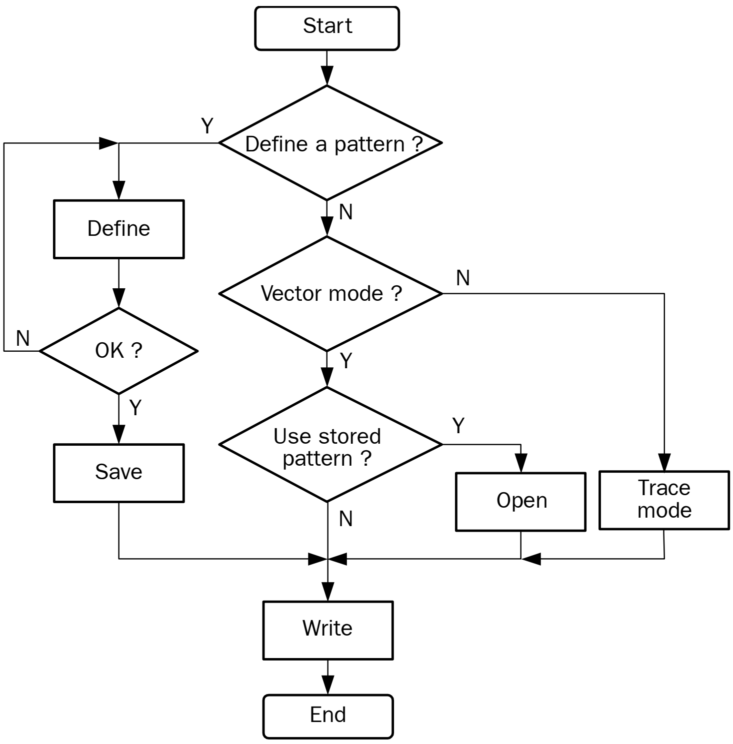
* Δϕ(units: eV) is the Work Function Difference (WFD) and Δϕ/q(units: V) is the Contact Potential Difference (CPD).

■ Lithography

When certain values are given to the bias voltage and tunneling current, the specimen surface structure may change due to the displacement or adsorption of atoms. "Lithography" lets you lithograph (or write on) the specimen surface using this phenomenon.



In SPM lithography, there are two modes, namely, the vector mode and the trace mode. The procedure for lithography is shown in the flow chart below:

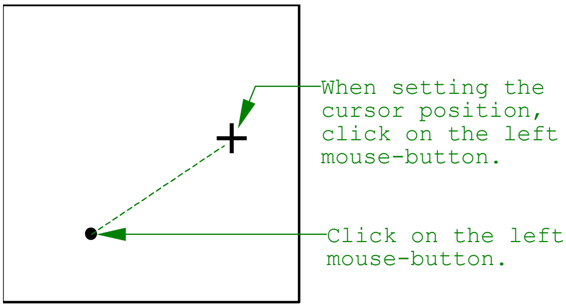


Lithography in Vector Mode

The following is the procedure for performing lithography in the vector mode:

1. Click on Lithography in the Advance tab window to open the Lithography window.
2. Observe an image as usual and capture it using the Grab function.
3. Specify the conditions for the sample to be lithographed using the Settings frame in the Lithography window.
4. Select Vector in the Write Mode frame. Then click on the Define button in the Vector Settings frame.

   Move the cursor to the Display Window. The cursor changes to the **+** mark.
5. Move the **+** mark to the initial point of the pattern that you want to write, and click the left mouse-button. Then drag it by holding the left mouse-button to draw a line. Click the left mouse-button again to set the final point.



   You can continuously define the pattern as explained above. To stop the pattern definition, click on the right mouse-button.
6. Click on the Write button to perform lithography.

   Lithography will be performed along the defined pattern.

Lithography in Trace mode

The following is the procedure for performing lithography in "Trace" mode.

1. Click on Lithography in the Advance tab window to open the Lithography window
2. Observe an image as usual and capture it using the Grab function.
3. Specify the lithography conditions in the Settings frame.
4. Select Trace in the Write Mode frame; then click on the Write button.

   Move the cursor to the Display Window. The cursor changes to the **+** mark.
5. Execute lithography by moving the mouse while holding the left mouse-button.

   Click the right mouse-button to stop the lithography.
6. Confirm the written pattern using the ordinary image-observation procedure.

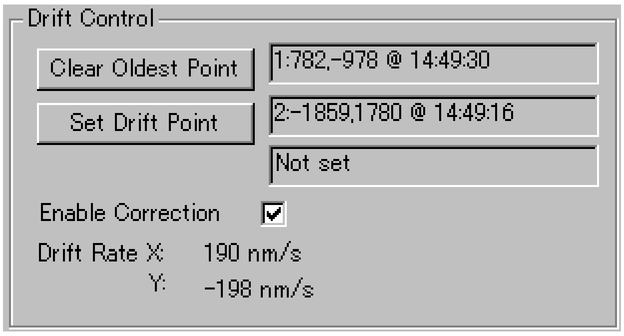
— CAUTION —

In order to prevent the tip from colliding with the specimen surface, the speed of the tip movement must not be faster than 200 nm/s.

■ Drift compensation

Sample thermal drift, no matter how small, poses a problem in continuous measurement at the atomic level under ultra high vacuum, as this is a procedure which requires a highly stable field of view. The Drift Control window is used to correct such drift as occurs in the measurement image due to thermal or, sometimes, other causes. Drift correction is done by shifting the center point of the scanning area in the same direction and through exactly the same distance as the drift, at the end of the scan. To implement drift compensation, therefore, it is necessary to carry out preparatory steps (to obtain the drift speed and direction).

In drift compensation, the amount of drift per unit of time is calculated from the distance between a certain point observed when you scan the field of view first and the same point observed when you scan it second. Each time the measurement ends, the field of view is shifted automatically by the inverse amount of drift corresponding to the elapsed time.



The functions of the buttons and indications in the Drift Control window are as follows:

Clear Oldest Point	You can erase the oldest of the set reference points.
Set Drift Point	You can set the reference points for computing the drift speed. You can specify up to three points.
Enable Correction	You can select this item if two or more reference points are set. While Enable Correction is being checked, the center point of measurement shifts exactly by the amount of drift correction each time measurement is performed.
Drift Rate	The computed drift speed is displayed. The drift speed is computed by a first order approximation based on the least square.

Carry out drift compensation as follows:

1. Click on the Advance button in the Advanced tab window to open the Advance Control window. Then click on the Scan tab.
2. Carry out measurement of the first image, and capture the image.
   Pick up features of the image such as a single bright point and hole that may indicate defects.
3. Click on the Set Drift Point button, and specify the first reference point.
   The mouse cursor changes to a cross shape, so specify the part of the measurement image that you picked up in advance.
4. Carry out measurement of the second image, and capture the image.
   Confirm that the picked-up part is included in the measurement image.
5. Click the Set Drift Point button, and specify the second reference point.

Like the setting of the first point, specify the picked-up part (the position may differ from that of the first image due to drift). When you set the second reference point, the drift speed and direction are automatically computed.

6. Check the Enable Correction checkbox by clicking on it.

Drift compensation is applied.

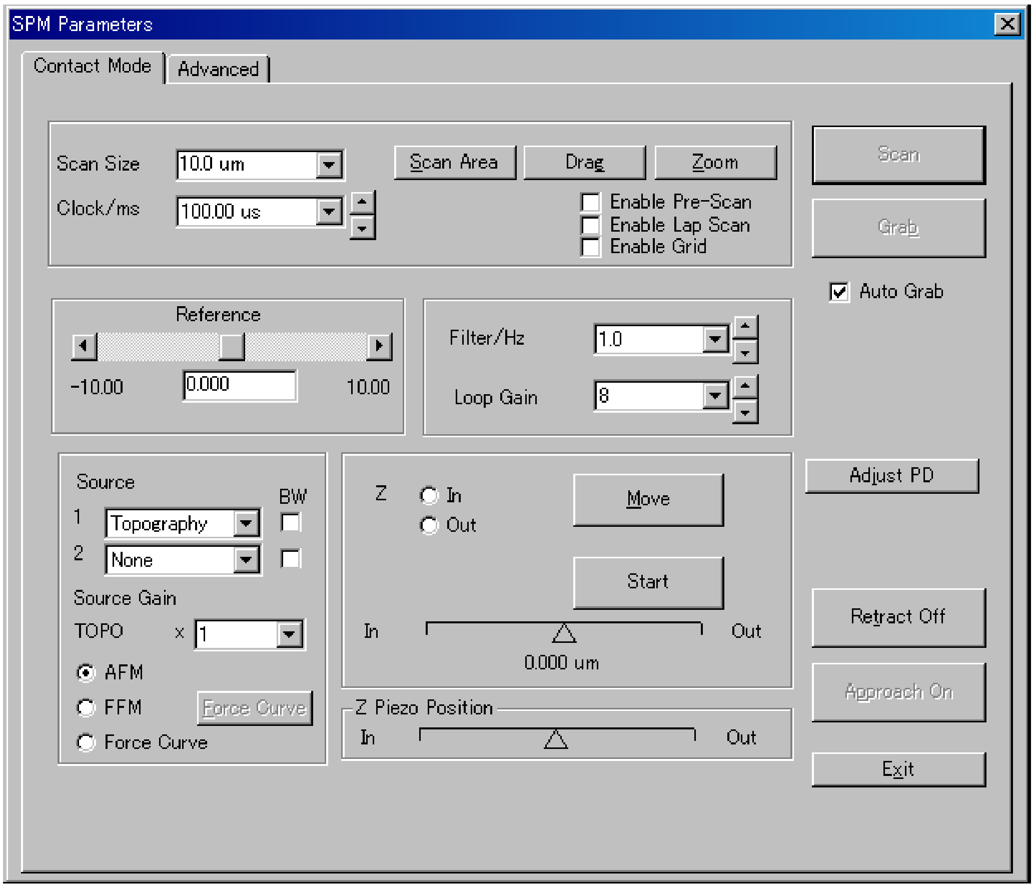
You can specify up to three points for drift compensation. When specifying the third point, carry out image measurement and reference point specification once again.

5.5 CONTACT AFM MODE

Observation in the contact mode is performed in the area in which repulsive force acts between the specimen and the cantilever tip.

5.5.1 Contact Mode Tab

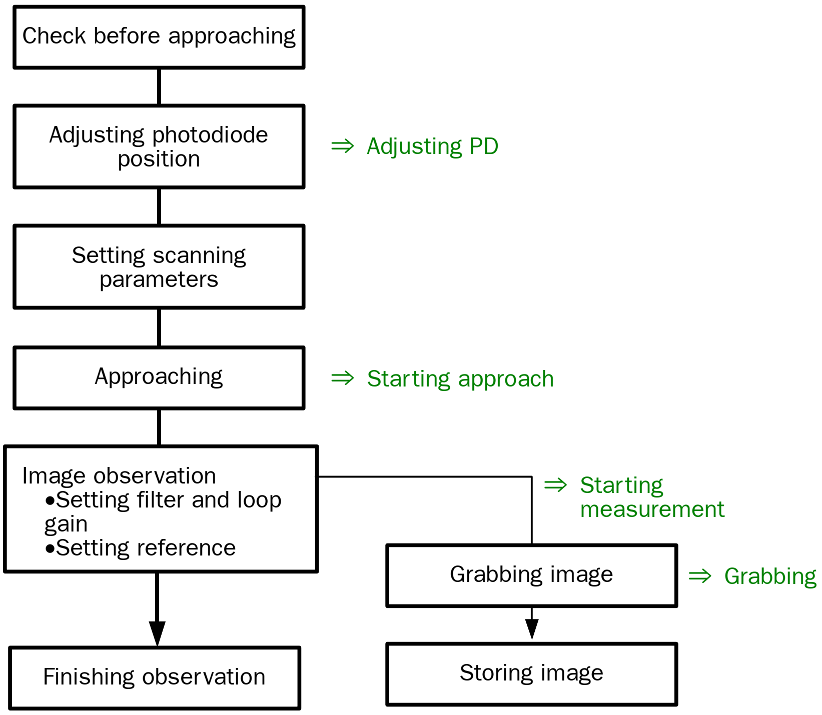
The following is an explanation of the method of observation using the Contact Mode tab window. The Contact Mode tab window is a basic operation window for a topography image observation in the contact AFM mode.



Contact Mode tab window

Flow chart of the operation

- The following is the flow chart of the operation in the contact mode.



Checking before approaching

Before performing approaching, check whether the preparation has been completed according to the procedure in Sect. 5.3, “Preparing Measurement”.

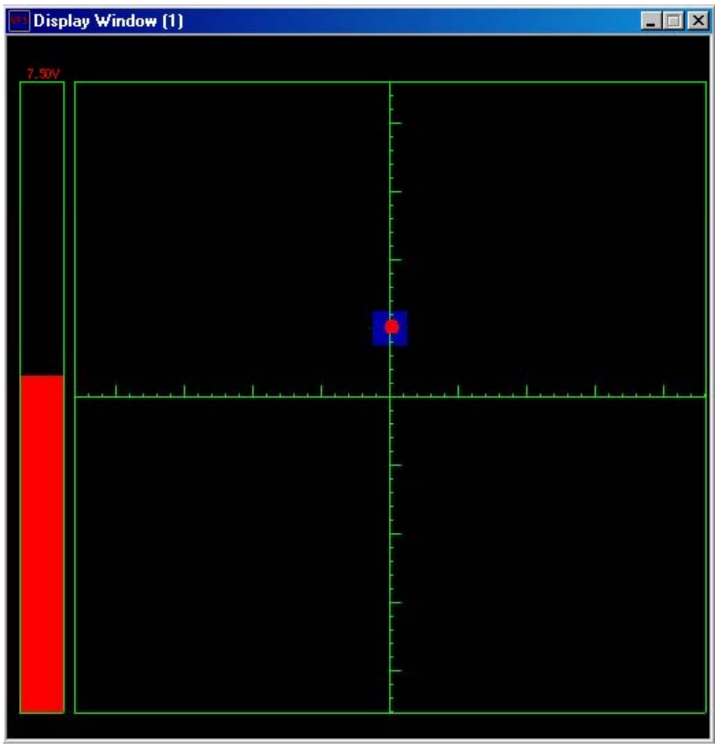
- Has coarse approaching been done in such a way that the distance between the cantilever tip and the specimen surface is within 0.3 mm or less?
- Is the Z stage position in the approaching-possible range?
- Is the SUM value of the AFM amplifier unit as negative as possible (–1.0 V to –9.0 V: the value depends upon the cantilever used)?

✍ After checking these points, set the indicator selection knob on the AFM amplifier unit to AFM.

■ Photodiode position adjustment

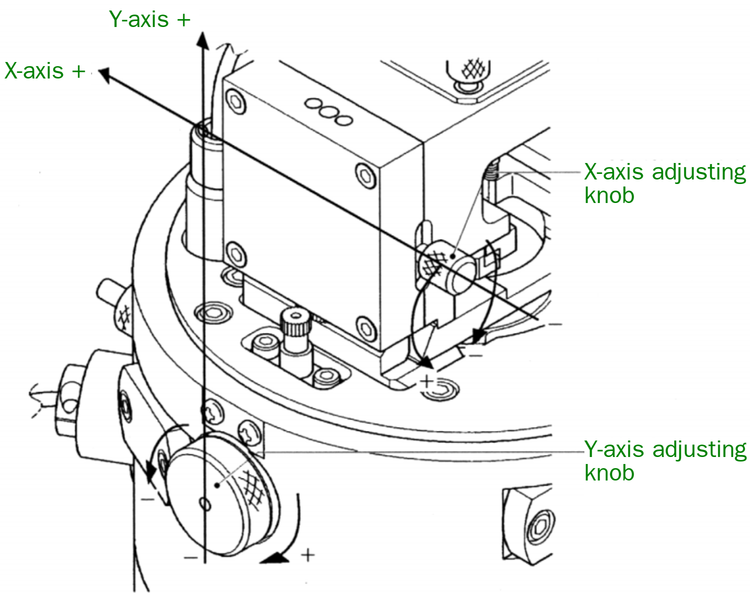
1. Click on the Adjust PD button in the Contact Mode tab window..

The following screen appears on the Display Window.



2. Rotate the photodiode position adjustment knob until the red spot enters the blue zone at the center.

Confirm that the SUM value of the AFM amplifier unit is as negative as possible.



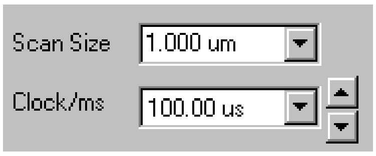
The figure above shows the model JSPM-5200.

■ Setting the scanning parameters

Before carrying out an approach operation, set the scanning parameters including the scanning area in the Contact Mode tab window. Although the values of these parameters differ depending upon the specimen and the purpose of use, rough values are as follows.

● Scan Size

◆ Click on the Scan Size selection box. When the numerical value is highlighted, enter 1 um using the keyboard and finalize the numerical value by pressing the Tab key. Or, click on the button in the Scan Size selection box and select a numerical value near 1,000 nm.



✍ Here, Scan Size differs depending on the scanner installed. In practice, set an appropriate value according to the observation area.

● Clock/ms

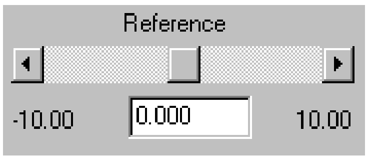
◆ Click on the button in the Clock/ms selection box and select 100.00 us.

This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen.

● Reference

◆ Double-click on the Reference box to highlight the numerical value and enter 0 using the keyboard; then determine 0 by pressing the Tab key on the keyboard.

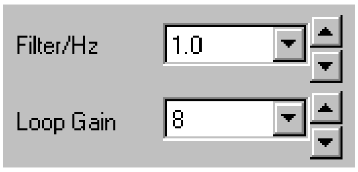
Reference is used to specify the force acting between the specimen and the cantilever tip. Change the value while observing the image, but now set it to 0.000 provisionally.



● Filter/Hz

◆ Click on the button in the Filter/Hz selection box and select 1.0 from the pull-down menu.

Filter/Hz is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, set the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.



● **Loop Gain**

◆ Click on the button in the Loop Gain selection box and select 8 from the pull-down menu.

The setting determines the gain of the feedback circuit. The larger the set value is, the higher the response gain becomes, thus obtaining a good image from an uneven specimen surface, but the feedback circuit easily oscillates.

● **Source (Selection of the acquired image type)**

• When you observe a topography (shape image)

This image is the constant atomic force mode for observing the topography of a specimen while keeping the repulsive force constant.

1. Select the AFM radio button at the left bottom of the Contact Mode tab window.
2. Click on the button in the Source 1 selection box and select Topography.
3. Click on the button in the Source 2 selection box and select None.
4. Click on the button in the Source TOPO selection box and select 1.

• When you observe a force image

You can observe a force image (atomic force image) by obtaining the movement of the cantilever as an image while keeping the distance between the cantilever and the specimen constant.

5. Select the AFM radio button at the left bottom of the Contact Mode tab window.
6. Click on the button in the Source 1 selection box and select Force.
7. Click on the button in the Source 2 selection box and select None.
8. Click on the button in the Filter [Hz] selection box and select 0.5 or less.

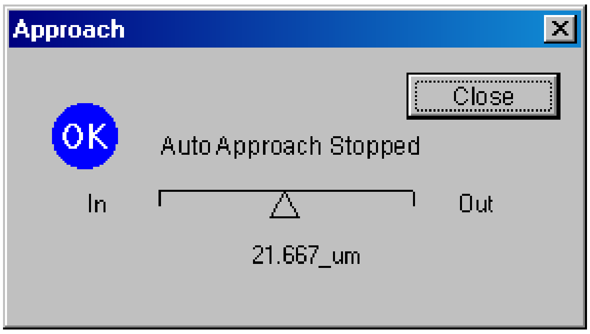
✍ When observing a force image, you keep the height of the cantilever constant and usually observe the image performing a slow feedback. Select a slower response for the feedback than that used for observing a topography image.

■ Approaching

1. Click on the Approach On button.

Automatically, approaching starts. When approaching finishes, the Approach window saying "Auto Approach Stopped" is displayed in the center of the screen.

2. Click on the Close button.



● Considerations in using Approach

◆ When the Approach On button is displayed in gray

Click on the Retract Off button. When the Retract OFF button is not selected, the Z scanner is forced to shrink most and cannot be approached.

◆ Speed of approaching

You can specify the speed of approaching in the advanced operation mode. You cannot adjust the speed of approaching in the basic mode. You cannot change the speed of approaching in the SPM instrument other than the ultra-high vacuum SPM.

◆ Judgment of approaching conditions

Whether approaching has finished or not is judged by measuring the voltage applied to the Z scanner. The voltage is set to ±0 V at the time of shipment from the factory. You can specify the approaching finish settings in the advanced operation mode.

◆ Halt of approaching

When approaching has begun, the Approach On button changes to the Approach Off button. If you click on this button, the approaching stops.

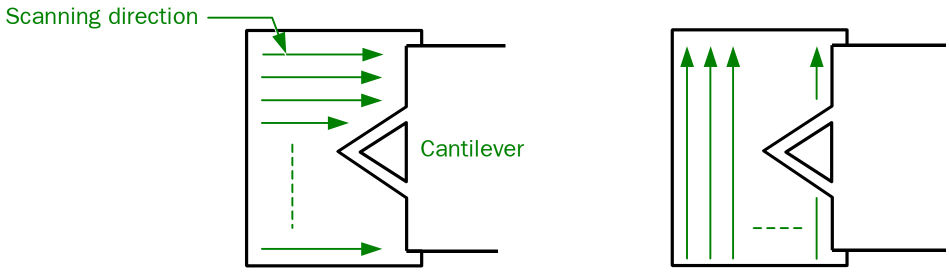
■ Image observation

◆ Click on the Scan button.

Scanning will start and an image will be displayed on the Display Window.

■ FFM observation

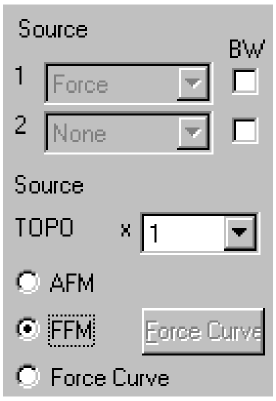
In the ordinary contact-mode AFM, the specimen-scanning direction is parallel to the cantilever axis as shown in the left figure below. In the case of FFM (Friction Force Microscope), on the other hand, the specimen-scanning direction is orthogonal to the cantilever axis as shown in the right figure below. The cantilever is twisted during scanning due to the friction force occurring between the specimen surface and the cantilever tip. The FFM measures the friction force from this torsion of the cantilever.



Ordinary contact mode AFM **FFM**

The following is the procedure for FFM observation.

1. Select the FFM radio button at the left bottom of the Contact Mode tab window.



2. Click on the Scan button.

Scanning starts, and a topography image and an FFM image are displayed on the Display Window.

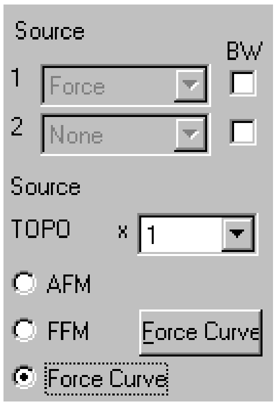
The scanning direction automatically changes by 90° when FFM is selected.
The white locations in the FFM image indicate the areas where the friction force is large.

Force Curve Measurement

A force curve is used to measure the force that acts between the specimen and the cantilever tip, by bending of the cantilever that occurs when changing the distance between the specimen and the cantilever tip in the contact mode.

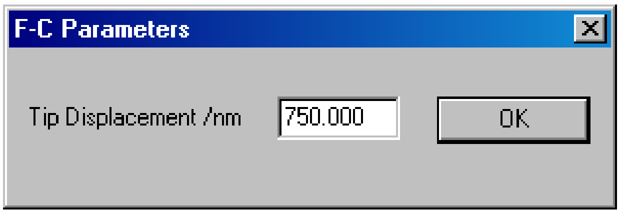
The measurement procedure is as follows.

1. Select the Force Curve radio button at the left bottom of the Contact Mode tab window.



2. Click on the Force Curve button.

The F-C Parameters window will be displayed.



3. Double-click on the Tip Displacement/nm box on the F-C Parameters window and enter the maximum value of the scanner Z scanning range using the keyboard.

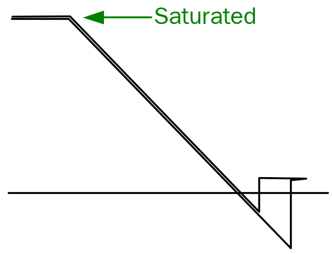
When the standard scanner (10 μm × 10 μm × 3 μm) is installed, enter about 1,500 nm (the total scanning range in the Z direction is 3,000 nm, because the value input is the limit of the scan in both the positive and the negative directions). In practice, however, even if a value exceeding the scanner Z scanning range is entered, the software automatically calculates and displays the maximum possible value.

4. Click on the Scan button on the Contact Mode tab window.

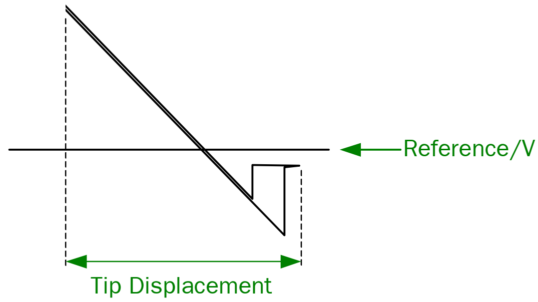
The Force Curve will be displayed on the Display Window.

● Acquired results

To grab the measured Force Curve, click on the Grab button during the measurement.
To change the display style of the Force Curve, select Display–Plot Parameters from the main menu after grabbing the Force Curve.
If the Force Curve goes out of the linear region and becomes saturated in the repulsive force domain, as shown below, it means that the measurement has been attempted outside the measurable range. In such a case, change the Tip Displacement/nm value in the F-C Parameters window to a smaller value; then repeat the measurement.

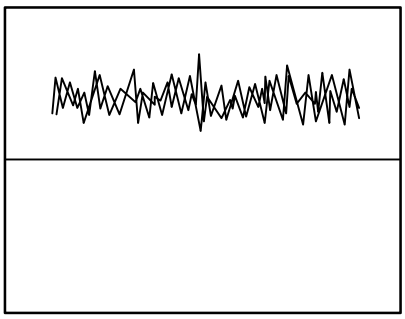


The relationship between Tip Displacement/nm and Reference/V is shown in the figure below.



Therefore, when the Reference/V value is set to 0 V, feedback is carried out at the point where the Force Curve crosses the 0 V line.

✍ If the Force Curve is not obtained correctly, it usually means that approaching has not been properly performed. If curves such as the one shown below are obtained, check whether approaching has been properly performed.



If the data obtained is something like the above, it means that the cantilever tip has not approached the specimen surface yet.

■ Acquiring an image

- Auto Grab in the Contact Mode window is selected
  Every time measurement finishes, images are automatically grabbed and stored.
- Auto Grab in the Contact Mode window is not selected
  To acquire an image, click on the Grab button while it is being scanned.
  When one image has been scanned, it is grabbed in the memory. At the same time, the measurement image is automatically stored as a temporary storage file in the specified program folder.
  Scan is repeated as long as you do not click on the Grab button and the acquired image during repetition is not grabbed.
- The image is displayed after the offset for the input signals is automatically computed.
  You can control the offset for the input signals only in the Advanced operation mode.

■ Cautions in observing images

In the Contact Mode, it is important to set the repulsive force that acts between the specimen and the cantilever tip. Unless this setting is carried out correctly, not only will it be impossible to obtain a satisfactory image, but also you may damage the specimen or the cantilever. Set the repulsive force that acts between the specimen and the cantilever tip using Reference.

Setting Reference to the – side reduces the repulsive force, while setting it to the + side increases the repulsive force. If you carry out an approach, setting to –2 V, and change Reference to the repulsive force side where –2 V is exceeded, the cantilever may sometimes separate from the specimen. As a result, you cannot obtain the image.

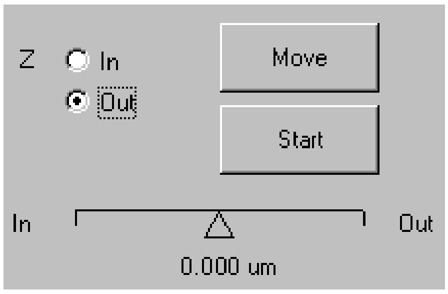
In the contact mode, generally carry out scanning in the domain in which the repulsive force is sufficiently small so as not to damage the specimen. To this end, set Reference to the position in which the cantilever and the specimen are as close to each other as possible.

However, in the case of a specimen that has low contrast because of large surface irregularities or matter adhering to its surface, it is sometimes a good idea to carry out scanning in the domain where the repulsive force is slightly large (Reference is on the + side). While scanning an image, change Reference a little at a time until you obtain the best image.

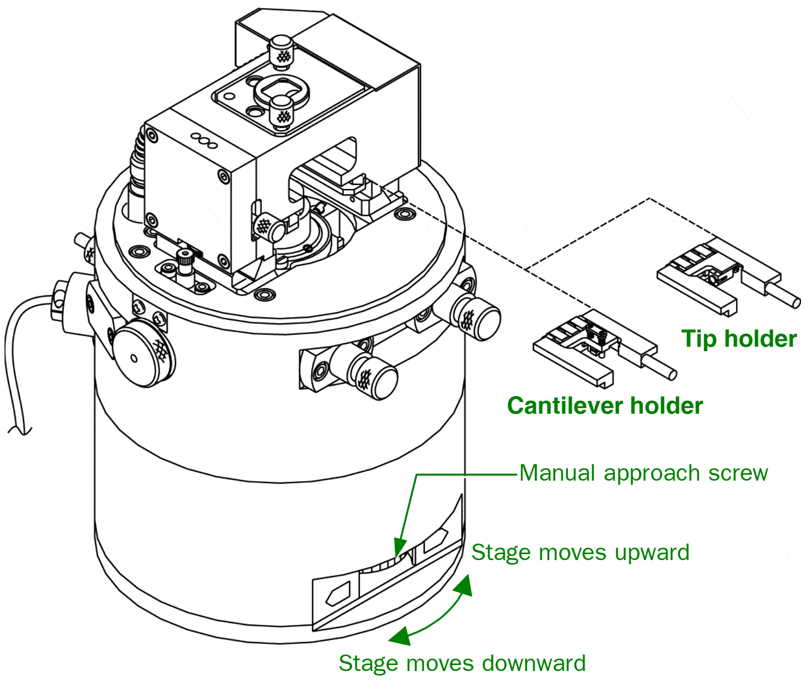
■ Terminating observation

Terminate observation according to the following procedure.

1. Stop scanning.
2. Click on the Retract On button to retract the cantilever tip.
3. Click on the Out button for Z and click on the Start button.



4. When the cantilever has moved 0.1 to 0.2 mm away from the specimen, click on the Stop button to stop the movement.
5. Separate the specimen and the tip fully turning the manual approach screw to move the specimen stage down.



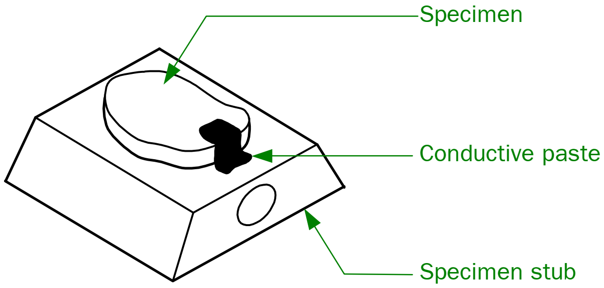
The figure above shows the model JSPM-5200.

5.5.2 Viscoelasticity Tab

You can perform viscoelasticity measurement by additionally installing the optional Lock-in Amplifier. When the lock-in amplifier is connected to the SPM controller, you have to set the device using the software to display the tab window for viscoelasticity measurement.

■ Affixing specimen

In order to observe a viscoelasticity image correctly, it is essential to affix the specimen firmly to the specimen stub using conductive paste instead of using a double-faced tape.



■ Checking before approaching

After affixing the specimen, adjust the laser and the photodiode and perform the coarse approaching as you perform in AC AFM measurement.

■ Observation of a topography image

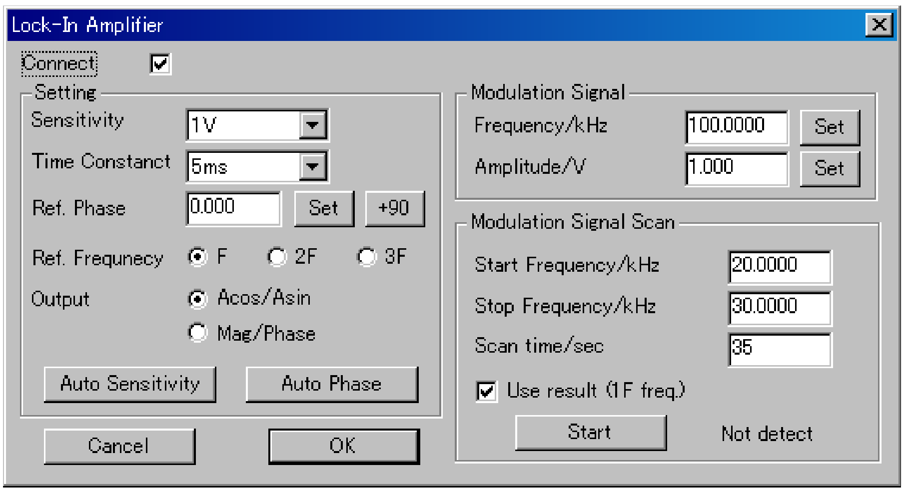
Observe a topography image of the specimen surface, and confirm that you can obtain an optimum image. Then retract the tip.

■ Setting the Lock-in Amplifier

● When using Model 7265

1. Click on the Lock-in button.

The Lock-In Amplifier dialog box opens.



2. Select Connect to connect the lock-in amplifier.

✍ It will take about one second until the amplifier starts up due to the initialization of parameters. If errors should happen, check the power supply, connections and settings of cables.

3. Specify the parameters according to the following table.

Sensitivity	1 mV
Time Constant	5 ms
Ref. Phase	0.000
Ref. Frequency	F
Output	ACos･ASin
OSC Frequency	20.000
OSC Level	0.200

4. Click on the Retract Off button in the Contact Mode tab window.

5. Click on the Auto Sensitivity button in the Lock-In Amplifier window.

The lock-in amplifier will automatically adjust the gain.

6. Click on the Auto Phase button in the Lock-In Amplifier window.

The lock-in amplifier will automatically adjust the phase.

● When using Model 5110

1. Turn on the POWER switch of the Lock-in Amplifier ① (☞ Sect. 5.2.5).

2. Set the Lock-in Amplifier according to the following steps a to c.

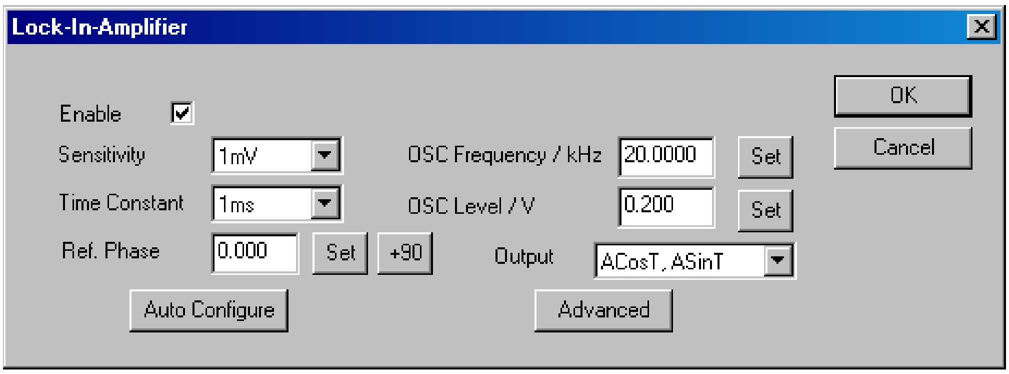
a. Press the A button of the Input selection switches ②.

b. To put the Amplifier into the FLOAT state, press the FLOAT/GROUND button of the Input selection switches ②.

c. To deselect the 10^8 and 10^6 buttons of the Input selection switches ②, put the buttons into the not pressed state.

3. Click on the Lock-in button.

The Lock-In Amplifier dialog box opens.



4. Select Enable to activate the Lock-in Amplifier.

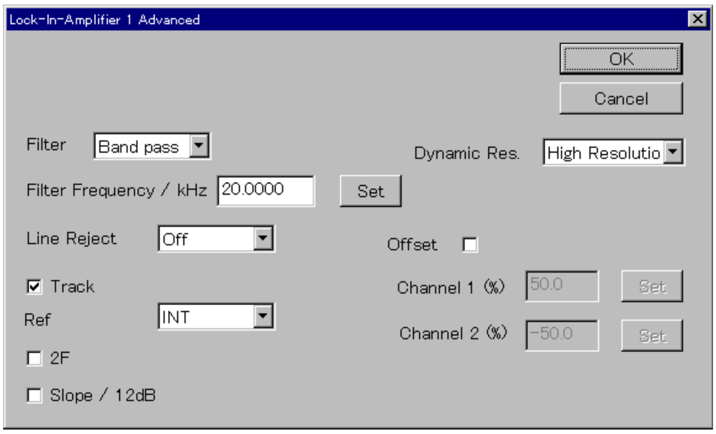
It will take about one second until the Amplifier starts up due to the initialization of parameters. If errors should happen, confirm connections and settings of cables.

5. Specify the parameters according to the following table.

Sensitivity	1 mV	**OSC Frequency**	20.000
Time Constant	1 ms	**OSC Level**	0.200
Ref. Phase	0.000	**Output**	ACosT, ASinT

6. Click on the Advanced button.

The Lock-In-Amplifier 1 Advanced window opens.



7. Specify the parameters according to the following table.

Filter	Band pass	Dynamic Res.	High Resolution
Filter Frequency/kHz	20.000	Offset	☐
Line Reject	Off		
Track	☑		
Ref	INT		
2F	☐		
Slope/12dB	☐		

8. Click on the Retract Off button in the Contact Mode tab window.

9. Click on the Auto Configure button in the Lock-In-Amplifier window.

The lock-in amplifier will adjust the phase and gain automatically.

■ Observation of an image

1. To start scans, click on the Scan button in the Contact Mode tab window.

The following images will be obtained.

Topography (Topography image)	Acosϕ (Elasticity image)
Asinϕ (Viscosity image)	

Sometimes an oscillating sound is made depending upon the characteristic frequency of the scanner that you use. If it happens, reduce the oscillation level (OSC Level/V), or shift the present oscillation frequency (OSC Frequency/kHz) setting position until the sound is not made.

2. Increase the input sensitivity of the lock-in amplifier (from 1 mV to 100 nV direction) using the Sensitivity setting key (▼) in the range in which the signals from the lock-in amplifier do not saturate.

When using Model 5110 and the signal becomes saturated, the OLVD LED lights up.

The area in which both Acosϕ (elasticity) and Asinϕ (viscosity) images become bright is the one in which elasticity and viscosity are large.

3. Specify the SPM parameters for usual operation so that you can obtain an optimum topography image.

4. Change the following parameters so that you can obtain an optimum elasticity image as well as an optimum viscosity image.

- Oscillation frequency (OSC Frequency/kHz)

  If the difference of specimens in elasticity and viscosity is small, for example, same kinds of materials such as composite plastic are mixed, increase oscillation frequency, and then you will obtain better images.

- Oscillation level (OSC Level/V)

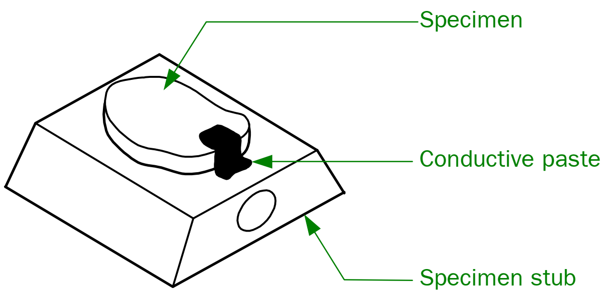
  When using hard cantilevers such as a Si cantilever, reduce oscillation level to observe the image. If oscillation level is too large, the cantilever may break. To the contrary, when using soft cantilevers, increase oscillation level. Generally speaking, when you measure viscoelasticity, to obtain a good image, use a hard cantilever.

5.5.3 Lateral Modulation FFM Tab

You can perform lateral modulation FFM measurement by additionally installing the optional Lock-in Amplifier. When the lock-in amplifier is connected to the SPM controller, you have to set the instrument using the software to display the tab window for lateral modulation FFM measurement.

■ Affixing specimen (for JSPM-5200/JSPM-5700)

In order to observe a lateral modulation FFM image correctly, it is essential to affix the specimen firmly to the specimen stub using conductive paste instead of using double-faced tape.



The figure above shows the specimen holder for JSPM-5200.

■ Checking before approaching

Affix the specimen, adjust the laser and the photodiode, and then perform the coarse approaching as you perform in AC AFM measurement.

■ Observation of a topography image

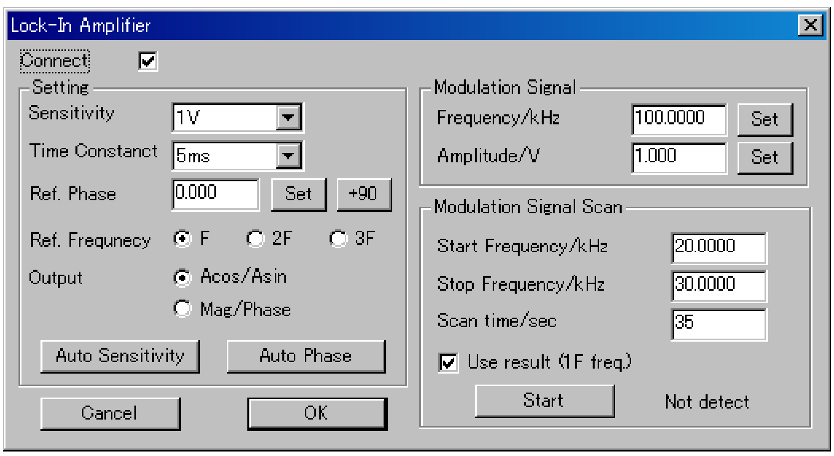
Observe a topography image of the specimen surface, and confirm that you can obtain an optimum image. Then retract the tip.

■ Setting the Lock-in Amplifier

● When using Model 7265

1. Click on the Lock In button.

The Lock-In Amplifier dialog box opens.



2. Select Connect to connect the lock-in amplifier.

✍ It will take about one second until the amplifier starts up due to the initialization of parameters. If errors should happen, check the power supply, connections and settings of cables.

3. Specify the parameters according to the following table.

Sensitivity	1 mV
Time Constant	5 ms
Ref. Phase	0.000
Ref. Frequency	F
Output	ACos・ASin
OSC Frequency	20.000
OSC Level	0.200

4. Click on the Retract Off button of the Contact Mode tab window.

5. Click on the Auto Sensitivity button of the Lock-In Amplifier window.

The lock-in amplifier will automatically adjust the gain.

6. Click on the Auto Phase button of the Lock-In Amplifier window.

The lock-in amplifier will automatically adjust the phase.

● When using Model 5110

1. Turn on the POWER switch of the Lock-in Amplifier ①.

2. Set the Lock-in Amplifier according to the following steps a to c.

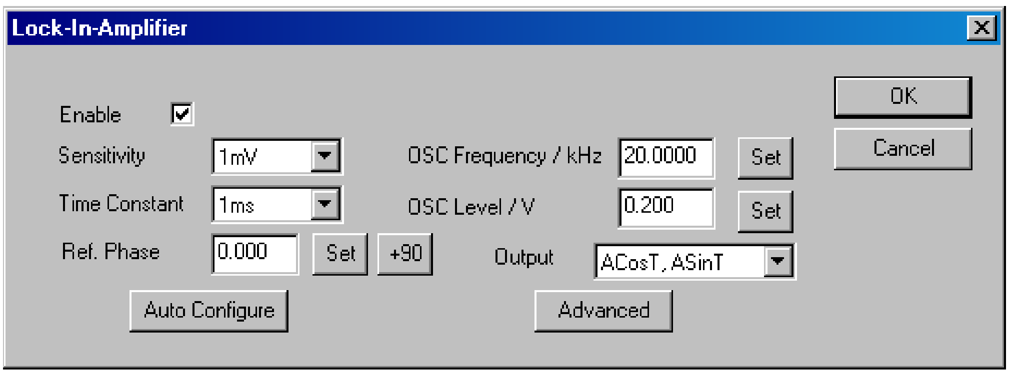
a. Press the A button of the Input selection switches ②.

b. To put the Amplifier into the FLOAT state, press the FLOAT/GROUND button of the Input selection switches ②.

c. To deselect the 10^8 and 10^6 buttons of the Input selection switches ②, put the buttons into the not pressed state.

3. Click on the Lock In button.

The Lock-In Amplifier dialog box opens.



4. Select Enable to activate the Lock-in Amplifier.

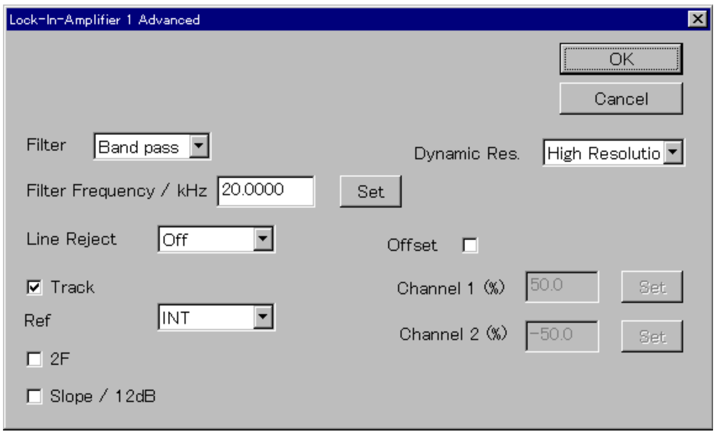
✍ It will take about one second until the Amplifier starts up due to the initialization of parameters. If errors should happen, confirm connections and settings of cables.

5. Specify the parameters according to the following table.

Sensitivity	1 mV	**OSC Frequency**	20.000
Time Constant	1 ms	**OSC Level**	0.020
Ref. Phase	0.000	**Output**	ACosT, ASinT

6. Click on the Advanced button.

The Lock-In-Amplifier 1 Advanced window opens.



7. Specify the parameters according to the following table.

Filter	Band pass	Dynamic Res.	High Resolution
Filter Frequency/kHz	20.000	Offset	☐
Line Reject	Off		
Track	☑		
Ref	INT		
2F	☐		
Slope/12dB	☐		

8. Click on the Retract Off button of the Contact Mode tab window.

9. Click on the Auto Configure button of the Lock-In-Amplifier window.

The lock-in amplifier will adjust the phase and gain automatically.

■ Observation of an image

1. To start scans, click on the Scan button of the SPM Parameters window.

The following images will be obtained.

Topography (Topography image)	Acosϕ
Asinϕ (Friction image)	

✍ Sometimes an oscillating sound is made depending upon the characteristic frequency of the scanner that you use. If it happens, reduce the oscillation level (OSC Level/V), or shift the present oscillation frequency (OSC Frequency/kHz) setting position until the sound is not made.

2. Increase the input sensitivity of the lock-in amplifier (from 1 mV to 100 nV direction) using the SENSITIVITY setting key (▼) in the range in which the signals from the lock-in amplifier do not saturate.

✍ When using Model 5110 and the signal becomes saturated, the OLVD LED lights up.

✍ The area in which Asinϕ (friction image) becomes white is the one in which friction is large.

3. Specify the SPM parameters for usual operation so that you can obtain an optimum topography image.

4. Change the following parameters so that you can obtain an optimum friction image.

- Oscillation level (OSC Level/V)

  Oscillation level depends upon the scan range.

  In this system, if the maximum scan range is scanned, the voltage of 300Vp-p or 400Vp-p will be applied to the scanner. Therefore, there is the following relationship between the scan range and the voltage applied to the scanner.

$$Vp-p = \frac{Observation\ range}{128} \div Y\ Sensitivity \div 15$$

(It is difficult to determine an exact Y sensitivity, since you have to execute distortion correction. However, the Y sensitivity can be estimated all the observation range/300 V.)

In practice, the output value is a little smaller than the calculated one, because a low pass filter is contained in the high voltage amplifier.

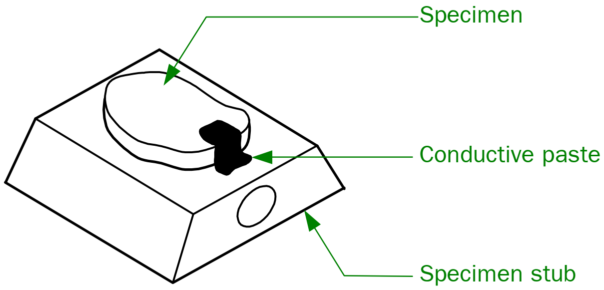
In lateral modulation FFM, set an excitation voltage to lateral amplitude of several nm to several tens of nm of the voltage applied to the scanner. The voltage amplitude applied to the scanner is 20 times larger than the amplitude input to the ADY. To obtain exact Y/20, use the optional oscilloscope.

5.5.4 Electrostatic Force Tab

You can perform electrostatic force measurement (capacitance measurement SCFM) by additionally installing the optional Model 7265 Lock-in Amplifier (Model 5110 is not available). When the lock-in amplifier is connected to the SPM controller, you have to set the instrument using the software to display the tab window for electrostatic force measurement.
Here, we discuss how to observe capacitance measurement SCFM.

■ Affixing a specimen

In order to observe an electrostatic force image (capacitance measurement SCFM) correctly, it is essential that conductivity between the specimen and the specimen stub is definitely secured. Affix the specimen firmly to the specimen stub using conductive paste instead of using double-faced tape.



■ Selecting a cantilever

In capacitance measurement you detect a component in 3F of the contact resonance frequency of the cantilever. It is necessary to select 80 kHz or less as the primary resonance frequency so that the resonance frequency does not exceed 250 kHz at 3F.
The recommended cantilever is the Nanosensor made CONT PtIr 5 (oscillation frequency 13 kHz, spring constant 0.2 N/m).

■ Checking before approaching

Before performing approaching, affix specimen, adjust the laser and photodiode, and then perform coarse approaching in the way you do when performing usual Contact AFM measurement.

■ Observation of a topography image

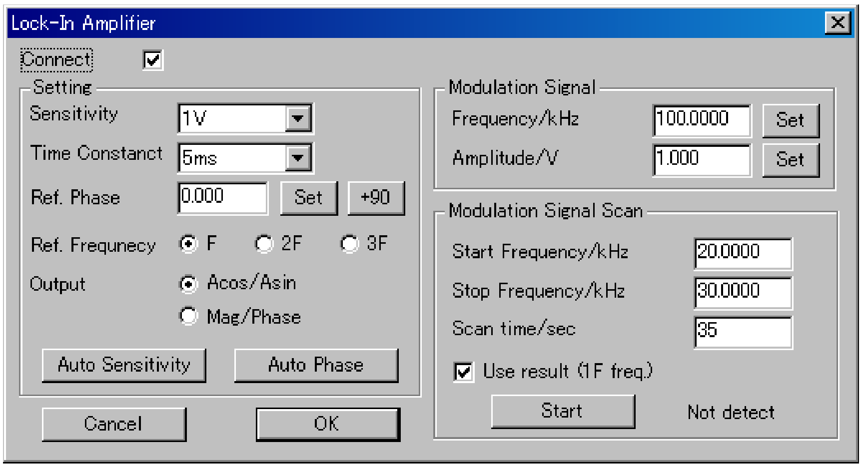
Observe a topography image of the specimen surface, and confirm that you can obtain an optimum image. Then retract the tip.

■ Setting the Lock-in Amplifier

● When using Model 7265

1. Click on the Lock In button.

The Lock-In Amplifier dialog box opens.



2. Select Connect to connect the lock-in amplifier.

✍ It will take several seconds until the amplifier starts up due to the initialization of parameters. If errors should happen, check the power supply, connections and settings of cables.

3. Specify the parameters according to the following table.

Sensitivity	50 mV
Time Constant	5 ms
Ref. Phase	0.000
Ref. Frequency	3F
Output	ACos･ASin
OSC Frequency	20.000
OSC Level	5.0
Use result (1F freq)	Select
Start Frequency/kHz	60 kHz
Stop Frequency/kHz	80 kHz

4. Click on the Retract Off button of the Contact Mode tab window.

5. Click on Start in Modulation Signal Scan.

Scan starts. The peak is being automatically searched and the oscillation frequency will be set. If the peak position is displayed in reverse, click on the +90 button and start scan again.

6. Set Ref. Frequency to 3F.

7. Click on Auto Phase to adjust phase.

■ Observation of an image

1. To start scans, click on the Scan button of the SPM Parameters window.

The following images will be obtained.

Topography (Topography image)	Acosφ (Capacitance image)

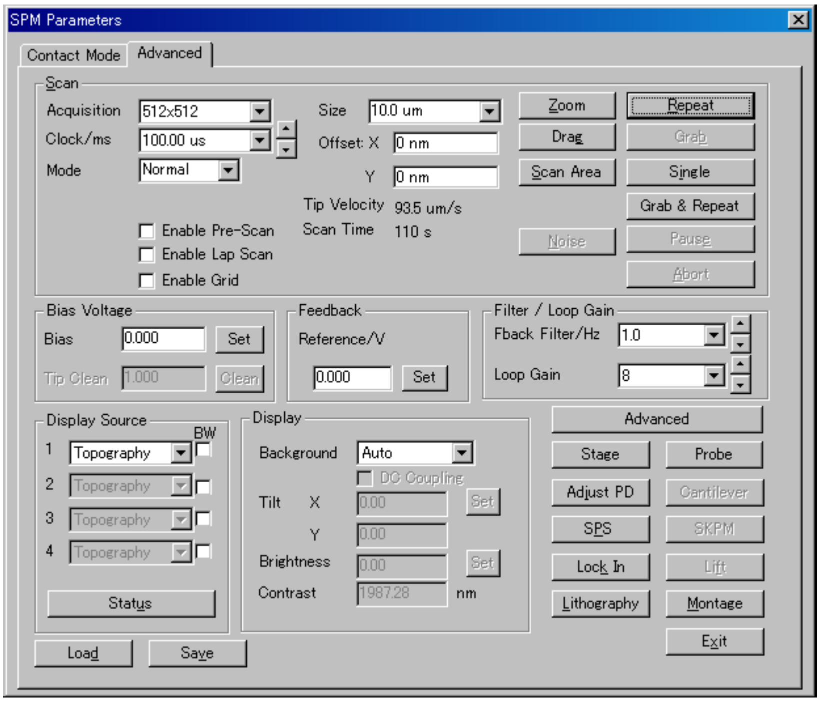
2. Specify the SPM parameters for usual operation so that you can obtain an optimum topography image.

3. Increase the input sensitivity of the lock-in amplifier (from 50 mV to 100 nV direction) using the SENSITIVITY setting key (▼) in the range in which the signals from the lock-in amplifier do not saturate.

✍ The area in which Acosφ (capacitance image) becomes white is the one in which capacitance is large.

5.5.5 Advanced Tab

The Advanced tab window is used for setting details for contact AFM mode. You can set details and you have to fill in all parameters in the tab window.



Advanced tab window

■ Checking before approaching

Before performing approaching, confirm whether the preparation procedure in Sect. 5.3, "Preparing Approach" is completed using the following items.

- Has coarse approaching been executed in such a way that the distance between the cantilever tip and the specimen surface is 0.3 mm or less?
- Is the Z stage position in the approaching-possible range?
- Is the AFM value of the AFM amplifier unit about –2.0 V?
- Is the FFM value of the AFM amplifier unit about 0 V?

✍ After checking these points, set the indicator selection knob on the AFM amplifier unit to AFM.

■ Setting parameters

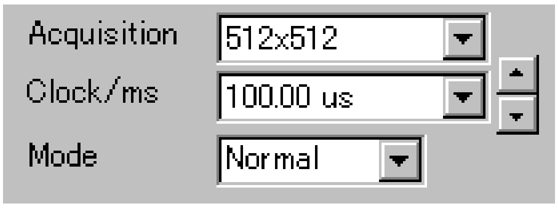
Here, we discuss the procedure to set parameters for shape measurement. Specify each parameter in the Advanced tab window according to the following procedure.

1. Click on the ▼ button in the Acquisition selection box and select 512×512 from the pull-down menu.
2. Click on the ▼ button in the Clock/ms selection box and select 100.00 us from the pull-down menu.

   This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen. Here, set it to 100.00 us provisionally.

3. Click on the ▼ button in the Mode selection box and select Normal from the pull-down menu.

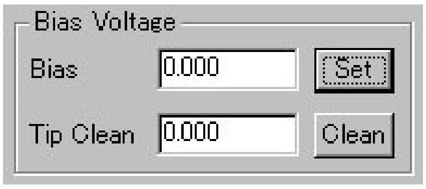
You can select measurement modes that are available in the contact AFM such as viscoelasticity, lateral modulation FFM and electrostatic force measurements. The types of measurement modes differ depending on the optional devices that are connected. When you select Normal, you can perform shape measurement mode.



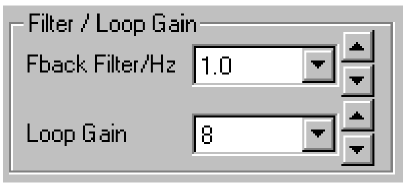
4. Click on the Size box. When the numerical value is highlighted, enter 1um using the keyboard and finalize the numerical value by pressing the Tab key. Or, click on the ▼ button in the Size selection box and select a numerical value near 1.000 um.

The value to set in Size differs depending on the scanner provided. In practice, specify an appropriate value according to the observation area you want to observe.

5. Click on the Bias box. When the numerical value is highlighted, enter 0 using the keyboard and finalize the numerical value by pressing the Tab key.



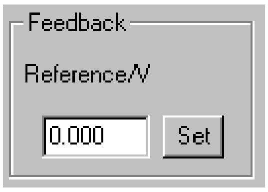
6. Click on the ▼ button in the Fback Filter/Hz selection box and select 1.0 from the pull-down menu.



Fback Filter/Hz is the parameter that determines the response speed of the feedback circuit. The larger the specified value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, select the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.

7. Click on the Reference/V input box to highlight the numerical value; then enter 0 using the keyboard and finalize it by pressing the Tab key.

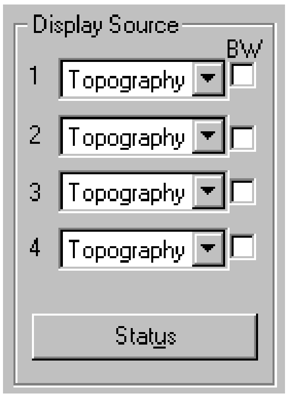
Reference/V is the parameter that sets the force between the specimen and the tip of the cantilever. You have to change this parameter while observing the image during scan. Here, set it to 0.000 provisionally.



8. Click on the button in the Loop Gain selection box and select 8 from the pull-down menu.

Loop Gain is the parameter that determines the gain of the feedback circuit. The larger the specified value is, the higher the gain becomes, thus producing a good image of a topographic specimen, but the feedback circuit easily oscillates.

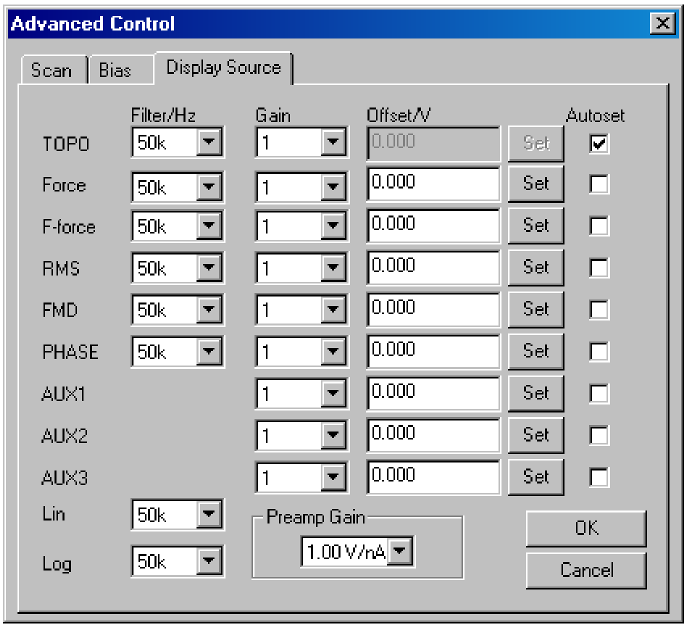
9. Click on the button in the Display Source 1 selection box and select Topography from the pull-down menu.



10. Click on the Advanced button.

The Advanced Control window is displayed.

11. Click on the Display Source tab, and then check the TOPO–Autoset box.



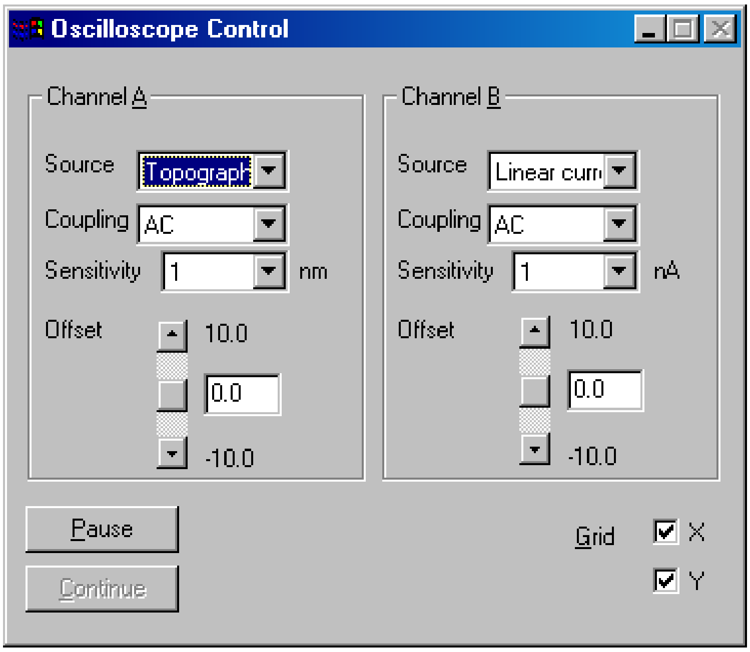
The "☐" or "☑" checking box is a toggle switch, and every time you click on it, it changes alternately between "☐" and "☑".
The "☑" checking box means that it is selected.

■ Setting Software Oscilloscope

Set Channel B following the procedure below.

1. Click on the "□" button of the Oscilloscope Control window.

The Oscilloscope Control window will open.



2. Click on the button in the Source selection box in the Channel B frame; then select Force from the pull-down menu.
3. Click on the button in the Sensitivity selection box in the Channel B frame; then select 5 from the pull-down menu.

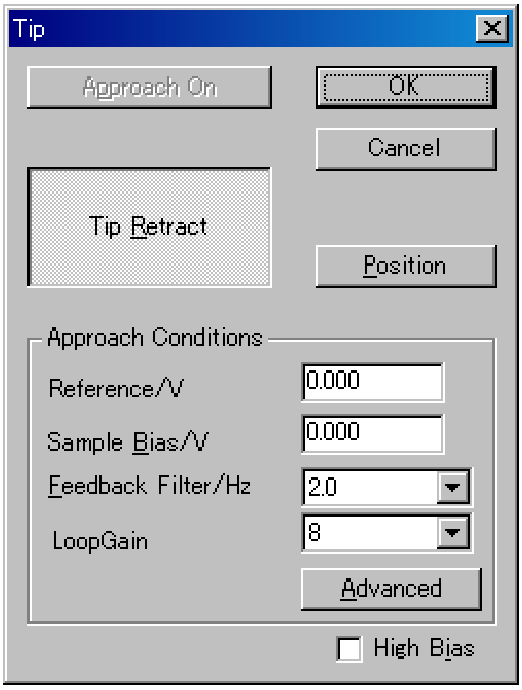
You can monitor the Force (A–B) signal. The Force (A–B) signal can be output up to ±15 V.

■ Approaching

Move the cantilever closer to the specimen until the voltage of Force (A–B) becomes the voltage specified in Reference/V. The cantilever movement automatically stops when the voltage of Force (A–B) reaches the Reference/V voltage. The following is the procedure for approaching.

1. Click on the Probe button on the Advanced tab window.

   The Tip window will appear.



2. Specify each parameter according to the following procedure.
   a. Click on the Reference/V input box. When the value in the box is highlighted, enter the desired value using the keyboard. Press the Tab key on the keyboard to finalize the value.
   b. Click on the button in the Feedback Filter/Hz selection box; then select 2.0 from the pull-down menu.

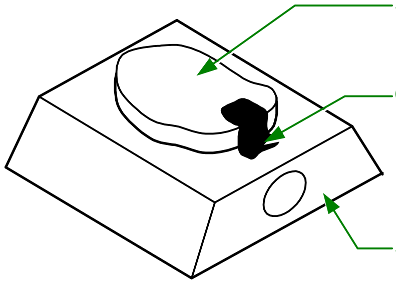
      Now, the Reference/V voltage and the response speed of the feedback circuit, which are used for approaching, have been determined. To prevent the cantilever from colliding with the specimen, set Feedback Filter/Hz to a value higher than that for image observation.
   c. Click on Tip Retract to deselect Tip Retract.
3. Before performing approaching confirm that the voltage applied to the Z scanner reaches the maximum voltage (+150 V or 200 V).

If the voltage applied to the Z scanner does not reach the maximum voltage, it is judged that the approaching has already been completed. So, approaching will not start even if you click on the Approach On button on the Tip window.

In such a case, check the following points.

- Make sure that Loop Gain is not so low.
  If Loop Gain is set to a low number, the gain of the feedback circuit is so small that the feedback voltage is not applied up to the maximum voltage.
- Make sure that the AFM value indicated on the AFM AMP unit is not near 0 V.
  If the AFM value is near 0 V, it is judged that approaching has already been completed. The following two reasons can be considered.
  - The photodiode position has changed.
    Readjust the photodiode position according to the procedure.
  - Approaching has already been completed, or the cantilever tip has collided with the specimen.
    Retract the cantilever tip from the specimen using. Then, try to readjust.
- Make sure that the cantilever is not too close to the specimen.
  When the cantilever tip gets fairly close to the specimen surface, the electrostatic force acting between the specimen surface and the cantilever tip might affect the cantilever, thus sometimes making approaching impossible. Most of such cases are due to an electrostatic force. Try the following steps.
  - Change the cantilever to a hard one (a cantilever with a high resonance frequency).
  - Change the cantilever to a conductive one (an Si cantilever or a cantilever with both sides gold-coated), and use a non-contact cantilever holder. A non-contact cantilever holder is virtually grounded via the operational amplifier in the SPM head unit.
  - Add a bias voltage to the specimen specifying it in the Sample Bias/V input box from 0 V to both positive and negative values.
  - Make sure that good conductivity is kept between the specimen and the specimen stub.

  Affix the specimen to the specimen stub using a conductive tape or conductive paste (Conductive paste). If possible, apply the conductive paste not only to the surface but to the side of the specimen as well.



If the specimen is an insulating material, make the specimen smaller or coat the masked observation area of the specimen with gold or any other suitable metal. Then, stick the specimen onto the stub as shown in the above figure.

4. Click on the Approach On button on the Tip window.

The motor for approaching starts to rotate and automatically stops when the AFM value becomes the same as the value given in Reference/V.

When approaching has completed, the indicator on the AFM AMP unit suddenly changes from the value during approaching (–2.0 V) to the Reference/V value (0 V). This phenomenon is called Jump-in.

If approaching finishes as the indicator on the AFM AMP unit slowly changes to 0 V, approaching might not have been correctly performed. In such a case, even though you try to measure a force curve (described later), you cannot obtain the force curve data, nor can you obtain the force curve image, either.

The possible reasons for this are the electrostatic force and interference of laser beams reflected on the specimen surface. For the former, take remedial measures as explained above. For the latter, readjust the photodiode position, click on the Approach Off button in the Tip window; then, click on the Approach On button in the Tip window again.

If approaching stops before the indicator on the AFM AMP unit indicates the Reference/V value, it is judged that the seeming state of approaching having completed occurred due to unexpected electrical noise or something like that. In this case, click on the Approach Off button in the Tip window; then, click on the Approach On button again.

You may hear an oscillation sound coming from the instrument when approaching is completing. This is because the setting of the feedback filter is so fast that it oscillates. If the sound continues, click on the  button in the Feedback Filter/Hz selection box and select a slow filter (a smaller value) from the pull-down menu.

■ Topography Image Observation

When approaching has completed, carry out scanning.

◆ Click on the Repeat button on the Advanced tab window.

Scanning will start and an image will appear in the Display Window.

✍ In the Contact mode, it is important to set the repulsive force that acts between the specimen and the cantilever tip. Unless this setting is carried out correctly, not only will it be impossible to obtain a satisfactory image, but also you may damage the specimen or the cantilever. Set the repulsive force that acts between the specimen and the cantilever tip using Reference/V.

● Setting Reference/V

The more negative Reference/V is, the smaller the repulsive force becomes. The more positive Reference/V is, the larger the repulsive force becomes. If you perform approaching under the condition of the Reference/V value set to –2 V, changing Reference/V to the repulsive force side in excess of –2 V might sometimes make the cantilever tip go away from the specimen surface, thus resulting in forming no image.

In the case of the Contact mode, generally, perform scanning in the domain of a small repulsive force to avoid specimen damage. Then, set Reference/V to the position where the cantilever tip and the specimen surface become closest to each other. However, in the case of a specimen having large unevenness or a specimen having a low contrast due to materials attached to the specimen surface, scanning with a little larger repulsive force (on the plus (+) side of Reference/V) would produce a good result.

Change the Reference/V value gradually from the value for approaching toward 0 V (closer to the specimen surface) while watching the image, and set it to the value that produces the best-quality image.

Other general cautions, grabbing, storing and processing of an image are detailed later in this manual.

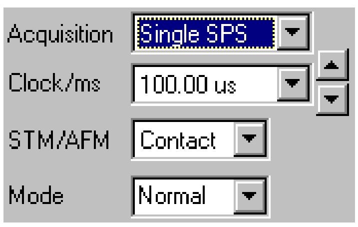
■ Force curve measurement

A force acting between the specimen surface and the cantilever tip is measured from the bending of the cantilever while varying the distance between the specimen surface and the cantilever tip in the contact mode. This measurement is called Force Curve measurement. The following is the procedure for Force Curve measurement.

● Measurement Method

The procedure up to approaching is exactly the same as that for the measurement method in the contact mode.

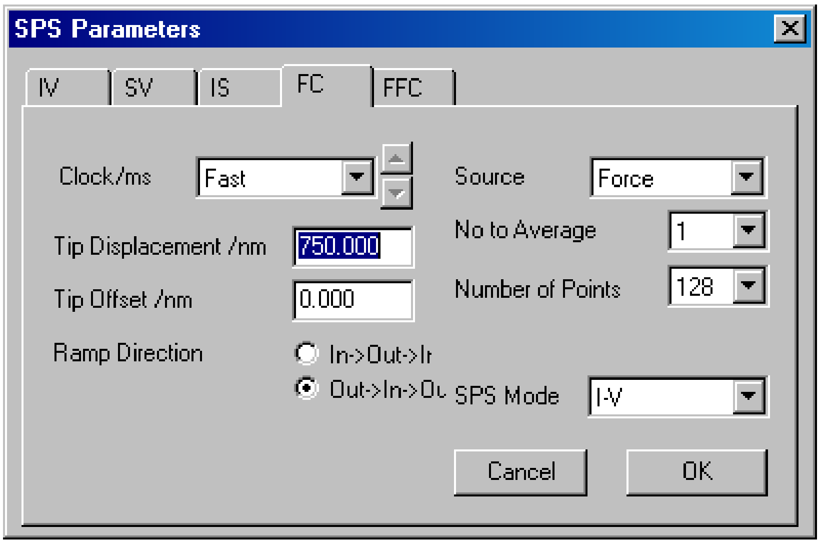
1. Click on the ▼ button in the Acquisition selection box and select Single SPS from the pull-down menu.



2. Click on the SPS button in the main menu.

The SPS Parameters window will be displayed.

3. Click on the FC tab.



4. Double-click on the Tip Displacement/nm input box on the FC window and enter the maximum value of the scanner Z scanning range using the key-board.

In practice, even if you entered a value exceeding the scanner Z scanning range, the software automatically calculates and indicates the maximum possible value (half distance of the Z scanning range as the tip displaces in the positive and negative directions).

5. Double-click on the Tip Offset/nm input box and enter 0 using the keyboard.

6. Set Ramp Direction to Out→In→Out.

7. Click on the  button in the No to Average selection box and select 1 from the pull-down menu.

8. Click on the  button in the Source selection box and select Force from the pull-down menu.

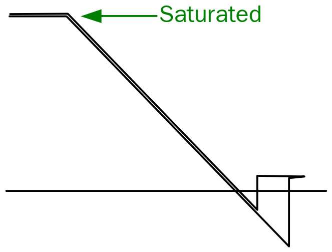
9. Click on the  button in the SPS Mode selection box and select Force Curve from the pull-down menu.

10. Click on the Repeat button on the Advanced tab window.

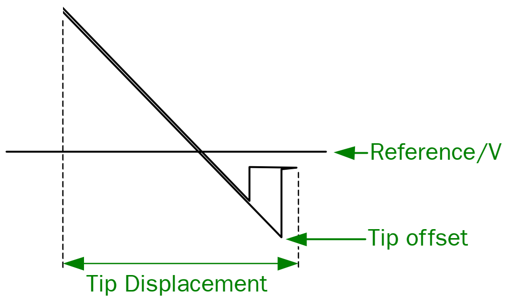
The Force Curve will be measured and displayed on the Display Window.

● Measurement result

- To grab the measured Force Curve, click on the Grab button during the measurement.
- To change the display style of the Force Curve, change it using the Plot Parameters item of the Display menu after grabbing the Force Curve.
- If the Force Curve goes out of the linear region and becomes saturated in the repulsive-force domain, as shown below, it means that the measurement has been attempted outside the measurable range of the detector and the A/D converter (±10 V). In such a case, change the Tip Displacement/nm value in the SPS Parameters window to a smaller value.

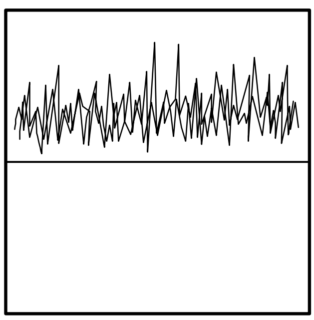


The relationship among Tip Displacement/nm, Tip Offset/nm and Reference/V is shown in the figure below.



Therefore, when the Reference/V value is set to 0 V, feedback is carried out at the point where the Force Curve crosses the 0 V axis.

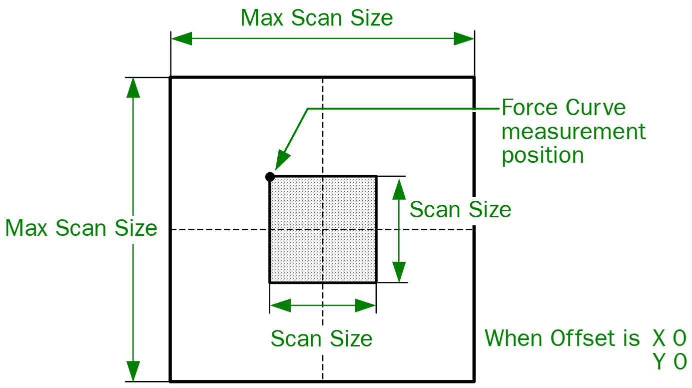
If the Force Curve is not obtained correctly, it usually means that approaching has not been properly performed.



If the data obtained is something like the above, that means that the cantilever tip has not yet approached the specimen surface.

● Measuring Force Curve at Specified Position

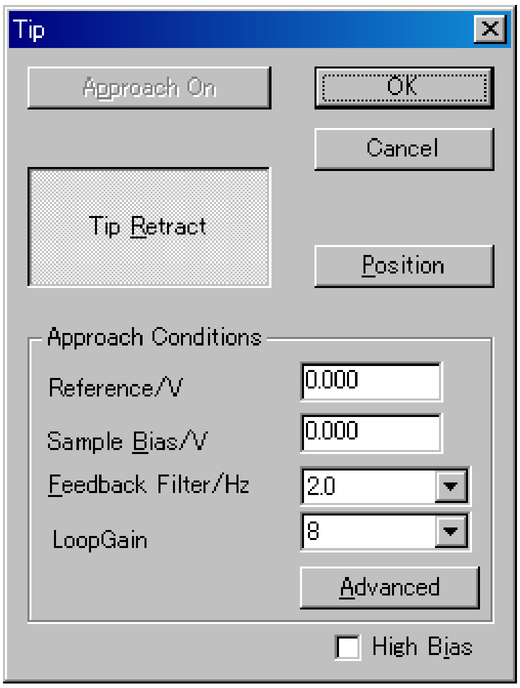
The Force Curve measurement explained in “Measuring Method” is carried out at the top-left corner of the image.



✍ In practice, however, the Force Curve measurement is often carried out at a certain specified point in an observed image, when you perform image observation in the contact mode.

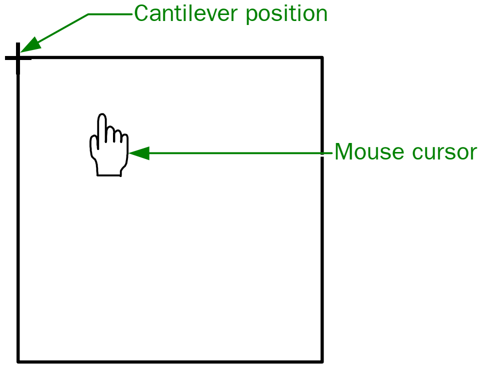
The following is the procedure for specifying the Force Curve measurement point.

1. Observe an image and grab it.
2. Specify the parameters in the FC tab window according to “Measurement Method.”
3. Click on the Probe button on the Advanced tab window.
   The Tip window will open.
4. Click on the Tip Retract button.

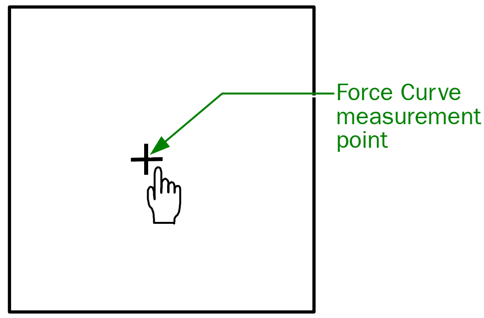


5. Click on the Position button in the Tip window.

The Tip window will close and the Tip position window will open. Move the cursor to the Display Window; then, the cursor changes to a hand mark.



6. Move the cursor to the cantilever position (+); then, drag it, while holding down the left mouse button, to the point where you want to measure the Force Curve.



The cantilever is actually moving in real time during the cursor dragging, so be sure to drag the **+** mark slowly enough.

7. After placing the + mark at the measurement point, press the right mouse button to finalize the position.

The Tip window will appear again.

8. Deselect Tip Retract.

9. Click on the Repeat button on the Advanced tab window.

✍ If you changed the measurement point by this method, the changed point becomes the initial position for the cantilever. So, when the measurement has been completed or Abort has been performed, the cantilever tip returns to this initial position.

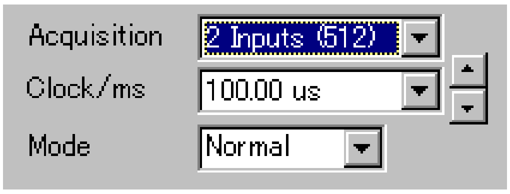
■ FFM Observation

In the ordinary contact mode, the scanning direction is parallel to the cantilever axis. In the FFM image observation, on the other hand, the scanning direction is orthogonal to the cantilever axis. The cantilever is twisted during scanning due to the friction force acting between the specimen surface and the cantilever tip. The FFM measures the friction force of the specimen surface from this torsion of the cantilever.

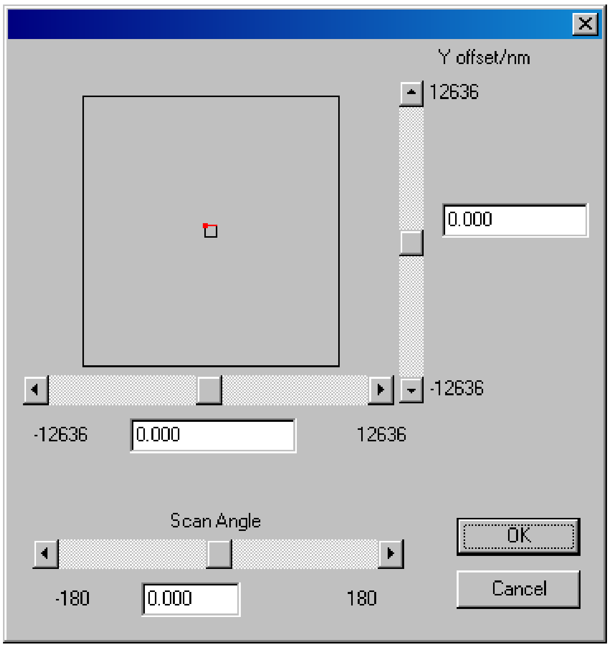
The following is the procedure for observing an FFM image in the Advanced contact mode.

1. Click on the ▼ button in the Acquisition selection box in the Scan frame and select 2 Inputs from the pull-down menu.

   This operation acquires and displays two images simultaneously. When you observe an FFM image, also acquire a topography image so as to compare it with an FFM image.

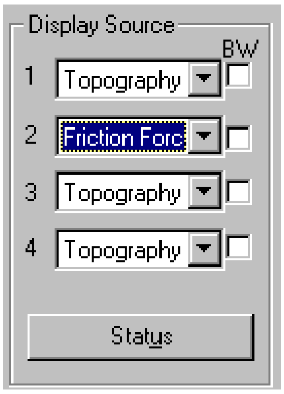


2. Click on the Scan Area button in the Scan frame to display the scan area window; then, double-click on the Scan Angle input box and enter 90 using the keyboard.

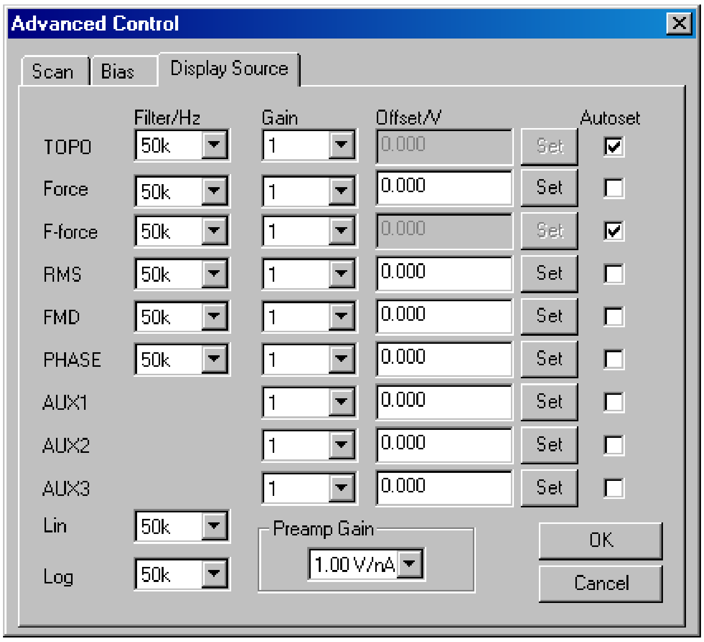


   Now, the specimen is scanned in a direction orthogonal to the cantilever axis.

3. Click on the ▼ button in the Display Source–2 selection box and select Friction Force from the pull-down menu.



4. Specify 1 for the TOPO and F-force Gain boxes and then check the Autoset check box ("☑").



5. Click on the Repeat button on the Advanced tab window.

Scanning starts and images are displayed on the Display Window as shown below.

The white locations in the FFM image represent areas of large friction force on the specimen surface.

● Precautions in observing FFM image

Since the cantilever torsion is observed statically, unevenness of the specimen surface affects the friction force image. Therefore, you must also observe the topography image simultaneously in order to properly evaluate the FFM image.

To reduce the effect of the unevenness of the specimen surface, it is recommended that you use the optional Lateral Modulation FFM attachment.

The contrast of an FFM image is affected by the scanning speed (Clock/ms) and the repulsive force between the specimen surface and the cantilever tip (Reference/V). For a specimen with less contrast, try changing Reference/V a little to the positive side to make the repulsive force larger.

In addition, you can adjust the brightness of a grabbed image using the image processing function (Brightness/Contrast).

☞ Other general cautions, grabbing, storing and processing of an image are detailed in Chapter 6, "Analysis Operation".

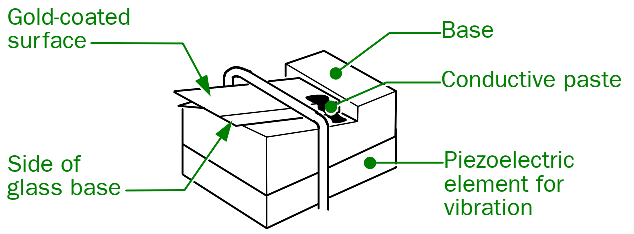
■ Current image observation

An amplifier for current detection is built in the AFM head unit. You can acquire a contact current image as well as a topography image using a conductive cantilever. Moreover, you can carry out an I-V measurement at a specified point of the specimen.

● Preparation for Current Image Observation

- Affixing a cantilever for JSPM-5200/JSPM-5700

  Use a conductive cantilever such as a Si cantilever or a cantilever with both sides coated with gold. Affix the cantilever on a non-contact cantilever holder. Make sure that good conductivity is kept between the cantilever and the cantilever holder. Use conductive paste such as Conductive paste especially for a gold-coated cantilever since the conductivity between the front face and the rear face is not so good.



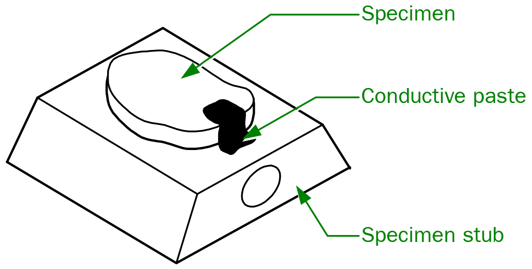
The figure above is for the JSPM-5200.

— CAUTION —

When applying conductive paste to the cantilever and the cantilever holder, be sure not to apply the conductive paste to the cantilever piezoelectric element. When replacing a cantilever, be sure to confirm that no previously used conductive paste remains on the holder. Otherwise, the cantilever will tilt, causing the reflected laser beam not to irradiate the right position.

- Affixing a specimen for JSPM-5200/JSPM-5700

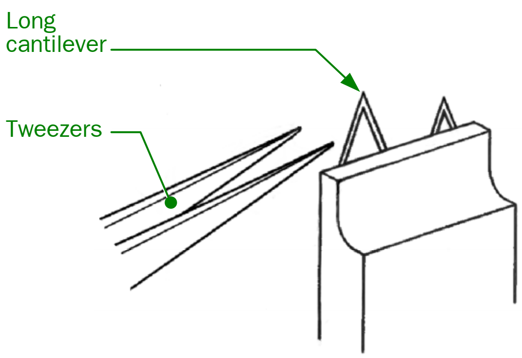
  In order to observe a current image correctly, it is essential that good conductivity be kept between the specimen and the specimen stub. Affix the specimen to the specimen stub with conductive tape or conductive paste such as Conductive paste. If possible, apply the conductive paste not only to the surface but to the side of the specimen as well.

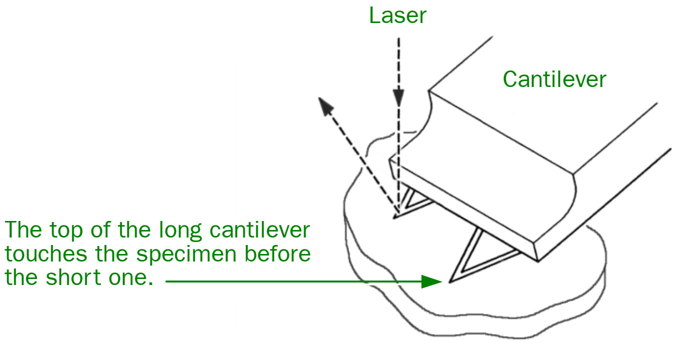


  The figure above shows the specimen for the JSPM-5200.

- Selecting a cantilever

  If there are two cantilevers, long and short, as shown in the figure below and you want to use the short cantilever for image observation, be sure to remove the long one using a pair of tweezers.



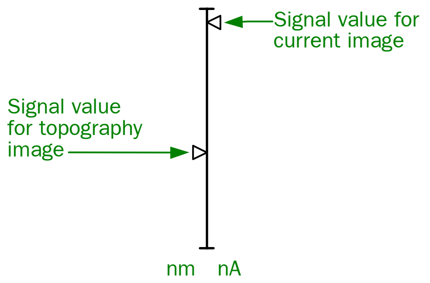


— CAUTION ———

When you select and use a short cantilever out of two cantilevers, long and short, be sure to remove the long one with a pair of tweezers. Otherwise, the top of the long cantilever touches the specimen before the short one does.

● Observing a contact current image

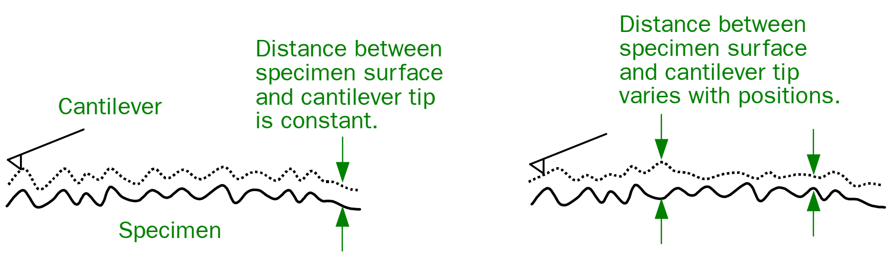
- The current measured in the contact mode is larger than that in the STM observation (for a conductive specimen). If the bar graph displayed in the Status window exceeds the maximum on the scale, reduce the set value of Preamp Gain in the Advanced Control window.



The maximum detectable current for each preamplifier gain is shown below.

Preamp gain	Maximum detectable current
0.01 V/nA	1 μA
0.1 V/nA	100 nA
1 V/nA	10 nA

- If the specimen has low conductivity like an insulating material, or the surface of the specimen is oxidized, the current changes little and the image contrast is poor.
- Linear current instead of Log current can be used to observe a current image. When the contrast does not increase with Log current, the apparent sensitivity can be increased with Linear current.
- In order to correctly observe a current image, a topography image must be acquired correctly. If the feedback filter setting is too slow, the cantilever response to the specimen surface topography becomes very slow, thus resulting in incorrect current measurement.



Appropriate feedback speed **Too slow feedback speed**

■ I-V Measurement Using Conductive Cantilever

The I-V measurement on the surface of a specimen is as commonly used as the observation of a current image.

● Precautions in using cantilever

Use the same type conductive cantilever as for the current image observation in the I-V measurement. Be sure that there is sufficient conductivity in the cantilever, the cantilever holder and the specimen stub. In the I-V measurement, a bias voltage is scanned, so an electrostatic force is applied to the cantilever. Therefore, if a soft cantilever is used, it may be bent by the electrostatic force during the bias voltage scanning, thus possibly resulting in incorrect I-V measurement. A hard cantilever such as a silicon cantilever should be used for accurate I-V measurement.

● I-V measurement

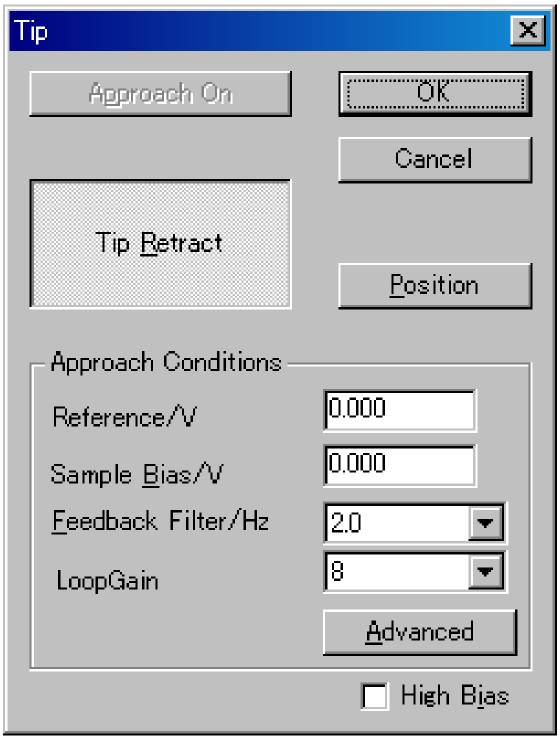
The following is the procedure for I-V measurement.

1. Observe the contact current image and grab it.

   Both a topography image and a current image are usually acquired to determine a point for measurement, but it is easier to determine the measurement point on a current image because there are points where no current flow is observed on some specimens.

2. Click on the Probe button in the Advanced tab of the SPM Parameters window.

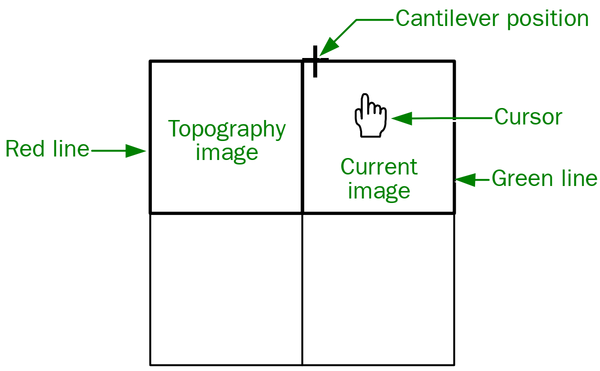
   The Tip window opens.



3. Click on the Tip Retract button to select it.
4. Click on the Position button in the Tip window.

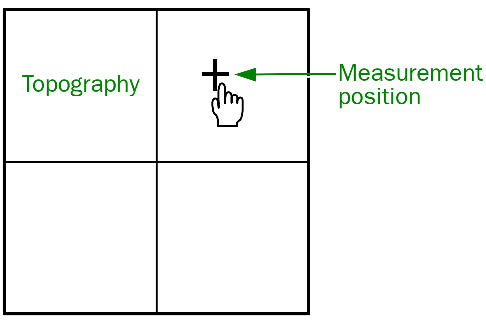
   The Tip window will close and the Tip position window will open. Move the cursor to the current image in the Display Window; then the cursor changes to a hand mark.

The present cantilever position is indicated by the "**+**" mark. Usually, the initial position is the top-left corner of the frame.



The cursor is in effect only inside of the active window in which the image is surrounded by a green line. The image surrounded by a red line is not active now. If you acquire the current image according to "Current Image Observation", the image will be grabbed later and becomes an active window.

5. Move the cursor to the cantilever position ("+"); then drag the "+" mark, while holding down the left mouse button, to the point where you want to perform I-V measurement.



The cantilever is actually moving in real time during the cursor dragging, so be sure to drag the "**+**" mark slowly.

6. After placing the "+" mark at the measurement point, press the right mouse button to finalize the position.

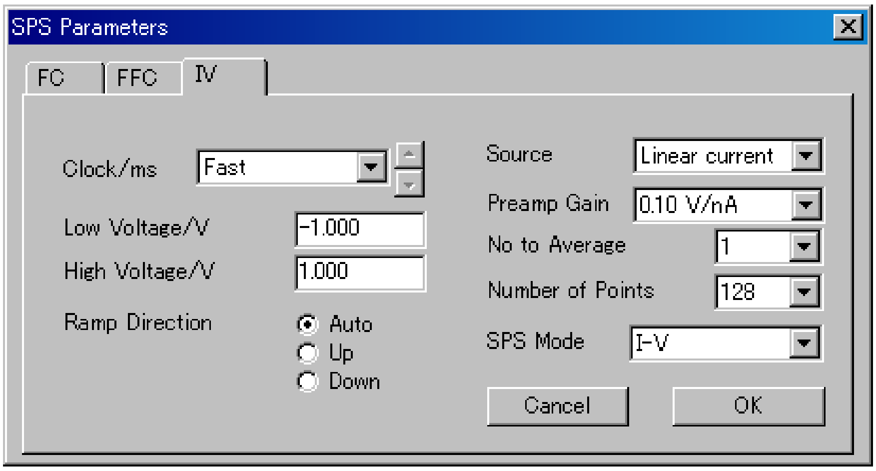
   The Tip window will be displayed.

7. Deselect Tip Retract.

8. Click on the SPS button.

   The SPS Parameters window will appear.

9. Click on the IV tab.



10. Specify the parameters for I-V measurement according to the following procedure.

a. Specify the voltage at which to measure I-V.

- Here, assume that the I-V measurement range is to be from –1.0 V to +1.0 V.
- Enter –1.000 in Low Voltage/V and 1.000 in the High Voltage/V input box using the keyboard.

This system executes capacitance compensation in such a way that when the input voltage is 0 V, the current is 0 nA. Therefore, specify the Low and High Voltages so that they encompass 0 V.

b. Click on the button in the Source selection box on the SPS Parameters window, and then select Linear current from the pull-down menu.

c. Click on the button in the Preamp Gain selection box on the SPS Parameters window, and then select 1.00 V/nA from the pull-down menu.

This value determines the preamplifier gain for I-V measurement. If the measured current gets saturated, decrease the gain.

d. Select Auto by clicking on the radio button for Ramp Direction; then the button changes to "⦿".

Ramp Direction determines the scanning direction of the bias voltage for I-V measurement. If Auto is selected, scanning is performed from a voltage near the voltage specified for Bias/V on the SPM Parameters window.

Suppose that Bias/V is set to 1.0 V, and Low Voltage/V to –1.0 V and High Voltage/V to 1.0 V.
If Auto is selected, the scanning will be performed from +1.0 V to –1.0 V.
If Up is selected, the scanning will be performed from –1.0 V to +1.0 V regardless of the value specified for Bias/V.
If Down is selected, the scanning will be performed from +1.0 V to –1.0 V regardless of the value specified for Bias/V.

e. Click on the button in the No to Average selection box and select 1 from the pull-down menu.

This specifies the number of I-V measurements for data averaging. Increase the number particularly when data is noisy or when a current to measure is very small.

f. Click on the button in the Number of Points selection box, and then select 128 from the pull-down menu.

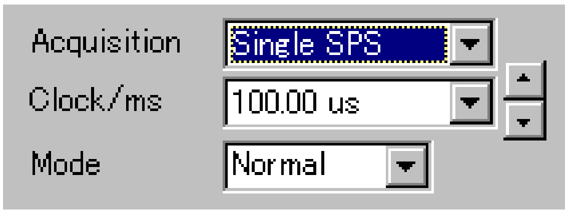
✍ This specifies the number of points for I-V measurement. The possible number is up to 2048 points.

g. Click on the button in the SPS Mode selection box and select I–V from the pull-down menu.

The I–V measurement is set to the specified SPS mode.

The foregoing are typical settings of SPS Parameters.

11. Click on the button in the Acquisition selection box, and then select Single SPS from the pull-down menu.



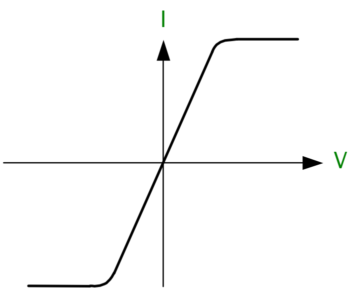
12. Click on the Repeat button on the Advanced tab window of the SPM Parameters window.

The I-V measurement will start. When you want to change the I-V display method, change it after grabbing the data by using the Plot parameters item of the Display menu in the main menu bar.

✍ If the measurement position is changed with this method, the changed position becomes the initial position. Therefore, when scanning has been finished or Abort has been performed, the cantilever tip is at the initial position.

● When measurement result is saturated

If the I-V measurement data is saturated as shown in the figure below, decrease the gain specified for Preamp Gain on the SPS Parameters window.



Decrease the value in Preamp Gain of the SPS Parameters window.

✍ If no stable data is obtained at the same measurement point or unreasonable data is obtained, the cantilever might be irregularly bent due to an electrostatic force during the measurement. In such a case, try to reduce the I-V scanning voltage range.

✍ Changing parameters during I-V measurement might cause errors for data that you grabbed. If you want to change parameters, do it while the measurement is suspended.

■ Observation of viscoelasticity image (optional measurement)

You can perform viscoelasticity measurement by additionally installing the optional Extended Lock-in Amplifier. When the lock-in amplifier is connected to the SPM controller, you have to set the instrument using the software to display the tab window for viscoelasticity measurement.

● Observation of a topography image

Observe a topography image of the specimen surface, and confirm that you can obtain an optimum image. Then retract the tip.

● Setting Lock-in Amplifier

Set the lock-in amplifier as you did in Sect. 5.5.2 when you observe an image in the viscoelasticity measurement tab window.

● Observation of an image

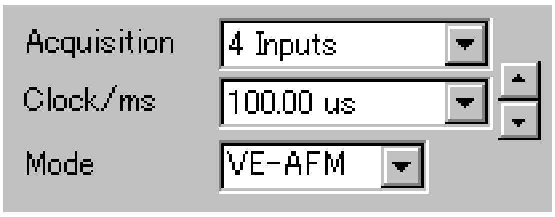
1. Carry out a topography image observation according to the usual method.

Confirm that you can observe well the AFM topography image.

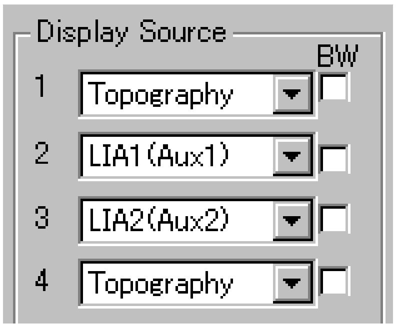
2. When scan is finished, specify parameters according to the settings of the following SPM Parameters window.

a. Select 4 Inputs from Acquisition.

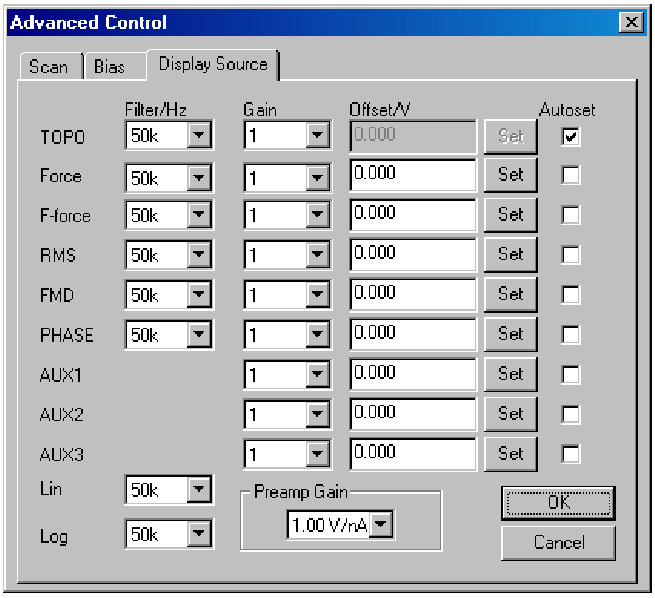
b. Select VE-AFM from Mode.



c. Set Display Source to the following.

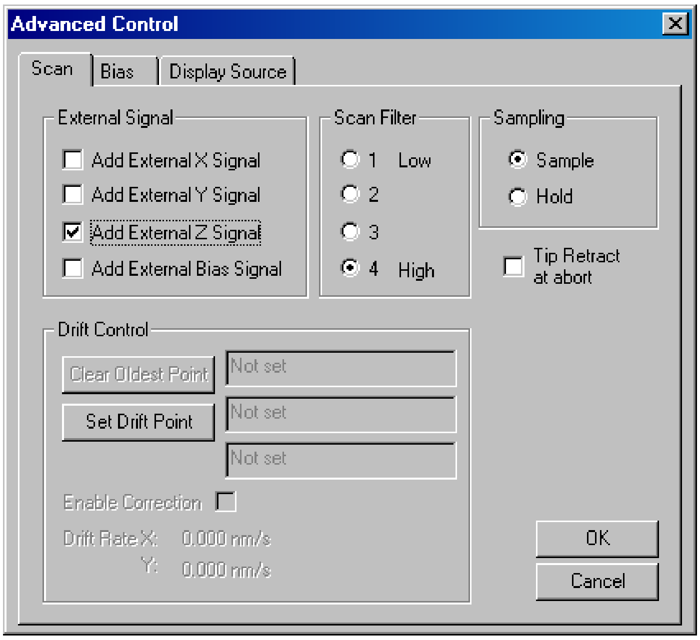


3. Click on the Advanced button in the Advanced tab window. Select Display Source tab in the Advanced Control window that appears. Set parameters as follows.



4. Select the Scan tab in the Advanced Control window, and then check the Add External Z Signal check box.

✍ Sometimes an oscillating sound is made depending upon the characteristic frequency of the scanner that you use. If it happens, reduce the oscillation level (OSC Level/V), or shift the present oscillation frequency (OSC Frequency/kHz) setting position until the sound is not made.



5. Click on the Probe button in the SPM Parameters window, and the Tip window opens; then deselect the Tip Retract button.

6. Set automatic adjustment for sensitivity and phase in the Lock-in-Amplifier window.

Click on Auto Configure when Model 5110 is used. Click on both Auto Sensitivity and Auto Phase when Model 7265 is used. The Lock-in-Amplifier will adjust the phase and gain automatically.

7. Increase the input sensitivity of the lock-in amplifier (from 1 mV to 100 nV direction) using the Sensitivity setting key (▼) in the range in which the signals from the lock-in amplifier do not saturate.

When using Model 5110 and the signal becomes saturated, the OLVD LED lights up.

8. To start scans, click on the Repeat button of the Advanced tab in the SPM Parameters window.

The following images will be obtained.

Topography (Topography image)	Acosϕ (Elasticity image)
Asinϕ (Viscosity image)	

The area in which both Acosϕ (elasticity image) and Asinϕ (viscosity image) become bright is the one in which elasticity and viscosity are large.

9. Specify the SPM parameters for usual operation so that you can obtain an optimum topography image.

10. Change the following parameters so that you can obtain an optimum elasticity image as well as an optimum viscosity image.

- Oscillation frequency (OSC Frequency/kHz)

  If the difference of specimens in elasticity and viscosity is small, for example, same kinds of materials such as composite plastic are mixed, increase oscillation frequency, and then you will obtain better images.

- Oscillation level (OSC Level/V)

  When using hard cantilevers such as a Si cantilever, reduce oscillation level to observe the image. If oscillation level is too large, the cantilever may break.

  To the contrary, when using soft cantilevers, increase oscillation level. Generally speaking, when you measure viscoelasticity, to obtain a good image, use a hard cantilever.

■ Observation of Lateral Modulation FFM Image (optional measurement)

You can perform lateral modulation FFM measurement by additionally installing the optional Extended Lock-in Amplifier. When the lock-in amplifier is connected to the SPM controller, you have to set the instrument using the software to display the tab window for lateral modulation FFM measurement.

● Observation of a topography image

You first observe the topography image of the specimen surface, and confirm that you can obtain a good image. Then retract the tip.

● Setting Lock-in Amplifier

Set the lock-in amplifier as you did in Sect. 5.5.3 when you observe an image in the lateral modulation FFM measurement tab window.

● Observation of an image

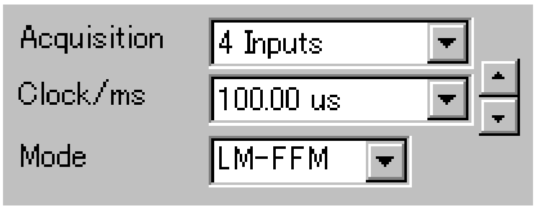
1. Carry out the AFM observation using the Contact mode according to the usual method.

Confirm that you can observe well the AFM topography image.

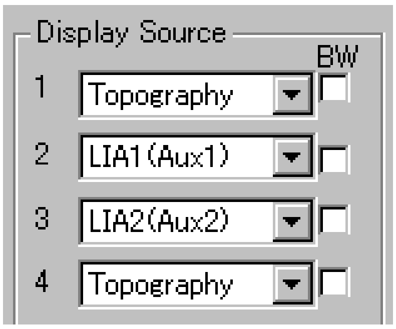
2. When scan is finished, specify parameters according to the settings of the following SPM Parameters window.

a. Select 4 Inputs from Acquisition.

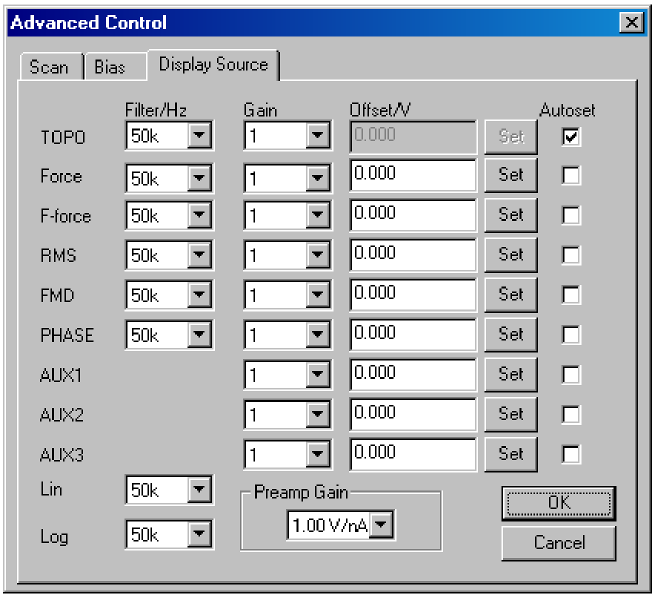
b. Select LM-FFM from Mode.



c. Set Display Source to the following.

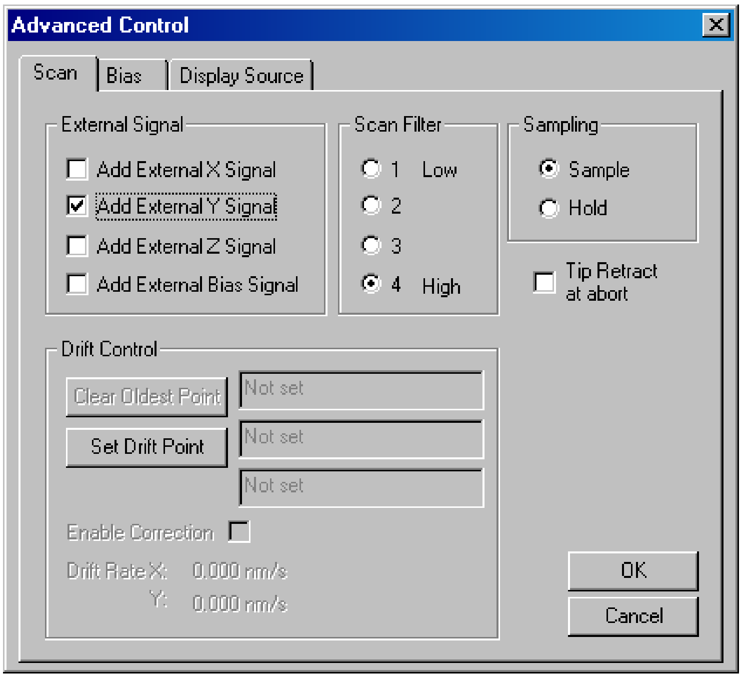


3. Click on the Advanced button in the Advanced tab window. Select Display Source tab in the Advanced Control window that appears. Set parameters as follows.



4. Select the Scan tab in the Advanced Control window, and then check the Add External Y Signal check box.

✍ Sometimes an oscillating sound is made depending upon the characteristic frequency of the scanner that you use. If it happens, reduce the oscillation level (OSC Level/V), or shift the present oscillation frequency (OSC Frequency/kHz) setting position until the sound is not made.



5. Click on the Probe button in the SPM Parameters window, and the Tip window opens; then deselect the Tip Retract button.

6. Click on Auto Configure in the Lock-in-Amplifier window.

The Lock-in-Amplifier will adjust the phase and gain automatically.

7. Increase the input sensitivity of the lock-in amplifier (from 1 mV to 100 nV direction) using the Sensitivity setting key (▼) in the range in which the signals from the lock-in amplifier do not saturate.

✍ When using Model 5110 and the signal becomes saturated, the OLVD LED lights up.

8. To start scans, click on the Repeat button of the Advanced tab in the SPM Parameters window.

The following images will be obtained.

Topography (Topography image)	Acosφ
Asinφ (Friction image)	

The area in which Asinϕ (friction image) becomes white is the one in which friction is large.

9. Specify the SPM parameters for usual operation so that you can obtain an optimum topography image.

10. Change the following parameters so that you can obtain an optimum friction image.

- Oscillation level (OSC Level/V)

  Oscillation level depends upon the scan range.

  In this system, if the maximum scan range is scanned, the voltage of 300Vp-p will be applied to the scanner. Therefore, there is the following relationship between the scan range and the voltage applied to the scanner.

$$Vp - p = \frac{Observation\ range}{128} \div Y\ Sensitivity \div 15$$

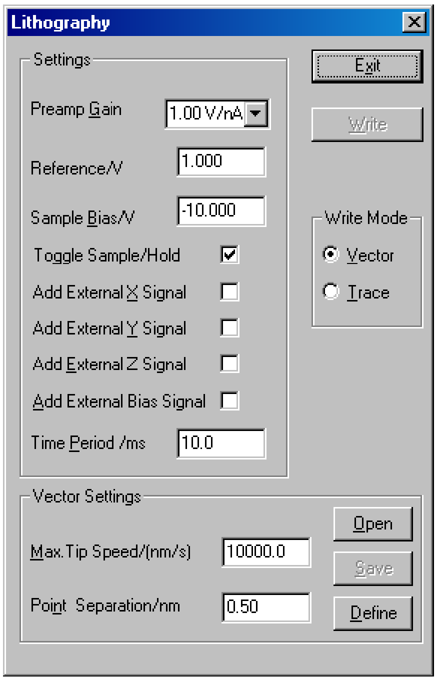
  (It is difficult to determine an exact Y sensitivity, since you have to execute distortion correction. However, the Y sensitivity can be estimated all the observation range/300 V.)

  In practice, the output value is a little smaller than the calculated one, because a low pass filter is contained in the high voltage amplifier. In lateral modulation FFM, set an excitation voltage to lateral amplitude of several nm to several tens of nm of the voltage applied to the scanner.

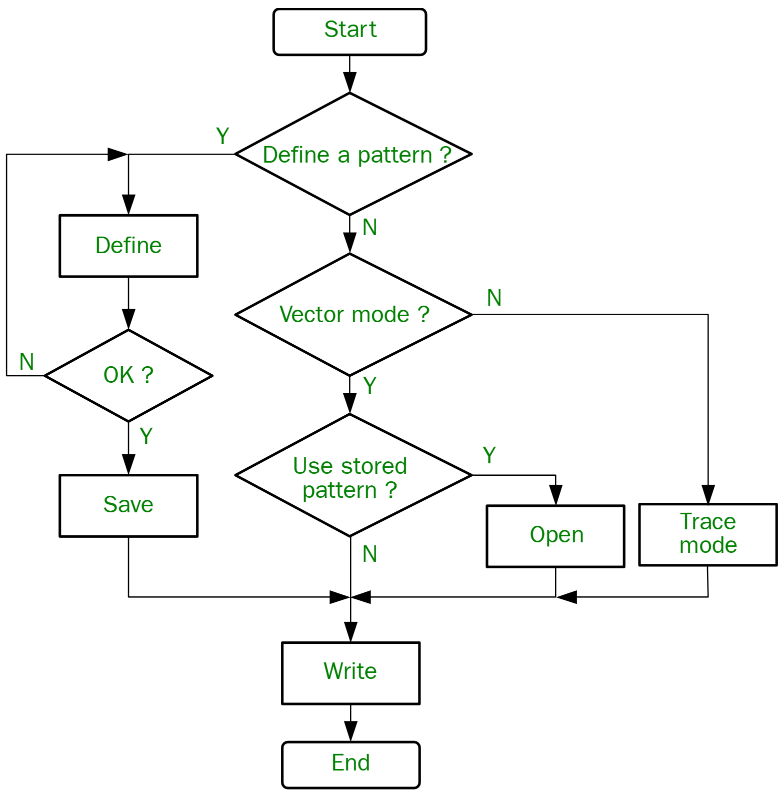
  The voltage amplitude applied to the scanner is 20 times larger than the amplitude input to the ADY. To obtain exact Y/20, use the optional oscilloscope.

■ Drawing using the lithography function

When certain values are given to the bias voltage and tunneling current, the specimen surface structure may change due to displacement, adsorption of atoms or anode oxidization. Lithography has the function to lithograph (write on) the specimen surface by using this phenomenon.



The lithography function has two modes: Vector and Trace.
The procedure for lithography is shown in the flow chart below.



● Lithography in Vector mode

The following is the procedure for performing lithography in the Vector mode.

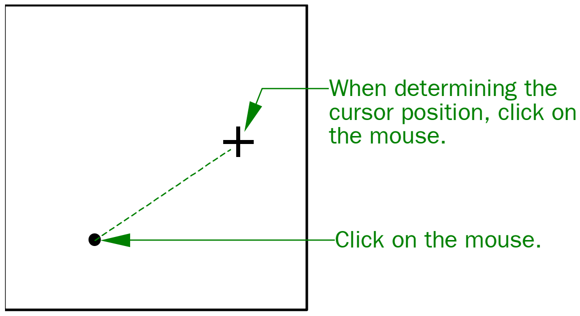
1. Click on the Lithography button in the Advanced tab window.
The Lithography window opens.

2. Observe an image as usual and grab it.

3. Specify the lithography conditions in the “Settings” frame.
Set parameters according to the specimen to write on.

4. Select Vector in the Write Mode frame; then click on the Define button in the Vector Settings frame.
Move the cursor to the Display Window. The cursor changes to the **+** mark.

5. Move the **+** mark to the initial point of the pattern that you want to write, and click on the mouse; then drag it by holding the mouse to draw a line, and click on the mouse again to determine the final point.



You can continuously define the pattern as explained above. To stop the pattern definition, click on the right mouse-button.

6. Click on the Write button to perform lithography.
Lithography will be performed along the defined pattern.

● Lithography in Trace mode

The following is the procedure for performing lithography in the Trace mode.

1. Click on the Lithography button in the Advanced tab window.
The Lithography window opens.

2. Observe the image as usual and grab it.

3. Specify the lithography conditions in the Settings frame.

4. Select Trace in the Write Mode frame; then click on the Write button.
Move the cursor to the Display Window. The cursor changes to the **+** mark.

5. Execute lithography by moving the mouse while holding the left mouse-button.
Click the right mouse-button to stop the lithography.

6. Check the written pattern using the ordinary image-observation procedure.

— CAUTION —

To prevent the tip from colliding with the specimen surface, the speed of the tip movement must not be faster than 200 nm/s.

■ Drift Compensation

Sample thermal drift, no matter how small, poses a problem in continuous measurement at the atomic level under ultra high vacuum, as this is a procedure which requires a highly stable field of view. The Drift Control window is used to correct such drift as occurs in the measurement image due to thermal or, sometimes, other causes. Drift correction is done by shifting the center point of the scanning area in the same direction and through exactly the same distance as the drift, at the end of the scan. To implement drift compensation, therefore, it is necessary to carry out preparatory steps (to obtain the drift speed and direction).

In drift compensation, the amount of drift per unit of time is calculated from the distance between a certain point observed when you scan the field of view first and the same point observed when you scan it second. Each time the measurement ends, the field of view is shifted automatically by the inverse amount of drift corresponding to the elapsed time.

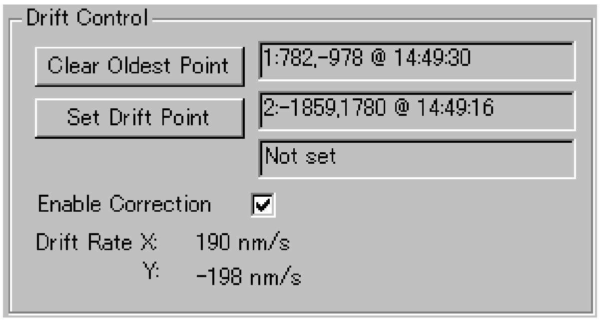
The procedure for drift compensation is as follows.

1. Click on the Advanced button in the Advanced tab window before starting measurement.

The Advanced Control window appears.

2. Select the Scan tab in the Advanced Control window.

Drift compensation uses the parameters in the Drift Control box in the Scan tab window.



3. Observe the first image and grab it.

Select a feature (a place such as a bright point or a hole that may indicate a defect) in the image.

4. Click on Set Drift Point to specify the first reference point.

The mouse cursor changes to the + mark; so specify the part of the measurement image that you selected in advance.

5. Observe the second image and grab it.

Confirm that the acquired image includes the selected feature.

6. Click on Set Drift Point to specify the second reference point.

Just as you selected the first feature point, specify the same feature in the second image (it has drifted to a different position). The drift speed and direction are calculated from the elapsed time and from the distance between the points in the first and second images.

7. Select Enable Correction.

Drift compensation begins.

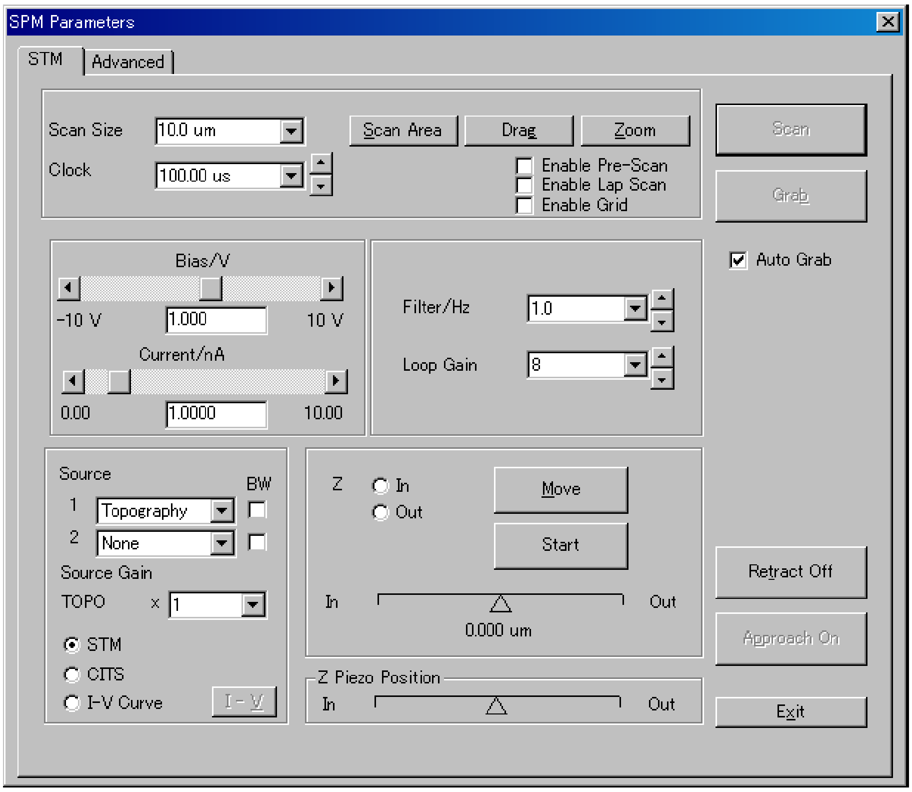
✍ You can specify the point up to three images for drift calculation. When you want to specify a third point, observe a third image and specify the point in it.

5.6 STM MODE

The SPM head unit with a tip holder is used for observation in the STM (Scanning Tunneling Microscope) mode.

5.6.1 STM Tab

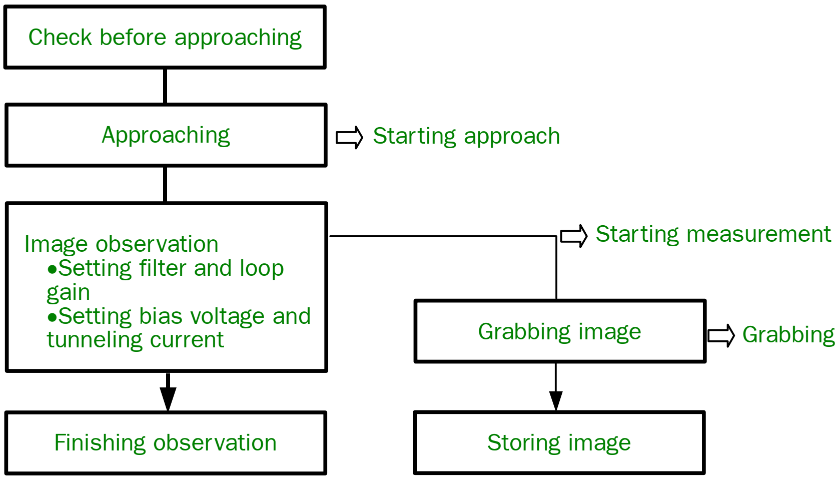
The STM tab window is a basic operation window for observing a topography measurement in the STM mode.



STM tab window

Flow chart of the operation

The following is the flow chart of the operation in the STM mode.



Checking before approaching

Before performing approaching, check whether the preparation has been completed according to the procedure in Sect. 5.3, "Preparing Approach."

- Has coarse approaching been executed in such a way that the distance between the cantilever tip and the specimen surface is 0.3 mm or less?
- Is the Z stage position in the approaching-possible range?

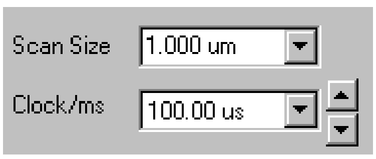
Setting the scanning parameters

Before carrying out an approach operation, set the scanning parameters including the scanning area.

Although the values of these parameters differ depending upon the specimen and the purpose of use, rough values are as follows.

● Scan Size

◆ Click on the Scan Size selection box in the STM tab window. When the numerical value is highlighted, enter 1 um using the keyboard and finalize the numerical value by pressing the Tab key. Or, click on the ▼ button in the Scan Size selection box and select a numerical value near 1,000 nm.



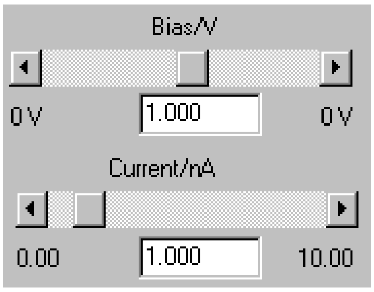
✍ Here, Scan Size differs depending on the scanner installed. In practice, set an appropriate value according to the observation area.

● Clock

◆ Click on the ▼ button in the Clock selection box and select 100.00 us.

✍ This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen.

- **Bias/V**
  - ◆ Click on the Bias/V box and when the numerical value is highlighted, enter 1 using the keyboard; then press the Tab key to finalize the value.



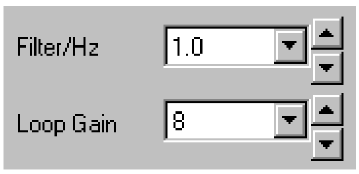
It is necessary to change Bias/V depending upon the specimen.
Normally, for specimens with high electrical conductivity, such as a metal, set the bias to a small value (0.2 V or less). For specimens such as a semiconductor or an oxide film, set it to a high value (1.0 V or more).

- **Current/nA**
  - ◆ Double-click on the Current/nA, and when the numerical value is highlighted, enter 1 using the keyboard; then press the Tab key to finalize the value.

Current/nA is used to specify the tunnel current between the specimen and the tip. Change it while observing the image that is being scanned. Here, set Current/nA to 1.000 for the time being.

- **Filter/Hz**
  - ◆ Click on the ▼ button in the Filter/Hz selection box and select 1.0 from the pull-down menu.

Filter/Hz is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, set the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.



- **Loop Gain**
  - ◆ Click on the ▼ button in the Loop Gain selection box and select 8 from the pull-down menu.

The setting determines the gain of the feedback circuit. The larger the set value is, the higher the response gain becomes, thus obtaining a good image from an uneven specimen surface, but the feedback circuit easily oscillates.

● Source (Selection of the acquired image type)

• When you observe a topography image

This image is the constant current mode for observing the topography of a specimen while keeping the current constant.

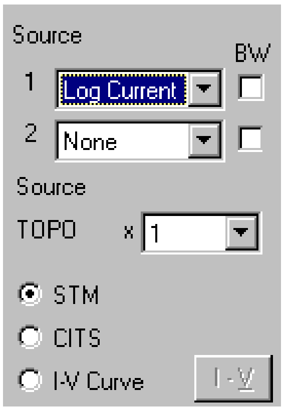
1. Select the STM radio button at the left bottom of the STM tab window.
2. Click on the ▼ button in the Source 1 selection box and select Topography.
3. Click on the ▼ button in the Source 2 selection box and select None.
4. Click on the ▼ button in the Source TOPO selection box and select 1.

• When you observe a current image

You can observe a current image by obtaining the current change as an image while keeping the distance between the cantilever and the specimen constant.

5. Select the STM radio button at the left bottom of the STM tab window.
6. Click on the ▼ button in the Source 1 selection box and select Log Current from the pull-down menu.
7. Click on the ▼ button in the Source 2 selection box and select None.
8. Click on the ▼ button in the Source TOPO selection box and select 1.
9. Click on the ▼ button in the Filter [Hz] selection box and select 0.5 or less from the pull-down menu.

✍ When observing a current image, you keep the height of the cantilever constant and usually observe the image performing a slow feedback. Select a slower response for the feedback than that used for observing a topography image.

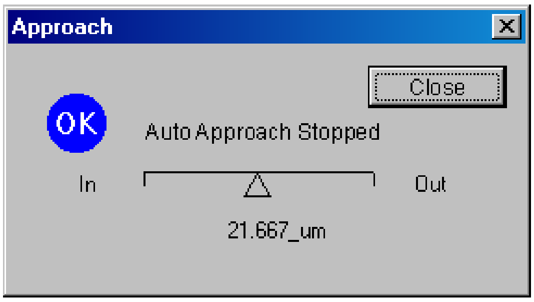


■ Approaching

1. Click on the Approach On button in the STM tab window.

Automatically, approaching starts. When approaching finishes, the Approach window asking “Auto Approach Stopped” is displayed in the center of the screen.

2. Click on the Close button.



● Considerations in using Approaching

- When the Approach On button is displayed in gray

  Click on the Retract Off button. When the Retract Off button is not selected, the Z scanner is forced to shrink most and cannot be approached.
- Speed of approaching

  You can specify the speed of approaching on the Advanced tab window. You cannot adjust the speed of approaching in the basic operation mode. Be aware that you can change the speed of approaching only when using the ultra-high vacuum SPM.
- Judgment of approaching conditions

  Whether approaching has finished or not is judged by measuring the voltage applied to the Z scanner. The voltage is set to ±0 V at the time of shipment from the factory. You can specify settings for finishing the approach on the Advanced tab window.
- Halt of approaching

  When approaching has begun, the Approach On button changes to the Approach Off button. If you click on this button, the approaching stops.

■ Image observation

◆ To observe an image, click on the Scan button.

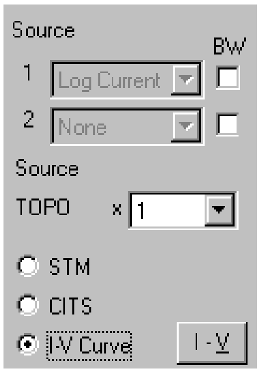
Scanning will start and an image will be displayed on the Display Window.

■ I-V measurement

The following is the procedure for measuring the I-V characteristic of the specimen surface.

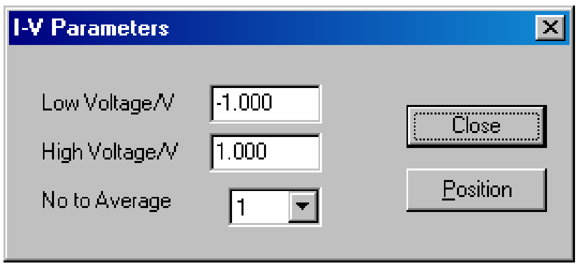
1. Observe a current image and grab it.

2. Select the I-V Curve radio button at the left bottom of the STM tab window.



3. Click on the I-V button.

The I-V Parameters window opens.

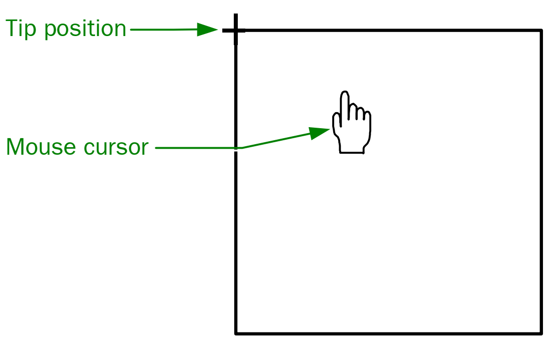


4. Click on the Retract On button in the STM tab window.

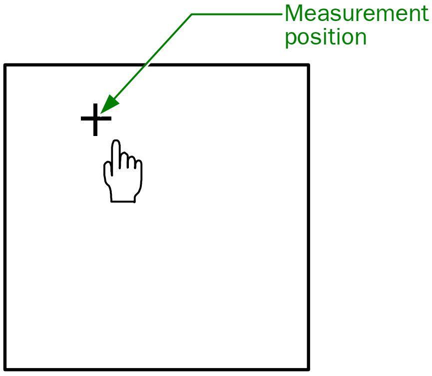
✍ Before setting the position for I-V measurement, retract the tip. This is for preventing the tip from contacting the specimen surface and deforming, when you move the tip to the position to measure.

5. Click on the Position button on the I-V Parameters window.

The I-V Parameters window will close and the Tip position window will open. Move the mouse cursor to the current image in the Display Window; then the cursor will change to a hand mark. The present position of the cantilever is displayed with a "+" mark. Usually, the initial position of the cantilever is the top left corner as shown below.



6. Move the cursor to the tip position; then press and hold down the left mouse button and drag it to the point where an I-V measurement is to be performed.



Be careful not to drag the mouse cursor very fast because the cantilever is actually moving in real time.

7. After placing the "+" mark at the measurement point, press the right mouse-button.

The I-V Parameters window will be displayed.

8. Deselect Retract On by clicking on it.

Release the Retract On button for measurement.

9. Specify the I-V measurement parameters according to the following procedure.

a. Specify the voltage range to perform the I-V measurement.

Here, as an example, we will explain how to set the I-V measurement range to –1.0 V to +1.0 V.

- Double-click on the input box for Low Voltage/V and enter –1 using the keyboard.
- Double-click on the input box for High Voltage/V and enter 1 using the keyboard.

In this system, the offset current is capacitance-corrected in such a way that when the input voltage is 0 V, the current is 0 nA. Therefore, the Low and High Voltages must be entered so that they encompass 0 V.

b. Click on the ▼ button in the No to Average selection box and select 1 from the pull-down menu.

This specifies the number of I-V measurements for data averaging. Increasing the number of measurement is effective particularly when data is noisy or when a very small current must be measured.

10. Click on the Scan button.

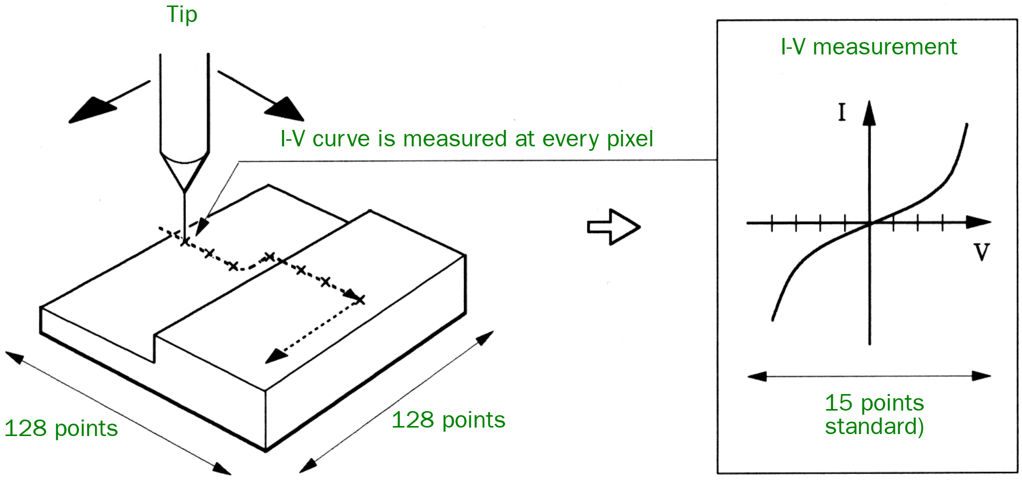
The I-V measurement will start.

When you want to change the I-V display method, change it using the Plot parameters of the Display menu after grabbing the data.

If the measurement position is changed with this method, the changed position becomes the initial position. Therefore, when scanning has been finished or Abort has been performed, the tip is at the initial position.

■ CITS image observation

A CITS (Current Imaging Tunneling Spectroscopy) image is a tunneling-current image produced when applying an optionally designated bias voltage while keeping the distance between the tip and the specimen surface (determined by the topographic-image observation conditions such as tunneling current and bias voltage) constant. I-V curves and data averaging at designated points on the specimen can also be obtained from the image captured in the CITS menu. In the case of CITS, unlike STS, I-V data is measured and an image is created at each pixel during tip scanning, so there is no influence of specimen drift or hysteresis so that the I-V curve at an arbitrary point of the image perfectly corresponds to the image points.

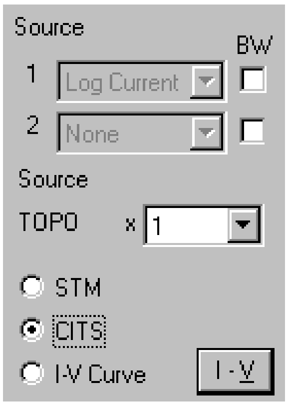


One method of determining the bias voltage is as follows.
Select a point where the image contrast varies greatly on an STM image and measure an I-V curve at that point once; then select the bias voltage of the position where the I-V curve varies greatly.

CITS measurement parameters such as Low Voltage and High Voltage are the same as those set in the I-V Parameters.

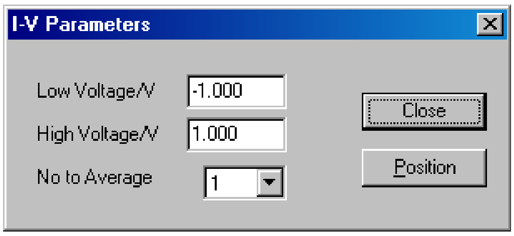
Observe a CITS image using the following procedure.

1. Select the CITS radio button at the left bottom of the STM tab window.



2. Click on the I-V button.

The I-V Parameters window opens.



3. Specify the I-V measurement parameters.

4. Specify the voltage range to perform the I-V measurement according to the following procedure.

Here, as an example, we will explain how to set the I-V measurement range to –1.0 V to +1.0 V.

a. Double-click on the input box for Low Voltage/V and enter –1 using the keyboard.

b. Double-click on the input box for High Voltage/V and enter 1 using the keyboard.

✍ In this system, the offset current is capacitance-corrected in such a way that when the input voltage is 0 V, the current is 0 nA. Therefore, the Low and High Voltages must be entered so that they encompass 0 V.

5. Click on the Scan button.

Scanning is performed and the following will be displayed.

Topo image	Current image	"	"
Current image	"	"	"
"	"	"	"
"	"	"	"

■ Acquiring an image

- When Auto Grab in the STM tab window is selected

  When acquisition is finished, the image is automatically grabbed and stored.

- When Auto Grab in the STM tab window is not selected

  To acquire an image, click on the Grab button while it is being scanned.

  When one image has been scanned, it is grabbed in the memory. At the same time, the measurement image is automatically stored as a temporary storage file in the specified program folder. Acquisition is repeated while you do not click on the Grab button and the acquisition images during repetition are not grabbed.

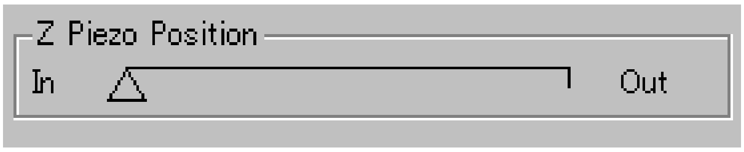
- The image is displayed after the offset for the input signals is automatically computed.

  You can control the offset for the input signals only in the Advanced operation mode.

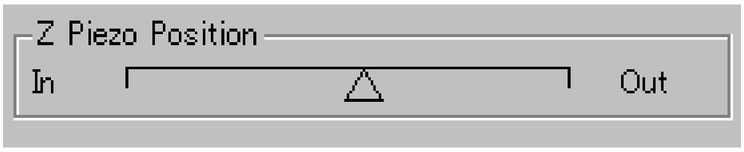
■ Cautions in observing image

In the STM mode, the settings of bias voltage and current are important points.
Unless the settings are carried out correctly, not only will it be impossible to obtain a satisfactory image, but also you may damage the specimen or the cantilever tip.
Control the distance between the specimen and the tip by adjusting Bias/V and Current/nA. If you set Bias/V to a small value and Current/nA to a large value, the distance between the specimen and the tip will be small. Theoretically, the resolution will increase, but the tip will be more liable to strike the specimen.

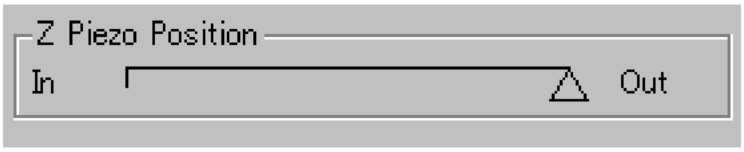
You can visually check the distance between the specimen and the tip at Z Piezo Position, which is in gray during scanning. So do it before starting to scan.



Condition in which the specimen and cantilever tip are completely separated (condition prior to approach)



Neutral position (condition at the end of approach)

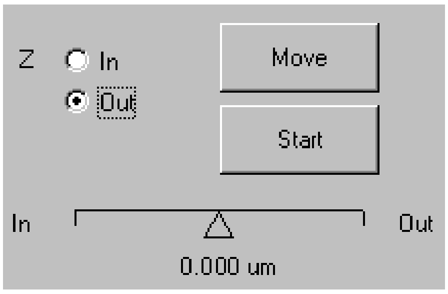


Condition in which the specimen and cantilever tip have fully struck each other

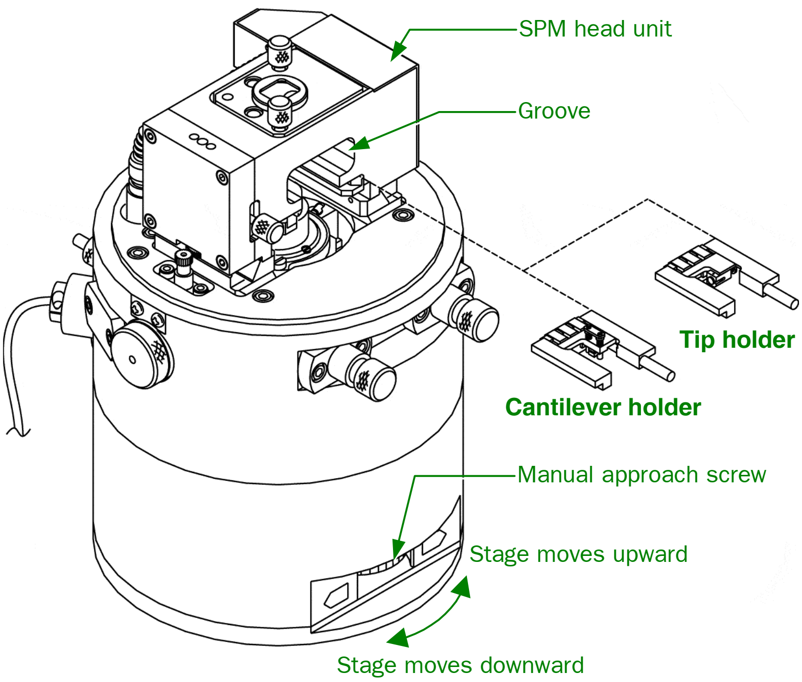
■ Terminating observation

Terminate observation according to the following procedure.

1. Stop scanning.
2. Click on the Retract On button to retract the cantilever tip.
3. Click on the Out button for Z and click on the Start button.



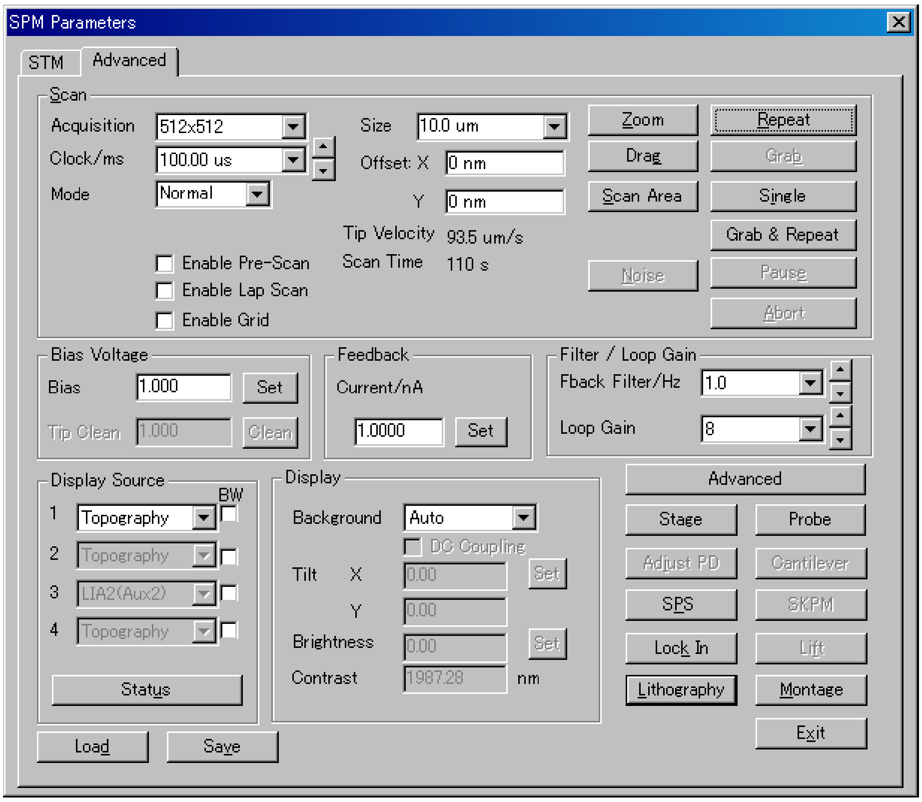
4. When the cantilever has moved 0.1 to 0.2 mm away from the specimen, click on the Stop button to stop the movement.
5. Turn the manual approach screw to move the specimen stage down.



The figure above shows the JSPM-5200.

5.6.2 Advanced Tab

The Advanced tab window is used for the advanced operation mode in the STM mode. It is possible to specify parameters in detail on the Advanced tab window, but you have to specify every parameter.



Advanced tab window

■ Checking before approaching

Before performing approaching, check whether the preparation has been completed according to the procedure in Sect. 5.3, "Preparing Approach."

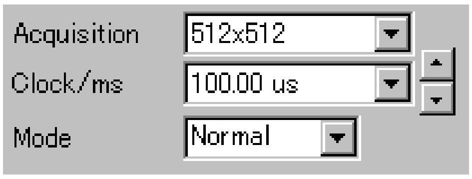
- Has coarse approaching been executed in such a way that the distance between the cantilever tip and the specimen surface is 0.3 mm or less?
- Is the Z stage position in the approaching-possible range?

■ Setting scanning parameters

Specify each parameter in the Advanced tab window according to the following procedure.

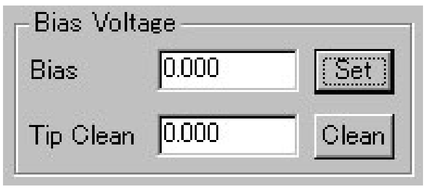
1. Click on the button in the Acquisition selection box and select 512×512 from the pull-down menu.
2. Click on the button in the Clock/ms selection box and select 100.00 us from the pull-down menu.

   This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen. Here, set it to 100.00 us provisionally.
3. Click on the button in the Mode selection box and select Normal from the pull-down menu.



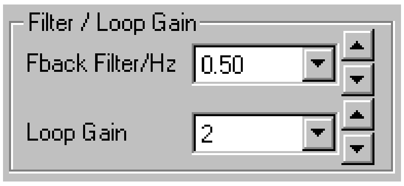
4. Click on the Size box. When the numerical value is highlighted, enter 1um using the keyboard and finalize the numerical value by pressing the Tab key. Or, click on the button in the Size selection box and select a numerical value near 1.000 um.

   Here, Size differs depending on the scanner installed. In practice, set an appropriate value according to the observation area.
5. Click on the Bias box. When the numerical value is highlighted, enter 1 using the keyboard and finalize the numerical value by pressing the Tab key.



   You should change the Bias value according to the specimen to observe. If it is a conductive specimen like a metal, specify a small value (0.2 V or less), and specify a large value (1.0 V or more) for a semiconductor specimen or a specimen having an oxidized film.

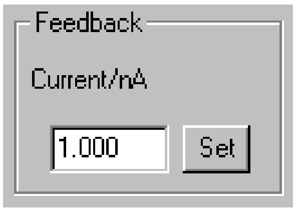
6. Click on the  button in the Fback Filter/Hz selection box and select 0.5 from the pull-down menu.



Fback Filter/Hz is the parameter that determines the response speed of the feedback circuit. The larger the specified value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, select the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.

7. Double-click on the Current/nA input box; then, when the numerical value is highlighted, enter 1 using the keyboard and finalize the 1 by pressing the Tab key.

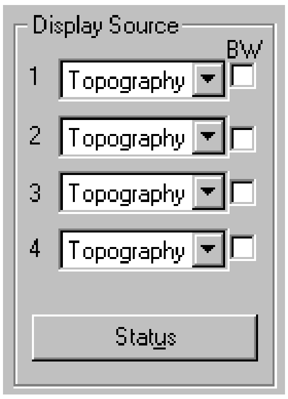
Current/nA specifies the tunneling current flowing between the specimen surface and the cantilever tip. You have to change the Current/nA value while watching an image during scanning. Here, enter 1.000 provisionally.



8. Click on the  button in the Loop Gain selection box and select 8 from the pull-down menu.

Loop Gain is the parameter that determines the gain of the feedback circuit. The larger the specified value is, the higher the gain becomes, thus producing a good image of a topographic specimen, but the feedback circuit easily oscillates.

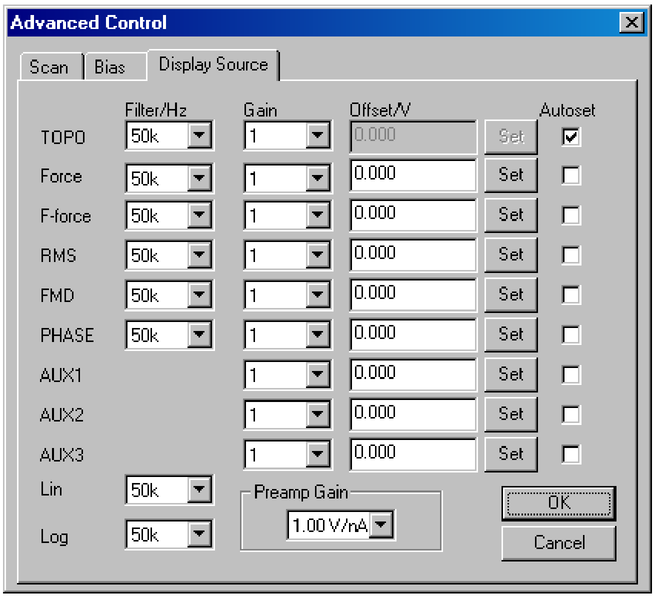
9. Click on the  button in the Display Source 1 selection box and select Topography from the pull-down menu.



10. Click on the Advanced button on the Advanced tab window.

The Advanced Control window is displayed.

11. Click on the Display Source tab, and then check the TOPO–Autoset box.

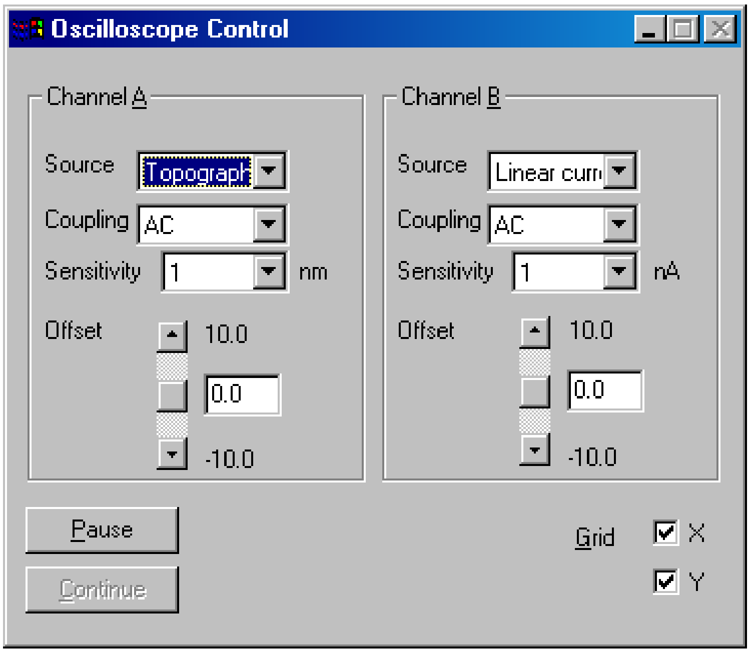


The “☐” or “☑” checking box is a toggle switch, and every time you click on it, it changes alternately between “☐” and “☑”.
The “☑” checking box means that it is selected.

■ Setting Software Oscilloscope

Set Channel B following the procedure below.

1. Click on the “🗗” button of the Oscilloscope Control window.
The Oscilloscope Control window will open.



2. Click on the button in the Source selection box in the Channel B frame; then select Log Current from the pull-down menu.

3. Click on the button in the Sensitivity selection box in the Channel B frame; then select 5 from the pull-down menu.

You can monitor the Log I signal.

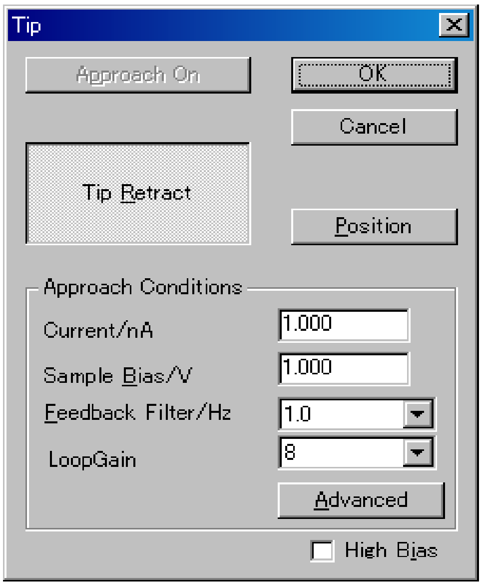
■ Approaching

Move the cantilever closer to the specimen until the value of the tunneling current becomes the value specified in Current/nA. The cantilever movement automatically stops when the tunneling current reaches the value specified in Current/nA.

The following is the procedure for approaching.

1. Click on the Probe button on the SPM Parameters window.

The Tip window will appear.



2. Specify each parameter according to the following procedure.

a. Double-click on the Current/nA input box. When the value in the box is highlighted, enter 1 using the keyboard. Press the Tab key on the keyboard to finalize the value.

b. Click on the button in the Feedback Filter/Hz selection box; then select 1.0 from the pull-down menu.

Now, the tunneling current and the response speed of the feedback circuit, which are used for approaching, have been determined. To prevent the cantilever from colliding with the specimen, set Feedback Filter/Hz to a value higher than that for image observation.

c. Deselect Tip Retract by clicking on it.

3. Before performing approaching, confirm that the voltage applied to the Z scanner reaches the maximum voltage (+150 V or 200 V).

If the voltage applied to the Z scanner does not reach the maximum voltage, it is judged that the approaching has already been completed. So, approaching will not start even if you click on the Approach On button on the Tip window.

In such a case, check the following points.

- Make sure that Loop Gain is not so low.
  If Loop Gain is set to a low number, the gain of the feedback circuit is so small that the feedback voltage is not applied up to the maximum voltage.
- Make sure that the tunneling current is already flowing.
  If Current/nA is set to a small value near 0 V, noise or a similar component may be mistaken for a tunneling current, thus resulting in performing no approaching (the computer judges that approaching has been completed). In such a case, specify a larger value for Current/nA; then try to find a Current/nA value where the Z voltage becomes the largest.

4. Click on the Approach On button on the Tip window.

The motor for approaching starts to rotate and automatically stops when the tunneling current becomes the same as the value given in Current/nA.

You may hear an oscillation sound coming from the instrument when approaching is completing. This is because the setting of the feedback filter is so fast that it oscillates. If the sound continues, click on the  button in the Feedback Filter/Hz selection box, and then select a slow filter (a smaller value) from the pull-down menu.

■ Topography image observation

When approaching has completed, carry out scanning.

● Starting scanning

◆ Click on the Repeat button on the Advanced tab window of the SPM Parameters window.

Scanning will start and an image will appear in the Display Window.
In the case of the STM mode, an important factor for obtaining a quality image is the setting of bias voltage and tunneling current. If this setting is inappropriate, not only can a quality image not be obtained, but also the specimen and the tip may be damaged.

● Setting Sample Bias and Current/nA

You can control the distance between the specimen surface and the tip by adjusting Sample Bias and Current/nA.
If Sample Bias is set to a small value and Current/nA to a large value, the distance between the specimen surface and the tip becomes short. Theoretically, the resolving power improves, but the tip could easily collide with the specimen.

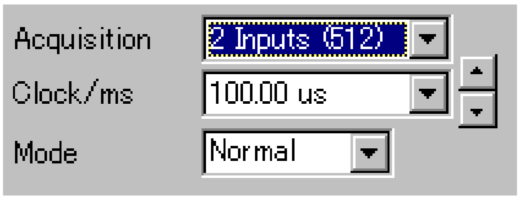
— CAUTION —
If the Sample Bias is set by using the slider during image observation, be careful not to move the slider button across 0 V. The tip would collide with the specimen surface if the bias voltage became 0 (zero).

■ Current image observation

The operation procedures for image observation in the STM mode that have been explained so far in this section are for the constant-current STM mode used to observe the topography of a specimen while keeping the tunneling current constant. In this mode it is also possible to observe a current image by obtaining the change of the current as an image while keeping the tip height constant. The following is the procedure for observing a current image.

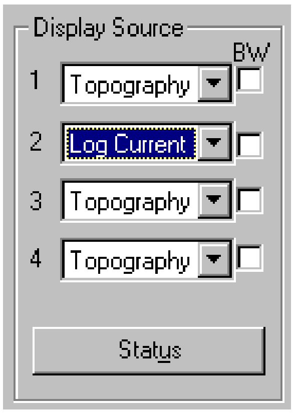
1. Click on the ▼ button in the Acquisition selection box on the Advanced tab window of the SPM Parameters window, and then select 2 Inputs (512) or 2 Inputs from the pull-down menu.

This action acquires two images and displays them simultaneously. When observing a current image, you usually acquire the topography image of the specimen and compare it with the current image.



2. Click on the ▼ button in the Display Source 2 selection box on the Advanced tab window of the SPM Parameters window, and then select Log Current from the pull-down menu.

For current-image observation, use Log Current instead of Linear Current.



3. Click on the ▼ button in the Fback Filter/Hz selection box, and then select 0.1 to 0.2 from the pull-down menu.

Usually, a current image is observed by applying a very slow feedback while keeping the height constant. Use a slower response for the feedback than that used for observing a topography image.

4. Click on the Repeat button on the Advanced tab window of the SPM Parameters window.

Scanning will start and an image will appear in the Display Window.

I-V measurement

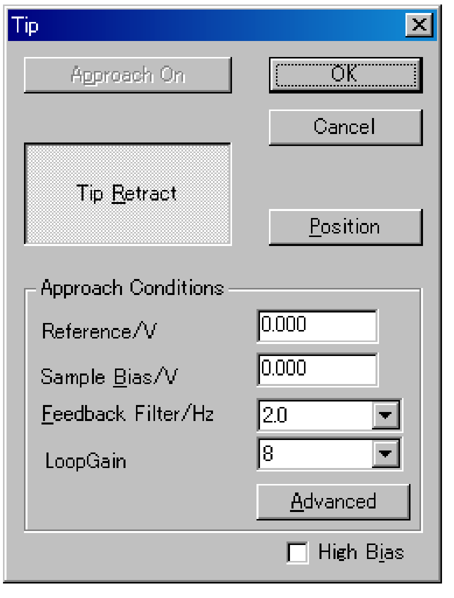
The I-V measurement on the surface of a specimen is as commonly used as the observation of a current image.
The following is the procedure for I-V measurement.

1. Observe a current image and grab it.

Both a topography image and a current image are usually acquired to determine a point for measurement, but it is easier to determine the measurement point on a current image because there are points where no current flow is observed on some specimens.

2. Click on the Probe button in the Advanced tab of the SPM Parameters window.

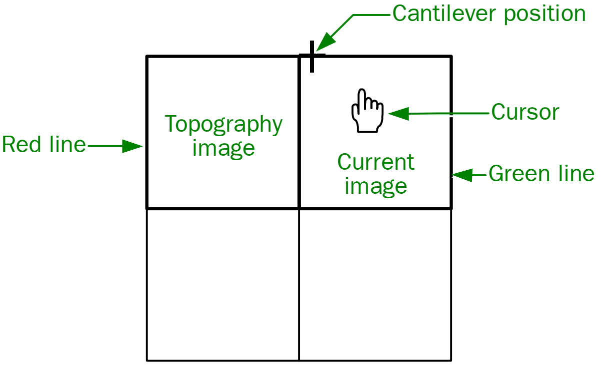
The Tip window opens.



3. Click on the Tip Retract button to select it.

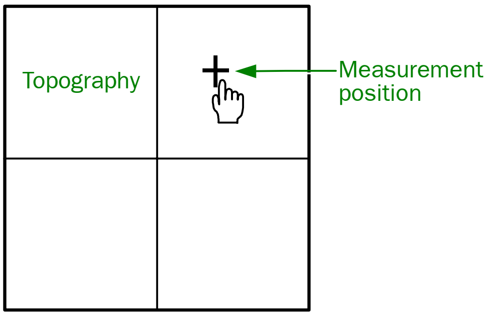
4. Click on the Position button in the Tip window.

The Tip window will close and the Tip position window will open. Move the cursor to the current image in the Display Window; then the cursor changes to a hand mark. The present cantilever position is indicated by the "+" mark. Usually, the initial position is the top-left corner of the frame.



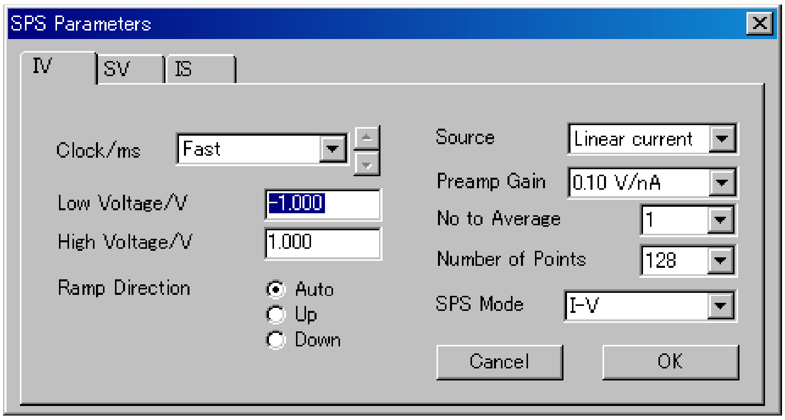
The cursor is in effect only inside of the active window in which the image is surrounded by a green line. The image surrounded by a red line is not active now. If you acquire the current image according to “Current Image Observation”, the image will be grabbed later and becomes an active window.

5. Move the cursor to the cantilever position (“+”); then drag the “+” mark, while holding down the left mouse button, to the point where you want to perform I-V measurement.



The cantilever is actually moving in real time during the cursor dragging, so be sure to drag the “**+**” mark slowly.

6. After placing the “+” mark at the measurement point, press the right mouse button to finalize the position.
   The Tip window will be displayed.
7. Deselect Tip Retract.
8. Click on the SPS button.
   The SPS Parameters window will appear.
9. Click on the IV tab.



10. Specify the parameters for I-V measurement according to the following procedure.
   a. Specify the voltage at which to measure I-V.
      Here, assume that the I-V measurement range is to be from –1.0 V to +1.0 V.
      Enter –1.000 in Low Voltage/V and 1.000 in the High Voltage/V input box using the keyboard.
      ✍ This system executes capacitance compensation in such a way that when the input voltage is 0 V, the current is 0 nA. Therefore, specify the Low and High Voltages so that they encompass 0 V.

b. Click on the button in the Source selection box on the SPS Parameters window, and then select Linear current from the pull-down menu.

c. Click on the button in the Preamp Gain selection box on the SPS Parameters window, and then select 1.00 V/nA from the pull-down menu.

This value determines the preamplifier gain for I-V measurement. If the measured current gets saturated, decrease the gain.

d. Select Auto by clicking on the radio button for Ramp Direction; then the button changes to "⦿".

Ramp Direction determines the scanning direction of the bias voltage for I-V measurement. If Auto is selected, scanning is performed from a voltage near the voltage specified for Bias/V on the SPM Parameters window.

Suppose that Bias/V is set to 1.0 V, and Low Voltage/V to –1.0 V and High Voltage/V to 1.0 V.
If Auto is selected, the scanning will be performed from +1.0 V to –1.0 V.
If Up is selected, the scanning will be performed from –1.0 V to +1.0 V regardless of the value specified for Bias/V.
If Down is selected, the scanning will be performed from +1.0 V to –1.0 V regardless of the value specified for Bias/V.

e. Click on the button in the No to Average selection box and select 1 from the pull-down menu.

This specifies the number of I-V measurements for data averaging. Increase the number particularly when data is noisy or when a current to measure is very small.

f. Click on the button in the Number of Points selection box, and then select 128 from the pull-down menu.

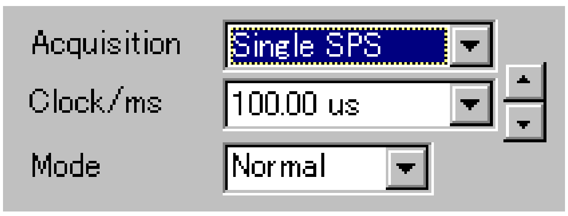
This specifies the number of points for I-V measurement. The possible number is up to 2048 points.

g. Click on the button in the SPS Mode selection box and select I–V from the pull-down menu.

The I–V measurement is set to the specified SPS mode.

The foregoing are typical settings of SPS Parameters.

11. Click on the button in the Acquisition selection box, and then select Single SPS from the pull-down menu.



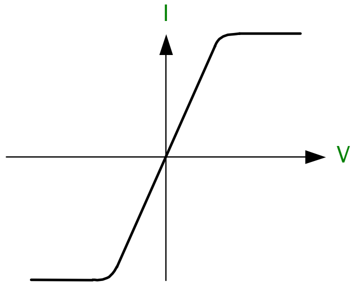
12. Click on the Repeat button on the Advanced tab window of the SPM Parameters window.

The I-V measurement will start. When you want to change the I-V display method, change it after grabbing the data by using the Plot parameters item of the Display menu in the main menu bar.

✍ If the measurement position is changed with this method, the changed position becomes the initial position. Therefore, when scanning has been finished or Abort has been performed, the cantilever tip is at the initial position.

- **When measurement result is saturated**

If the I-V measurement data is saturated as shown in the figure below, decrease the gain specified for Preamp Gain on the SPS Parameters window.



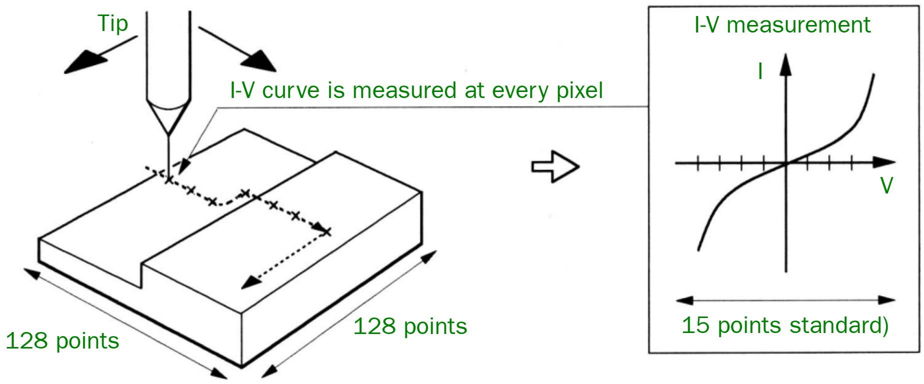
Decrease the value in Preamp Gain of the SPS Parameters window.

✍ If no stable data is obtained at the same measurement point or unreasonable data is obtained, the cantilever might be irregularly bent due to an electrostatic force during the measurement. In such a case, try to reduce the I-V scanning voltage range.

✍ Changing parameters during I-V measurement might cause errors for data that you grabbed. If you want to change parameters, do it while the measurement is suspended.

■ CITS image observation

A CITS (Current Imaging Tunneling Spectroscopy) image is a tunneling-current image produced when applying an optionally designated bias voltage while keeping the distance between the tip and the specimen surface (determined by the topographic-image observation conditions such as tunneling current and bias voltage) constant. I-V curves and data averaging at designated points on the specimen can also be obtained from the image captured in the CITS menu. In the case of CITS, unlike STS, I-V data is measured and an image is created at each pixel during tip scanning, so there is no influence of specimen drift or hysteresis so that the I-V curve at an arbitrary point of the image perfectly corresponds to the image points.

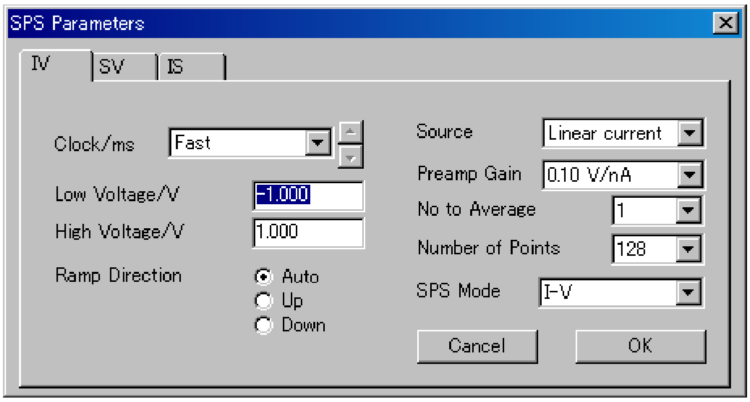


One method of determining the bias voltage is as follows.
Select a point where the image contrast varies greatly on an STM image and measure an I-V curve at that point once; then select the bias voltage of the position where the I-V curve varies greatly.
CITS measurement parameters such as Low Voltage and High Voltage are the same as those set in the SPS Parameters window.

Observe a CITS image using the following procedure.

1. Click on the SPS button on the Advanced tab window of the SPM Parameters window.

   The SPS Parameters window will appear.



2. Click on the IV tab.
3. Specify the parameters for I-V measurement according to the following procedure.

a. Specify the voltage at which to measure I-V.

- Here, assume that the I-V measurement range is to be from –1.0 V to +1.0 V.
- So, Enter –1.000 in Low Voltage/V and 1.000 in the High Voltage/V input box using the keyboard.

This system executes capacitance compensation in such a way that when the input voltage is 0 V, the current is 0 nA. Therefore, specify the Low and High Voltages so that they encompass 0 V.

b. Click on the button in the Source selection box on the SPS Parameters window, and then select Linear current from the pull-down menu.

c. Click on the button in the Preamp Gain selection box on the SPS Parameters window, and then select 1.00 V/nA from the pull-down menu.

This value determines the preamplifier gain for I-V measurement. If the measured current gets saturated, decrease the gain.

d. Select Auto by clicking on the radio button for Ramp Direction; then the button changes to “⦿”.

Ramp Direction determines the scanning direction of the bias voltage for I-V measurement. If Auto is selected, scanning is performed from a voltage near the voltage specified for Bias/V on the SPM Parameters window.

Suppose that Bias/V is set to 1.0 V, and Low Voltage/V to –1.0 V and High Voltage/V to 1.0 V.

If Auto is selected, the scanning will be performed from +1.0 V to –1.0 V.

If Up is selected, the scanning will be performed from –1.0 V to +1.0 V regardless of the value specified for Bias/V.

If Down is selected, the scanning will be performed from +1.0 V to –1.0 V regardless of the value specified for Bias/V.

e. Click on the button in the No to Average selection box and select 1 from the pull-down menu.

This specifies the number of I-V measurements for data averaging. Increase the number particularly when data is noisy or when a current to measure is very small.

f. Click on the button in the SPS Mode selection box and select I–V from the pull-down menu.

The I–V measurement is set to the specified SPS mode.

4. Observe an STM image by performing the operations.

Since a CITS image is scanned in a range of 128×128 pixels, specify 128×128 for STM observation, too, and confirm that you can obtain a quality image.

5. Click on the button in the Acquisition selection box on the Scan frame in the SPM Parameters window and then select SPS Mapping from the pull-down menu.

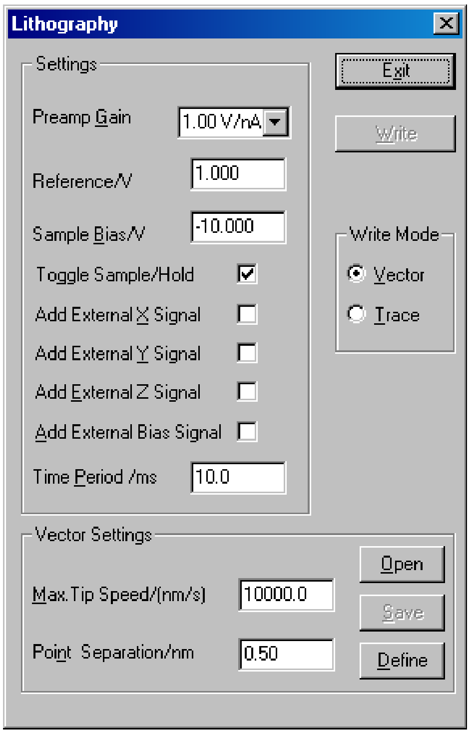
6. Click on the Repeat button in the SPM Parameters window.

The acquired CITS images will be displayed on the Display Window.

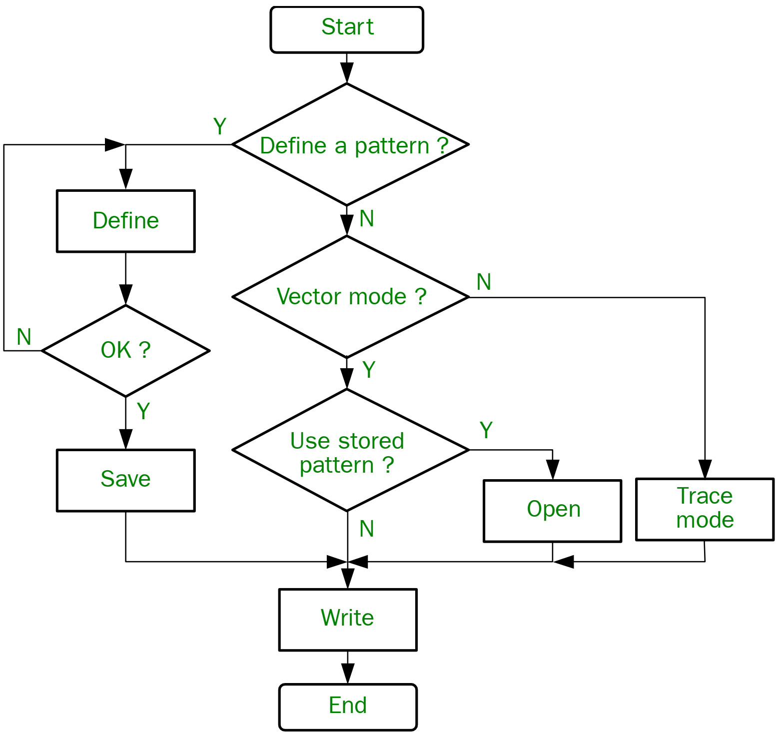
CITS images are displayed on one screen with divided frames. During scanning, the imaging on each divided frame progresses simultaneously in real time. Watch the progressing images on the screen, and if you are satisfied with the quality of the images, grab the images before the present frame scan is completed. Otherwise, the next frame scan starts automatically without storing the data when the present scan finishes.

Drawing using the lithography function

When certain values are given to the bias voltage and tunneling current, the specimen surface structure may change due to displacement, adsorption of atoms or anode oxidization. Lithography has the function to lithograph (write on) the specimen surface by using this phenomenon.



The lithography function has two modes: Vector and Trace.
The procedure for lithography is shown in the flow chart below.



● Lithography in Vector mode

The following is the procedure for performing lithography in the Vector mode.

1. Click on the Lithography button in the Advanced tab window.

The Lithography window opens.

2. Observe an image as usual and grab it.

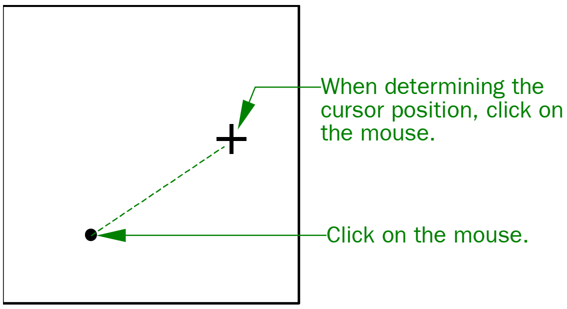
3. Specify the lithography conditions in the Settings frame.

Set parameters according to the specimen to write on.

4. Select Vector in the Write Mode frame; then click on the Define button in the Vector Settings frame.

Move the cursor to the Display Window. The cursor changes to the + mark.

5. Move the + mark to the initial point of the pattern that you want to write, and click on the mouse; then drag it by holding the mouse to draw a line, and click on the mouse again to determine the final point.



You can continuously define the pattern as explained above. To stop the pattern definition, click on the right mouse-button.

6. Click on the Write button to perform lithography.

Lithography will be performed along the defined pattern.

● Lithography in Trace mode

The following is the procedure for performing lithography in the Trace mode.

1. Click on the Lithography button in the Advanced tab window.

The Lithography window opens.

2. Observe an image as usual and grab it.

3. Specify the lithography conditions in the Settings frame.

4. Select Trace in the Write Mode frame; then click on the Write button.

Move the cursor to the Display Window. The cursor changes to the + mark.

5. Execute lithography by moving the mouse while holding the left mouse-button.

Click on the right mouse-button to stop the lithography.

6. Confirm the written pattern using the ordinary image-observation procedure.

— CAUTION —

To prevent the tip from colliding with the specimen surface, the speed of the tip movement must not be faster than 200 nm/s.

■ Drift Compensation

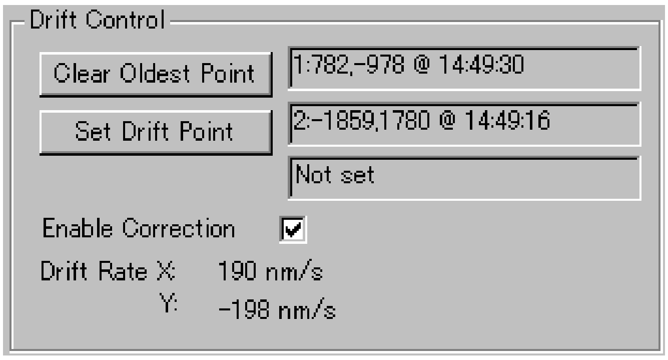
Sample thermal drift, no matter how small, poses a problem in continuous measurement at the atomic level under ultra high vacuum, as this is a procedure which requires a highly stable field of view. The Drift Control window is used to correct such drift as occurs in the measurement image due to thermal or, sometimes, other causes. Drift correction is done by shifting the center point of the scanning area in the same direction and through exactly the same distance as the drift, at the end of the scan. To implement drift compensation, therefore, it is necessary to carry out preparatory steps (to obtain the drift speed and direction).

In drift compensation, the amount of drift per unit of time is calculated from the distance between a certain point observed when you scan the field of view first and the same point observed when you scan it second. Each time the measurement ends, the field of view is shifted automatically by the inverse amount of drift corresponding to the elapsed time.

The procedure for drift compensation is as follows.

1. Click on the Advanced button in the Advanced tab window before starting measurement. And select the Scan tab in the Advanced Control window that appears.

Drift compensation uses the parameters in the Drift Control box in the Scan tab window.



2. Observe the first image and grab it.

Select a feature (a place such as a bright point or a hole that may indicate a defect) in the image.

3. Click on Set Drift Point to specify the first reference point.

The mouse cursor changes to the + mark; so specify the part of the measurement image that you selected in advance.

4. Observe the second image and grab it.

Confirm that the acquired image includes the selected feature.

5. Click on Set Drift Point to specify the second reference point.

Just as you selected the first feature point, specify the same feature in the second image (it has drifted to a different position). The drift speed and direction are calculated from the elapsed time and from the distance between the points in the first and second images.

6. Select Enable Correction.

Drift compensation begins.

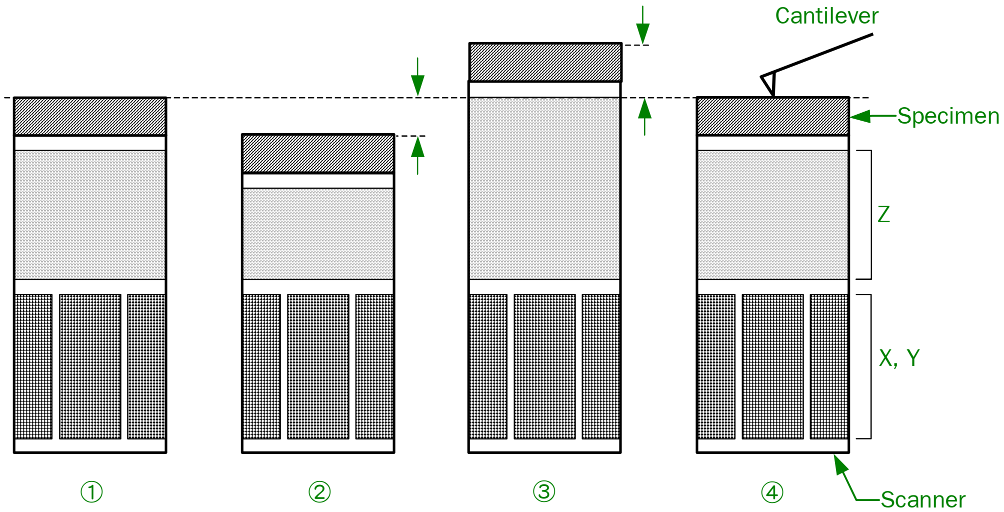
✍ You can specify the point up to three images for drift calculation. When you want to specify a third point, observe a third image and specify the point in it.

5.7 GENERAL PRECAUTIONS FOR IMAGE ACQUISITION

Explained in this section are the scanning method for image acquisition and other notes.

■ Retracting Tip

When you turn Tip Retract on, the Z-direction length of the scanner is forced to shrink. Refer to the figure below.



① No voltage is applied to the scanner (neutral position).

② Tip Retract is on, and the Z-axis piezoelectric element shrinks most.

③ Tip Retract is off, and the Z-axis piezoelectric element expands most.

④ Tip is in the Approach On position, and the tip is moved toward the specimen slowly by motor driving , with the Z-axis piezoelectric element in nearly neutral position (feedback is working).
The motor stops at the moment a tunneling current is detected.

✍ Tip Retract is used when the cantilever and the tip must be retracted temporarily.

■ Z position readjustment

During scanning, stage drift may cause the tip position to change along the Z-axis (the Z/20 value on the oscilloscope may deviate greatly from 0). In such a case, you can readjust the Z position of the tip by moving the Z stage while performing approaching. Carry out readjustment according to the following procedure.

1. Click on the Abort button in the Scan frame of the SPM Parameters window to stop scanning.
2. Click on the Tip Retract button in the Tip window to retract the tip.
   ✍ The purpose of this step is to prevent the tip from colliding with the specimen during motor driving.
3. Set the direction of the motor drive for the Z stage to Out, if the tip is too close to the specimen. Or, set it to In, if the tip is too far from the specimen. And then move the motor drive a little.

The tip position is readjusted.

— **CAUTION** ———

If you move the motor drive greatly, the tip gets too close to the specimen surface or gets too far from the specimen.

4. Click on the Tip Retract button in the Tip window to deselect it.

Confirm using the oscilloscope that Z/20 is close to 0. If not, repeat steps 2 to 4 above.

✍ The specimen-stage Z-axis motor-driving mechanism can be mechanically dismounted to shut out external disturbances such as vibration and noises. When the motor-driving mechanism is rotated backward for dismounting, there is a backlash of about 3/10 of a revolution.

■ Shifting observation field (Large shift)

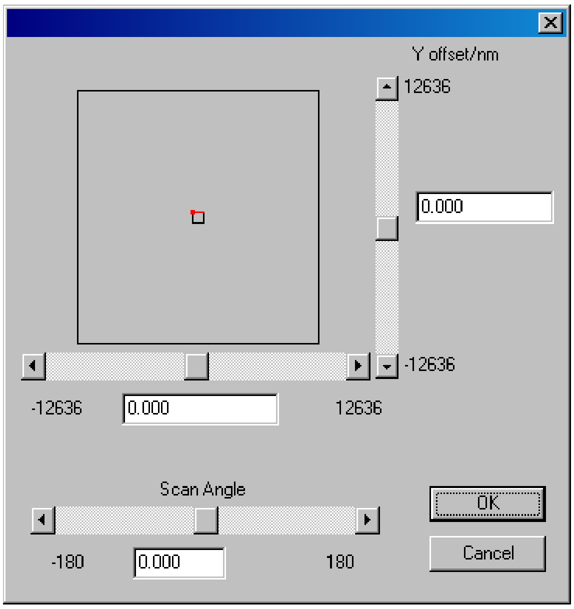
When you want to greatly shift the observation field, retract the tip or cantilever then manually shift the specimen stage.

■ Shifting observation field (Middle shift)

When you want to shift the observation field within the scanner movement range, shift it according to the following procedure.

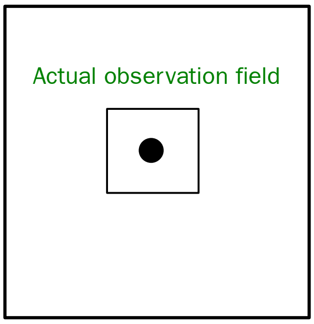
1. Click on the Scan Area button in the Scan frame in the SPM Parameters window.

The following window will be displayed.



2. Shift the observation field using the X and Y sliders or directly drag the field.

The relationship between the actual observation field and the maximum observation field is shown below.



Maximum observation field

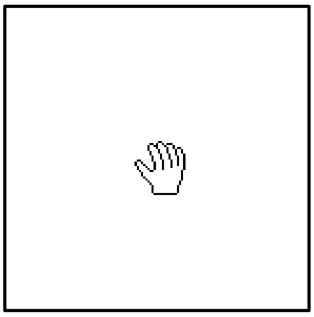
✍ Shift the observation field very slowly.

■ Shifting observation field (Small shift)

If you wish to change the observation field within the range in which the measured image is displayed, change the observation area using the following procedure.
Note that you cannot perform this operation in the basic mode.

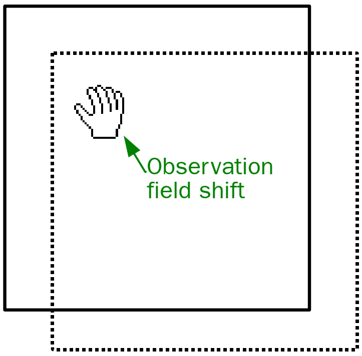
1. Click on the Drag button in the Scan frame of the SPM Parameters window.

When you move the cursor into the Display Window, it changes to the cursor shown below.



2. Hold down the left mouse button and drag the Display Window.

The observation field will shift by exactly the amount that you drag the cursor.
To stop shifting the observation field, click on the right mouse button.



✍ Shift the observation field very slowly.

■ Grabbing data in computer memory

The image that is being scanned and the I-V data are cleared when next scan starts. The following is the procedure for grabbing the data in the computer memory.

✍ The grabbed data will be written in the RAM and also temporarily stored in the folder specified by the SPM software (a tmp folder that is in the folder that has the winspm32.exe file). The temporarily stored data is cleared when the SPM software is started next time.

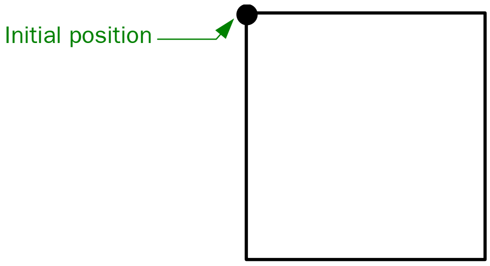
1. When data that you want to save is obtained, click on the Grab button in the Scan frame of the SPM Parameters window. Be sure to click on the button while the scan is in progress.
2. While the Grab button is active by clicking on it, the image data is normalized after scanning of one image completes, and the Title dialogue box opens, prompting you to enter an image name (title). Enter the title using the keyboard.

   ✍ The title is not a file name used for transferring the data to and from the disk, but is simply an image title used for identification and selection of the data. Therefore, an easily understandable name is preferable.
3. The image data will be stored in the computer memory. If you want to continue the scanning, click on the Repeat button in the Scan frame again.
4. Then, the next image will be scanned. Grab (store) the image data in the computer memory following steps 1 to 3 above.
5. After finishing the observation, retract the tip, and then save the image data that you want on a disk.

✍ Difference between the image that appears during scanning and the grabbed image
Sometimes there is a large difference between the image that appears during scanning and the image that is grabbed. This is because during scanning, the brightness and contrast of each acquired line are adjusted based on the highest and lowest values in each line, whereas when the image is grabbed the brightness and contrast are computed based on the highest and lowest values over the entire screen. Consequently, if there are steps in the image, or the Z-axis movements, the grabbed image will be quite different from the scanned image.
This phenomenon often occurs during observation at high magnification, particularly in the contact mode. It is thought that this is because the bending of the cantilever occurs during scanning. For this reason, carry out the Reference/V adjustment very carefully.

■ Precaution for Autoset

If Autoset is selected in the Display Source tab of the Advanced Control window, the offset is measured before an image is acquired. The offset of the Z-axis voltage is measured in the initial position as shown in the figure below, and an offset is automatically set so that this value becomes zero.

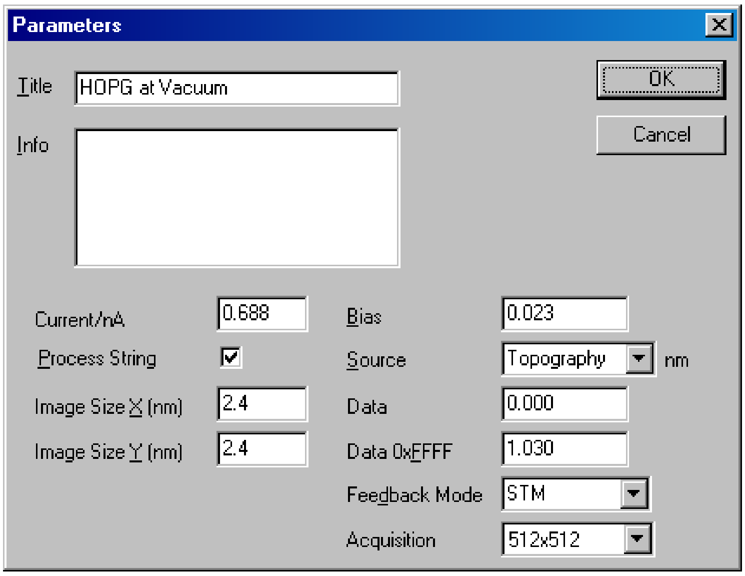


If the specimen height level in the initial position, where the offset was measured, is high (protruding) or low (hollow), or the specimen surface is extremely inclined, the image may become black or white during scanning, thus resulting in no image contrast. In such a case, change the observation area or deselect Autoset by clicking on the “Autoset ☑” mark and set Offset/V manually.

■ Saving an image

You save the image data that is stored in the computer memory on a hard disk for later use. Of course, all the grabbed data will be temporarily and automatically stored on a hard disk, but do not forget to save the grabbed data that you want to save. For convenience’s sake, it is suggested that you make a data directory and write a comment for each data.

1. To display the image that you want to save on the Display Window, select Select from the main menu, and then select the desired image name from the list that appears.
2. Return to the main menu, and select Display; then select Change Para… from the pull-down menu.



3. Enter the specimen name and observation conditions in the Info box in the Parameters window using the keyboard. After checking the parameters, click on the OK button.

✍ You can freely enter any comment such as measurement conditions, which will be very convenient for later use.

4. Select File from the main menu; then select Save AS... from the pull-down menu.

The Save AS... window will appear. Enter a file name for the image to save and designate the directory in which the data is to be saved.

5. Click on the OK button.

The image data will be saved on the disk.

6. Repeat Steps 1 to 5, as necessary.

5.8 TERMINATING MEASUREMENT

Explained in this section is the procedure for terminating measurement after a series of operations has been completed.

1. Stop scanning by clicking on the Abort button in the Scan frame of the SPM Parameters window.
2. Open the Tip window by clicking on the Probe button in the SPM Parameters window.
3. Click on the Tip Retract button to select it.

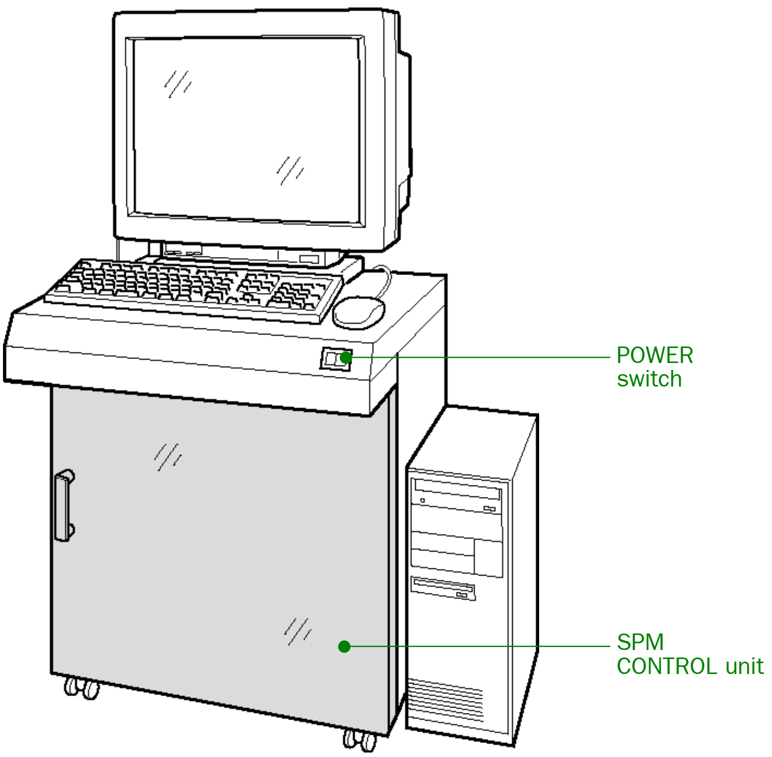
   The tip will retract.
4. Click on the Stage button in the SPM Parameters window.

   The Coarse Stage window opens.
5. Select Out for Z in the Direction frame; then click on the Start button in the Coarse Stage window. Retract the cantilever or tip far enough from the specimen surface.
6. Confirm that the cantilever or tip has retracted far enough from the specimen surface. Then, retract the cantilever or tip far away manually.

5.9 TERMINATING OPERATION

After saving the desired data on a disk upon completing image observation, you terminate the system. The following is the termination procedure.

1. Select File from the main menu and select Exit from the pull-down menu.
2. Confirm that all necessary data has been saved on a disk, and click on the OK button.
   If data is still in the computer memory, a warning message appears in the window.
3. Confirm that the SPM software has been terminated and the screen has returned to Windows™.
4. Move the cursor to the bottom-left corner of the screen and click on the Start button; then click on the Shut Down button from the pop-up menu.
5. Select Shut down the computer?; then click on the YES button.
   The computer is turned off.
6. Turn off the POWER switch of the SPM CONTROL unit.



7. Confirm that the power to all the units is completely off.

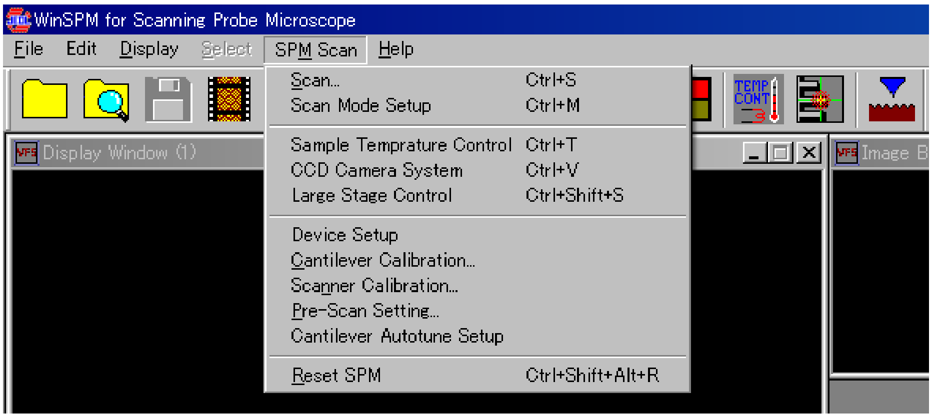
— CAUTION —

The software must be terminated before the power is turned off. Never turn off the power while the software is in operation.
Wait 10 seconds or more before restarting the system.

5.10 REFERENCE

5.10.1 SPM Scan Menu

The SPM Scan menu is the key menu for measurements and operations. It contains the following items:



■ Scan… Ctrl+S

This is the most important item for starting measurements and operations. It will be explained later in more detail.

■ Scan Mode Setup Ctrl+M

This displays the Scan Mode Setup dialog that sets the SPM measurement function to start up.

This dialog is used when you have checked the “Don’t show this window when start up” box of this dialog, when you change the SPM measurement function to start up, or when you want to display the Scan Mode Setup dialog at measurement start-up.

■ Sample Temperature Control Ctrl+T

This displays the Sample Temperature Control dialog that controls specimen temperature.

☞ For details, refer to Sect.5.10.5 “Controlling Specimen Temperature.”

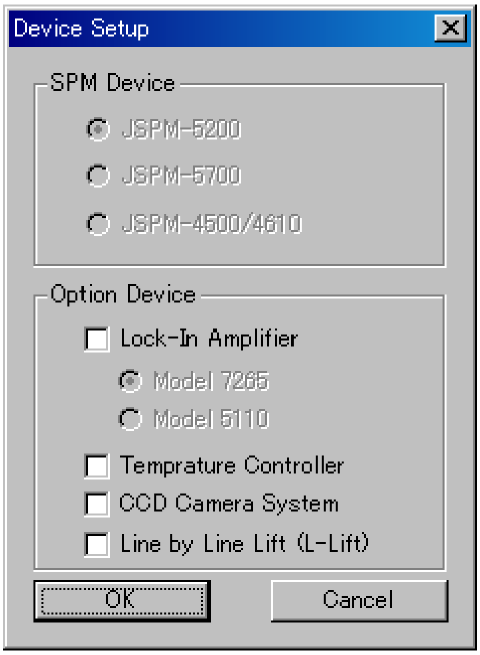
■ CCD Camera System　Ctrl+V

This displays the CCD camera window that shows images from the CCD camera.

☞ For details, refer to Sect.5.10.6 “CCD Camera.”

■ Device Setup

This selects the SPM device, and sets the optional devices that are connected to and controlled by the SPM device.



● SPM Device

This selects a type of the SPM device controlled by the WinSPM software.
Since the basic setting for the WinSPM software differs depending on the selected SPM device, you might cause malfunction of the device unless this device is set properly.
Moreover, since the piezo-drive power-supply voltage differs depending on the instrument (±150 V or ±200V), you might cause instrument trouble unless it is set properly.

✍ This setting has been properly done before shipment.
Only a user with administrator privilege can change the setting. If the setting of the SPM device is wrong, exit the software once and log into it again with administrator privilege.

● Option Device

Unless the optional device boxes are checked, you cannot control the optional devices nor perform optional measurement using the WinSPM software even if the optional devices are connected to the SPM device. So be sure to check these boxes.

■ Cantilever Calibration

Selecting Cantilever Calibration from the SPM Scan menu opens the Cantilever Calibration window, in which you can specify the cantilever calibration values for calculating interatomic force and friction force that are obtained from bending and torsion of the cantilever, respectively.

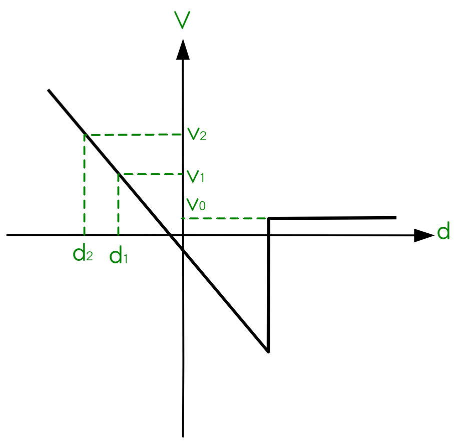
● Force Calibration

Perform cantilever calibration for calculating the interatomic force from the bending of the cantilever.

The interatomic force is calculated based on the following equation:

$$F = ka(V - V_0)[nN]$$

- Apply
  When the Apply check box is checked, the force image or force curve appears with an interatomic force value calculated from the applied voltage.
- Spring Constant k [N/m]
  Enter the spring constant of the cantilever in this input box.
- Sensitivity a [nm/V]
  This is the factor related to the sensitivity of the optical lever method.
- Reference V_0 [V]
  Enter the Force signal value obtained when the force applied to the cantilever is zero in the Reference V0 [V] input box. This value depends upon the instrument or cantilever used. Click on the Apply check box to remove the check mark. Acquire a force curve; then calculate it. When the following force curve is obtained, calculate each parameter as follows:



$$a = \frac{|d_2| - |d_1|}{V_2 - V_1}$$

● Friction Force Calibration

Perform cantilever calibration for calculating friction force from the torsion of the cantilever.

The friction force is calculated based on the following equation:

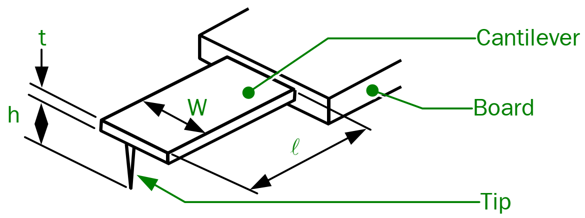
$$F = \frac{ka(V - V_0)}{2d} \times 10^9 [nN]$$

- Apply

  When the Apply check box is checked, the friction-force image appears with a friction-force value calculated from the applied voltage.
- Spring Constant k [N/rad]

  Enter the spring constant of the cantilever in the torsional direction in the Spring Constant k [N/rad] input box.

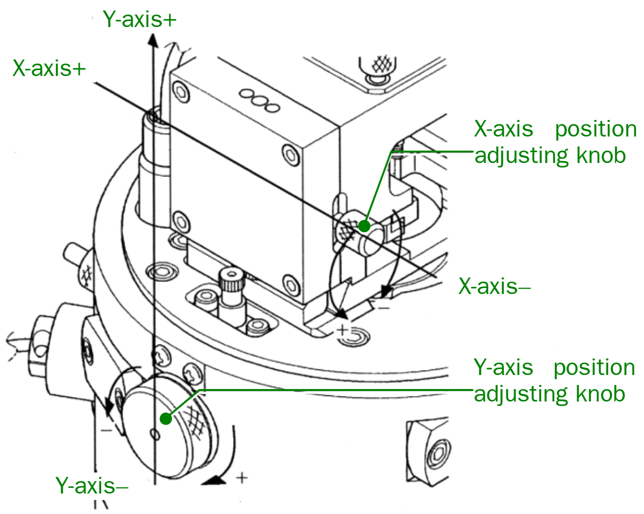
$$k = \frac{wt^3 G}{3l(h + t/2)}$$



✍ where G is the modulus of rigidity for w>>t. When the material of the cantilever is silicon, $G=5\times10^{10}$ [N/m^2].

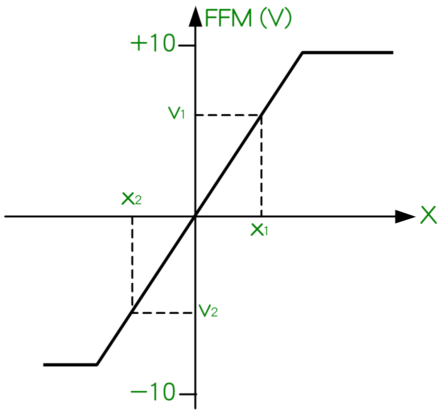
- Sensitivity a [mm/V]

  This value depends upon the instrument used. Change the photodiode position (in the X-axis), then calibrate the sensitivity using the FFM value shown on the AFM AMP indicator.



This figure is for JSPM–5200. X and Y shift 0.5 and 0.25 mm per evolution, respectively.

When the following result is obtained, calculate the calibration value from this graph:



$$a = \frac{x_1 - x_2}{V_1 - V_2}$$

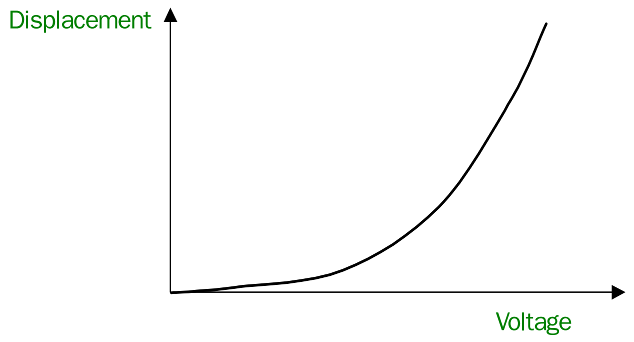
✍ The shifts per evolution of the photodiode position-adjustment knob are as follows:

X-axis shift (mm)	Y-axis shift (mm)
0.5	0.25

- Cantilever-PD distance d [mm]
  Enter the distance 40.0 between the cantilever and the photodiode in this input box.
- Reference V_0 [V]
  Enter the Friction Force signal value obtained when the force applied to the cantilever is zero.

■ Scanner Calibration

A tube-shaped piezoelectric scanner is used in ultra-high vacuum SPM. Generally, the piezoelectric element of such a type shows a nonlinear dependence on displacement against voltage in scanning as shown below:



In the SPM controller, the distortion-compensation unit is installed so that nonlinear displacement can be removed.

Specify the parameters for compensation and the values for displacement range compensation in scanning. These corrections have been made in the factory before shipment.

- Scanner

  The Scanner Calibration window allows you to save up to six sets of parameters specified for a scanner calibration so that you can use multiple scanners. Choose the desired set of parameters by clicking on the desired number in the pull-down number list.

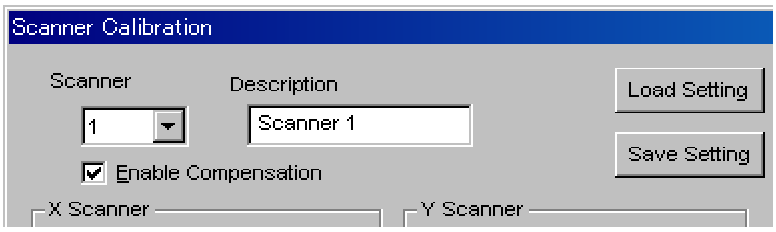
  ✍ When you change the present set of parameters, parameters such as the voltage for scanner driving will be changed. Be sure not to choose a wrong set of parameters.
- Description

  You can name six sets of parameters to distinguish them. When you change a set of parameters, the information in the bottom right of an application window will be changed, and the name given to the set of parameters will appear.
- Enable Compensation

  When this check box is checked, the distortion compensation to the XY scanner will function. However, even if this is not checked, calibration of the scanning range will work.
- Changing Compensation Parameter

  Only a user with administrator privilege can change the compensation parameter.

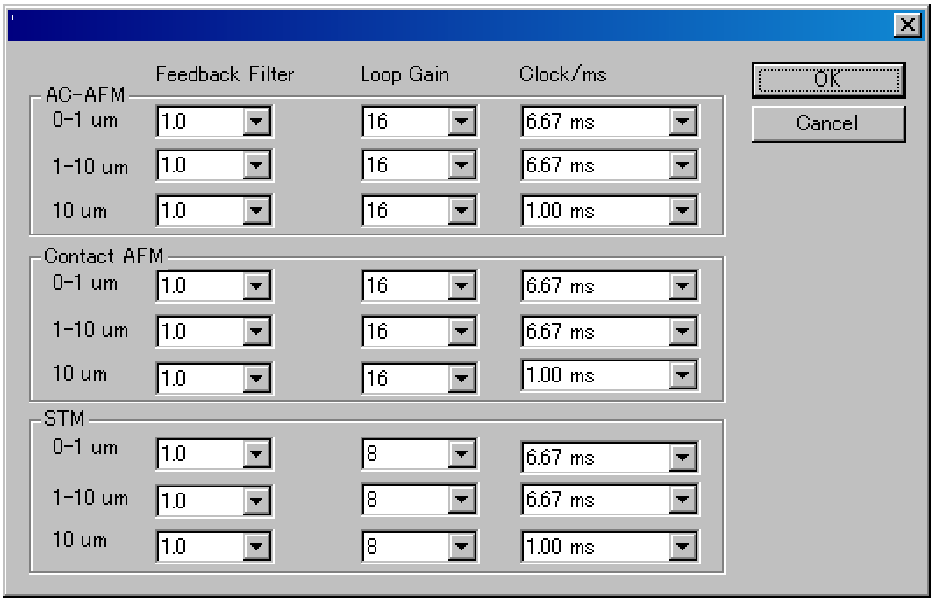
  A floppy disk, which has recorded the calibration data for each scanner, is attached to the instrument at its shipment from the factory. You can read the calibration data from the floppy disk by clicking on the Load Setting button.



■ Pre-scan Setting

Selecting Pre-scan Setting from the SPM Scan menu opens the Pre-Scan Setting window, in which you can specify parameters for pre-scan measurement. The pre-scan will be performed when you have checked the Enable Pre-Scan check box in the SPM Parameters window.

In pre-scan measurement, 32×32 points will be measured in the specified scanning area. Then the source signal gain and offset voltage will be calculated. If you perform pre-scan, since the amount of change in the source signal is calculated for the whole measurement area, you can obtain measurement images under optimum conditions.



You can specify independent values as pre-scan parameters to each AC-AFM, Contact AFM, and STM. You can select parameters from three kinds of parameters according to scan size.

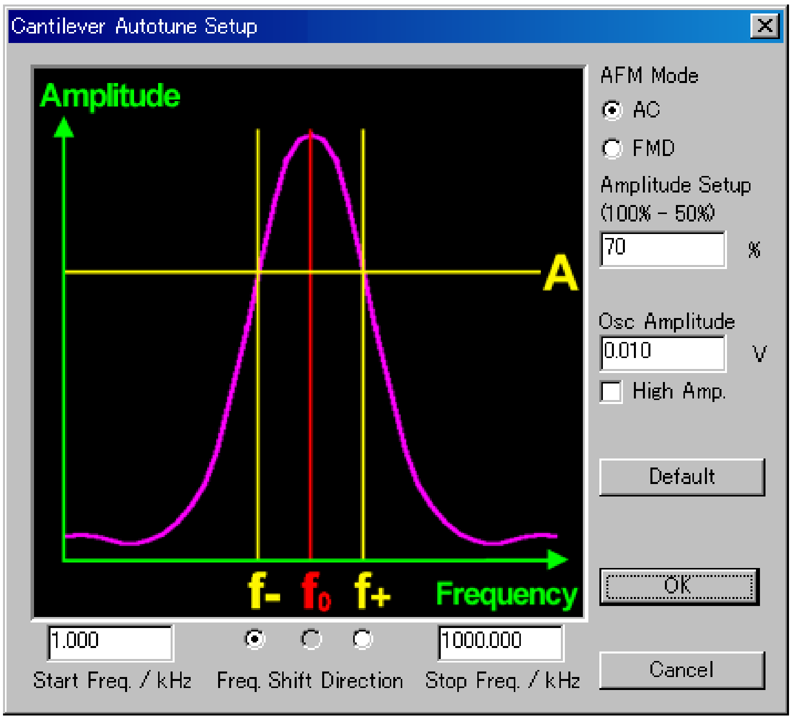
- Measurement data is not displayed on the screen during pre-scan.
- Select such parameters that slow scans can be performed to avoid contact between the tip and the specimen during pre-scan.

■ Cantilever Autotune Setup

This displays the Cantilever Autotune Setup dialog in which you carry out the basic settings for the automatic adjustment of the cantilever resonance point in the AC and AFM measurement modes.

● AC Mode Setting

When you select **AC** under the AFM Mode on the upper right of the dialog, AFM Mode changes to AC mode.



• Excitation Voltage

In the automatic adjustment sequence, the software scans the frequency to search for the resonance point of the cantilever, and sets the excitation voltage of the cantilever at the resonance point. If the amplitude signal (RMS signal) scales over the limit range, decrease the setting voltage.

• Amplitude Setup

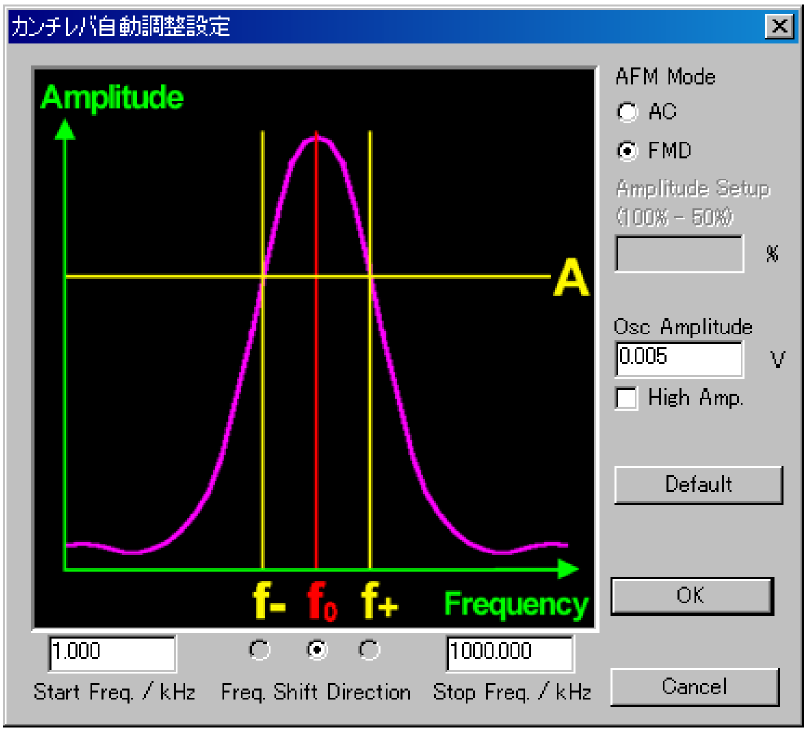
In the automatic adjustment sequence, after searching the resonance point of the cantilever, the software adjusts the RMS signal to about 8 V once, maintaining the resonance frequency.

Since the AC mode utilizes the tilt of the resonance wave of the cantilever (the amplitude decreased by the force that the cantilever receives), set the amount of decrease that shifts the frequency from the resonance until the amplitude decreases by some amount from the resonance amplitude. You can set a value from 100% to 50 %. If you set the value to 100 %, measurement is performed at the resonance frequency; if you set the value to 50 %, measurement is performed at a frequency shifted from the resonance until the amplitude is decreased to 50 % from that of the cantilever resonance.

- Frequency Shift Direction
  In the adjustment operations mentioned above, set the shift direction whether you shift the frequency to the lower frequency or higher frequency from the resonance frequency. The nature of the force that the cantilever receives changes depending on the frequency shift direction (repulsive force or attractive force).
- Start Frequency/Stop Frequency
  Set the start and stop values at kHz order in the frequency scan for detecting resonance.

● FMD Mode Setting

When you select **FMD** in the AFM Mode on the upper right of the dialog, AFM Mode changes to FMD mode.



- Excitation Voltage
  In the automatic adjustment sequence, the software scans the frequency to search for the resonance point of the cantilever, and sets the excitation voltage of the cantilever at the resonance point. If the amplitude signal (RMS signal) scales over the limit range, decrease the setting voltage.
- Start Frequency/Stop Frequency
  Set the start and stop values at kHz order in the frequency scan for detecting resonance.

● Standard Settings

The software returns the present setting values to the standard settings.

• Standard settings for AC mode

Oscillation voltage	0.01V
Oscillation Amplitude	70%
Frequency shift direction	Lower frequency
Start frequency	1 kHz
Stop frequency	1000 kHz (1 MHz)

• Standard settings for FMD mode

Oscillation voltage	0.005 V
Start frequency	1 kHz
Stop frequency	1000 kHz (1 MHz)

Selection of the AFM mode changes to AC.

■ Reset SPM

The SPM CONTROL unit is initialized by the signal from the software when the WinSPM software starts up. Therefore, the power of the SPM CONTROL unit must be turned on when the software starts up. You have to reset the SPM CONTROL unit using the software whenever you have switched off the SPM CONTROL unit to replace the scanner or the SPM head, then have switched it on again.

Reset the SPM CONTROL unit according to the following procedure:

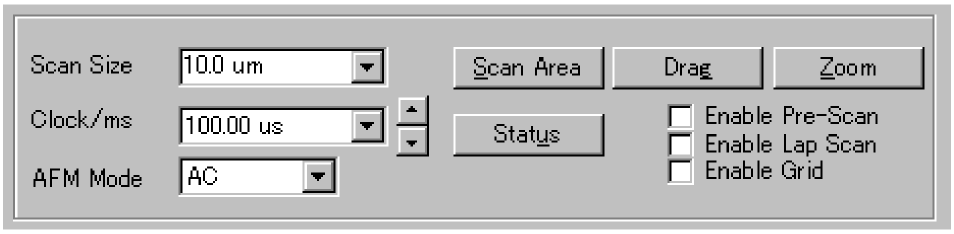
1. Click on the SPM Setup menu from the main menu and select Reset SPM from the pull-down menu.

   The Reset SPM window appears.

2. Confirm that the power supply of the SPM CONTROL unit is turned on, and select the OK button.

5.10.2 SPM Parameters (Simple)

■ Scan



● Scan Size

Specify the scanning area in this selection box. Two methods are provided:

◆ Click on the button in the selection box and select a scanning area from the pull-down menu showing some scanning areas.

◆ Enter a value in the selection box using the keyboard. Then, the nearest scanning area value is selected.

✍ The selected scanning area value is not always the same as the one entered because the value is rounded off.

The maximum scanning area depends on the scanner calibration value selected in the SPM Calibration••• window.

You can also enter the following units:
nm: 10^{-9} m
um: 10^{-6} m
For example, when you have entered 3.000 um, the scanning area is 3.0 μm. If you have not entered a unit, the previously displayed unit is applied.

✍ The value displayed in the Scan–Size selection box will differ a little from the value that you entered, because of torsion correction and voltage resolving power.

● Clock/ms

Specify scanning speed in this selection box, selecting the time per pixel. You can select a speed from 6.67 μs/point to 10.0 ms/point. You can change the scan speed during scanning.

• Scan speed and Scan time
Under the selected scanning speed, the relative speed between the tip and specimen, and the required time for scanning one image appear in the Scan speed and Scan time respectively.

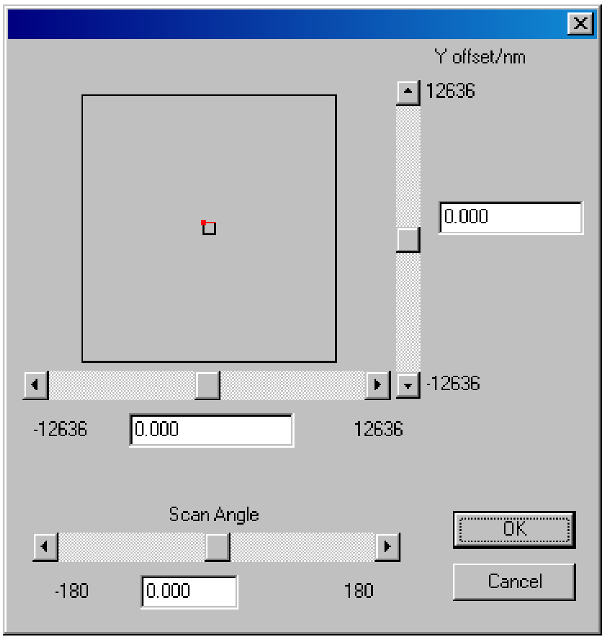
● AFM Mode

This appears only for AC and AFM modes. You use this for setting the feedback mode (AC or FM).

● Scan Area

The WinSPM software defines the center position of the total scan area of the scanner as the image-offset coordinate (0, 0). It also defines the scan angle in the range of ±180 degrees by setting 0 degrees as the origin.

Here you specify the image-offset coordinate and the scan-rotation angle, and display the current state of the image offset and the scan-rotation angle.



✍ This window shows the current scanning area.
The large square shows the total scan area of the scanner, and the inside square shows the current scanning area within the total scanning area. The shape and position of the inside square change according to the scan size, the amount of image shift and the scan rotation angle.

● Setting the Amount of Image Offset

There are 3 methods for setting the amount of image shift, as follows:

- Dragging

  Move the cursor to the current scanning area. The cursor will change to the **+** mark. Then, drag the cursor to the desired position.

  ✍ The scanner shifts in real-time with the movement of the cursor during dragging, so shift it slowly.

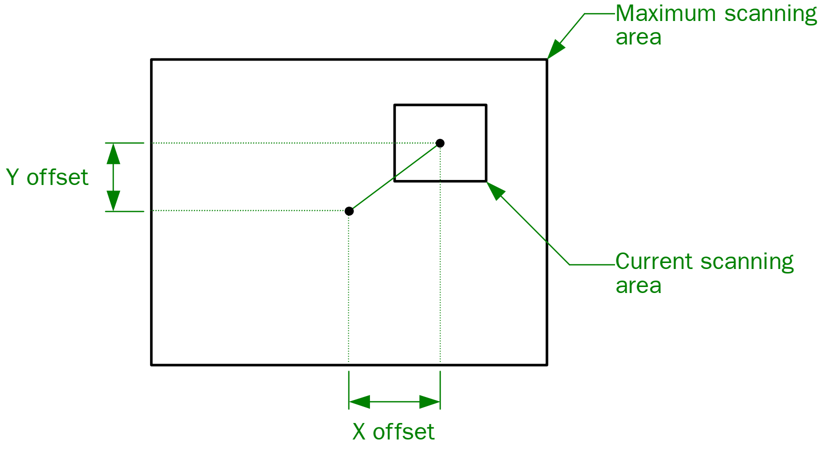
- Using the “Offset” input boxes

  Enter the offset values directly into the Offset input boxes using the keyboard.

  ✍ When performing scanning immediately after using the Scan Area, the image may sometimes become distorted due to hysteresis or creep of the scanner. In the case of creep, it may take several minutes until the image distortion disappears.

- Using the scroll bar

  Move the current scanning area by using the scroll bar. This method is useful for a tiny scanning area such as for observing an atomic image.



✍ The scanner shifts in real-time with the positional change of the scroll-bar, so shift it slowly.

● Setting the Scan Rotation Angle

Specify the scan-rotation angle by moving the scroll-bar at the Scan Angle or by inputting the rotation angle in the text box. You can specify the rotation angle from –180° to +180°.

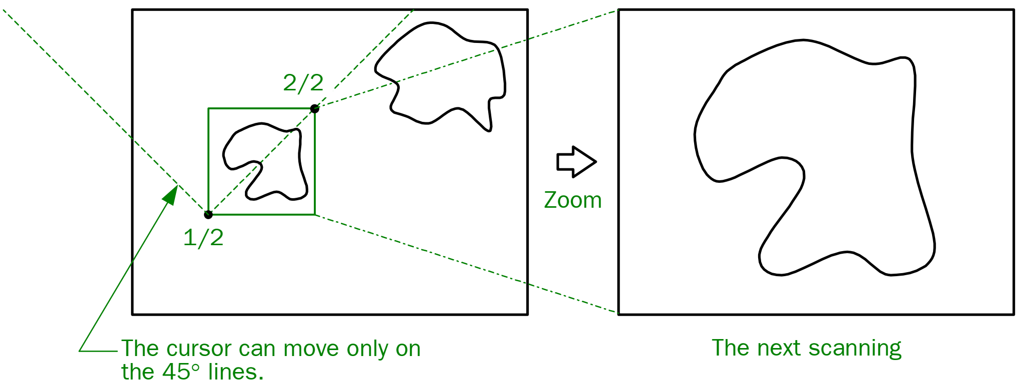
Even if you change the scan-rotation angle, any action involving scanner movement such as change of the scanner coordinate does not arise because only the scan direction changes at the start of the scan. However, when you start the scan after changing the scan-rotation angle, since the scanner moves to the different direction from the previous one, the image may sometimes become distorted due to creeping in the scanner for a short while after starting the scan.
✍ Usually use 0 degrees.

● Zoom

The area that you specify in the displayed image will be scanned as a new scanning area. This operation can change the scan size and scan area at the same time.

1. Click on the Zoom button; then move the cursor to the Display Window.
The cursor will change to the **+** mark.

2. Specify a new scanning area by moving the curser from one point to another diagonally as shown below.



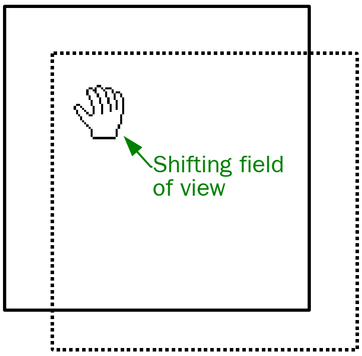
The new scanning area appears in the Size and Offset boxes.

✍ You cannot carry out this operation during scanning. Stop scanning by clicking on the Abort button; then specify a new scanning area.

- **Drag**

You can shift the center point of the scanning area in the image to measure. This operation is convenient when you wish to shift the field of view by a very small amount during measurement.

1. If you move the mouse curser in the Display Window while pressing and holding down the left mouse button, the center point of the scanning area will shift by exactly the distance through which you dragged the mouse curser. You can shift the field of view continuously by repeating this operation.
2. To end this operation, click on the right mouse button.



✍ The field of view shifts in real-time, so shift it slowly.

- **Enable Pre-Scan**

If you have checked the left side check box, pre-scan will be performed before scanning and the measurement-signal source gain and the offset value are adjusted automatically. Concerning how to set the scan for pre-scan, refer to Pre-scan Setting in the SPM Setting Menu.

- **Enable Lap Scan**

If you have checked the left side check box, unidirectional scan from top to bottom in ordinary mode will be changed to bi-directional scan from top to bottom in special mode.

- **Enable Grid**

If you have checked the left side check box, the four markers you can move will appear on the Display Window. The marker indicates the same coordinate point of each image when multiple images appear on the Display Window.

✍ You can drag the position of the marker using the mouse.

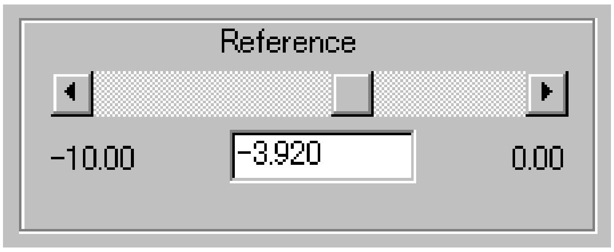
■ Reference

Set a target value (reference value) for the reference signal that is used in the feedback. The feedback circuit of the SPM controller operates around the set value for the reference signal, which differs depending on the measurement mode.

● At AC AFM mode

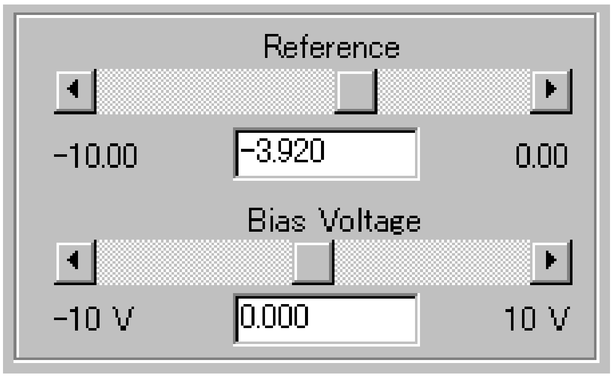
- AC-AFM/ Magnetic Force measurement / Viscoelasticity measurement tab windows

  The reference signal becomes the RMS signal in AC mode and the FMD signal in FM mode, respectively. Specify each signal voltage within the range of 0 to −10 V.



- Surface potential measurement tab window

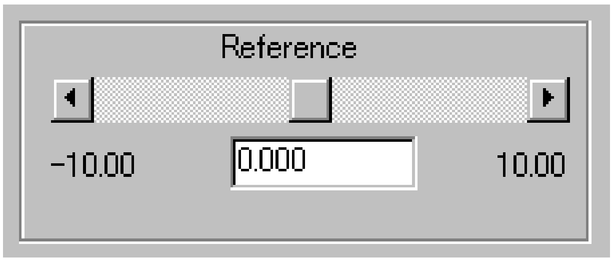
  In the surface potential measurement, both reference and bias voltage settings appear because the bias voltage control is required. You can specify the bias voltage up to ±10 V.



● At Contact AFM mode

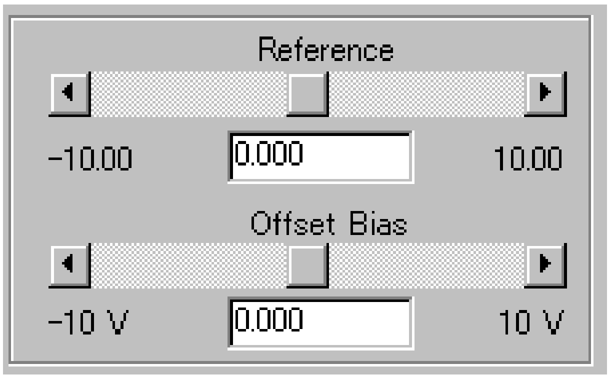
- Contact AFM/ Viscoelasticity measurement / Lateral-modulation measurement FFM measurement tab windows

  The reference signal is the Forth signal. Specify the reference voltage within the range of ±10 V.



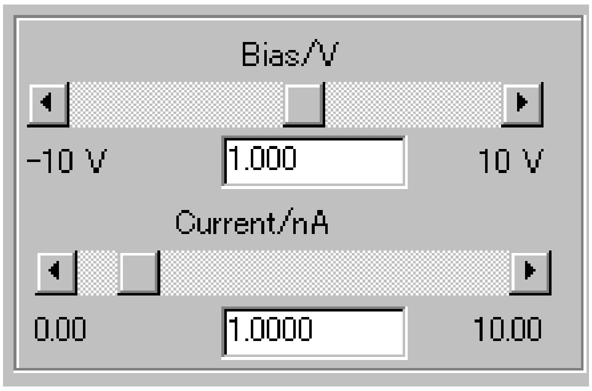
• Electrostatic force measurement tab window

In the electrostatic force measurement (EFM/SCFM), both reference and offset-bias voltage settings appear because offset-bias voltage control is required. You can specify the offset-bias voltage up to ±10 V.



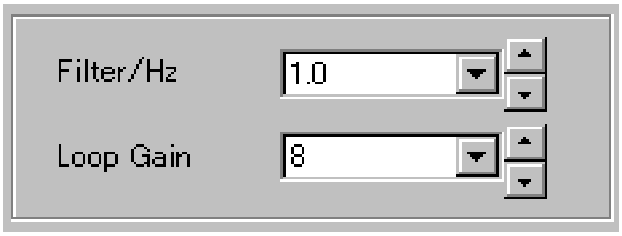
● STM mode

The reference signal is a Log Current signal. Set not only the reference signal but also the bias voltage. You can specify the bias voltage up to ±10 V. Although the setting range of the reference signal changes depending on the range of the preamplifier, it is normally 0 to 10 nA.



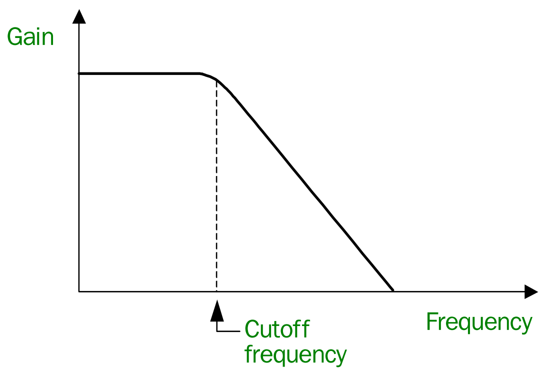
■ Filter/Loop Gain

Set a filter and gain amplifier for the feedback signal.



● Fback Filters/Hz

Specify the cutoff frequency of the feedback loop in this selection box. You can select from 16 frequencies between 0.01 Hz and 5 Hz. Response of the feedback loop becomes slower when a smaller frequency is selected, and vice versa. In ordinary topographical observation, select as high a frequency as possible. Too high a frequency causes the feedback circuit to be prone to oscillation. So set a frequency that is high but does not cause oscillation. In the cases of the current image and force image, on the other hand, select a lower frequency than that for topographical observation. The filter used in this system is a low-pass filter, and the cutoff frequency indicates the beginning frequency of gain decrease. Its characteristics are shown below:



The sensitivity decreases gradually as the frequency becomes higher than the cutoff frequency.

● Loop Gain

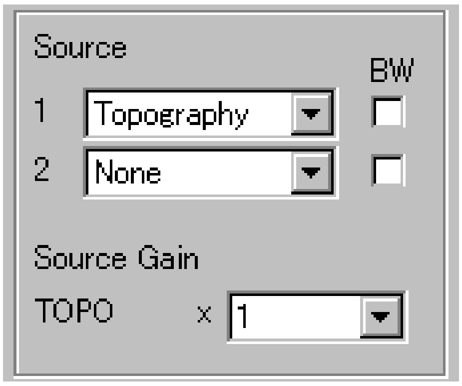
You specify the loop gain of the feedback circuit. The gain becomes higher as the number becomes larger. Usually, select a higher number (8 to 64) for the AFM mode, and select a lower number (4 to 32) for the STM mode. Loop Gain and Filter/Hz are closely related to each other. Even if the Loop Gain is small, a large Filter/Hz (faster response) causes the feedback circuit to be prone to oscillation. Even if the Loop Gain is large, a small Filter/Hz (slower response) causes the feedback circuit not to be prone to oscillation.

During image observation, select about 8 for the Loop Gain; adjust Filter/Hz; then select a one-step larger number for the Loop Gain if no oscillation occurs. When setting the Loop Gain to 1, make sure that the Z position is near zero volts. If the Z position is far from zero, the tip may collide with the specimen or go far away from the specimen surface, because the Z position can follow only within ±20 V to ±30 V when the Loop Gain is 1.

■ Display Source

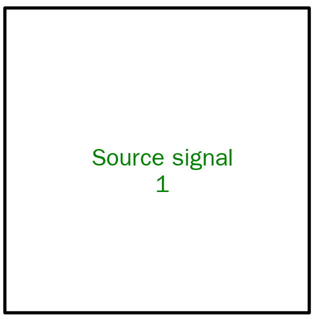
You select source signals and set their characteristic measurement conditions. Since these settings include the characteristic measurement conditions, the contents differ according to the tab window.

● AC–AFM tab window

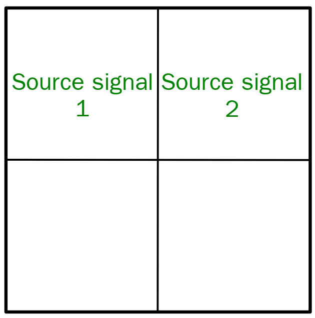


• Source 1, 2

Select the signal sources for images. The selection of signals also affects the number of source signals. You must select either Topography, RMS or Phase for source signal 1, and either Topography, RMS, Phase or None for source signal 2.
If source signal 2 is None, measurement is performed using only source signal 1. The image display during measurement appears as shown in the left hand figure below. The image size is 512×512 pixels, which corresponds to the 512×512 scan mode in the advanced control mode.
If the source signal 2 is other than None, measurement is performed using both source signal 1 and source signal 2. The image display during measurement is as shown in the right hand figure below. The image size is 512×512 pixels, which corresponds to the 2 Input (512) scan mode in the advanced control mode.



If Source signal 2 is None



If Source signal 2 is other than None

• BW

Usually, the source signal that is obtained by performing the forward scan (left-to-right scan) on the specimen is used to display the image. However, if you have checked the BW check box, the source signal will be obtained by performing the backward scan (right -to-left scan) on the specimen.
If you select Topography for Display Source 1 and 2 for measurement, for example, and you check the BW check box (backward scan) to a display source, and you do

not check it (forward scan) to the other display source, then you can obtain the forward scan image and the backward scan image at the same time.

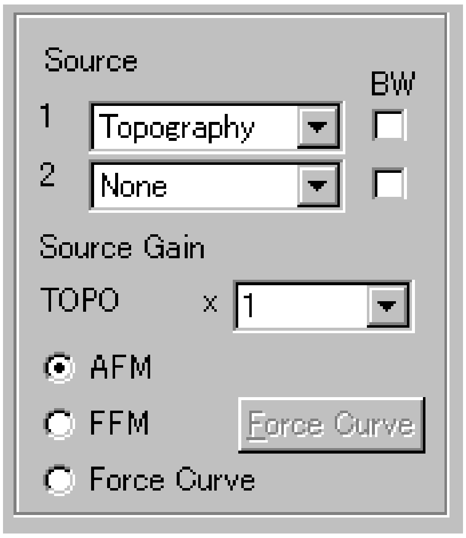
• Source Gain

Set the source-signal gain for the TOPO signal (shape signal) using it as a measurement signal. You can set 6 steps from 1 to 32 for the gain. You use them when you cannot obtain enough contrast in the measurement image such as an atomic image observation. If you set a high gain when you observe such specimens with a large region or with a very bumpy surface, the source signal might become saturated. Usually, observe under low gain and increase the gain when you cannot obtain enough contrast.

✍ The setting here does not affect feedback operations.

✍ If the Enable Pre-Scan check box is checked, the system will automatically obtain the optimum gain from the result of Pre-Scan.

● Contact AFM tab window



• Source 1, 2

Select the signal sources for images. The selection of signals also affects the number of source signals. You must select either Topography or Force for source signal 1, and either Topography, Force or None for source signal 2. The relation between source signals and the number of measurement images is the same as that in the AC-AFM tab window.

• BW

Same as that in the AC-AFM tab window.

• Source Gain

Same as that in the AC-AFM tab window.

• AFM

When you perform normal measurement, select this radio button. Measurement settings follow the current settings.

• FFM

When you perform viscoelasticity-image measurement, select this radio button. Set Topography for source signal 1, Friction Force for source signal 2, and the scan rotation angle to 90 degrees. Other measurement settings follow the current settings.

• Force Curve

Select this when you perform the Force Curve measurement.

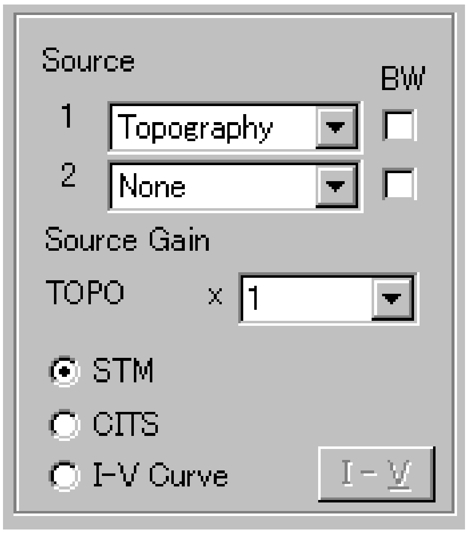
You can set the Z scanner shift distance for the Focus Curve measurement from the FC settings that can be operated when you select this radio button. Other measurement settings are similar to Focus Curve settings set from advanced operation mode, but the default values are as follows:

Clock:	Fast
Offset position:	0.0 nm
Lamp direction:	Out→In→Out
Source signal:	Force
Number of accumulation:	1
Measurement points:	128

• Force Curve setting button

This button opens the Focus Curve setting dialog that sets the shift distance when you perform Focus Curve measurement. This button is operable only when the Focus Curve radio button is selected.

● STM tab window



• Source 1, 2

You select the signal sources for images. Signal selection also affects the number of source signals. You must select either Topography, Linear Current or Log Current for source signal 1, and either Topography, Linear Current, Log Current or None for source signal 2. The relation between source signals and the number of measurement images is the same as that in the AC-AFM tab window.

• BW

The same as that in the AC-AFM tab window.

- Source Gain

  The same as that in the AC-AFM tab window.
- STM

  When you perform normal measurement, select this radio button. Measurement settings follow the current settings.
- CITS

  When you perform CITS (Current Imaging Tunneling Spectroscopy) measurement, select this radio button. This corresponds to performing I-V mapping measurement under the SPS Mapping scan mode in the advanced operation mode. The measurement pixels of this mapping are 128×128. The measurement images appear as follows:

Topo image	Current image	〃	〃
Current image	〃	〃	〃
〃	〃	〃	〃
〃	〃	〃	〃

  You can set the bias-voltage change-width of the I-V measurement from the I-V setting by selecting this radio button. In addition, the image measurement clock is employed for the measurement clock. Other measurement settings are similar to I-V settings that are set from the advanced operation mode, but there are some parameters that cannot be changed.

Lamp direction:	Automatic (unchangeable)
Source signal:	Linear current (unchangeable)
Preamplifier gain:	0.10 V/nA (unchangeable)
Number of accumulation:	1 (unchangeable)
Measurement points:	128 (unchangeable)

- I-V Curve

  Select this radio button when you perform the I-V Curve measurement.

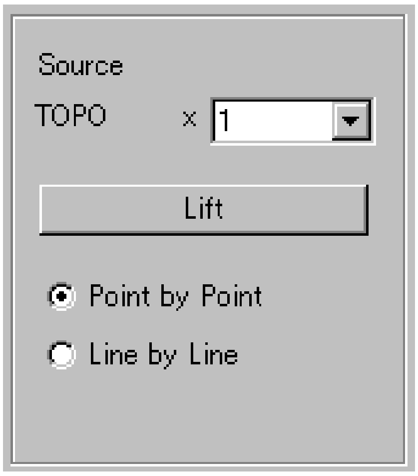
  You can set the bias-voltage change-width and the number of accumulation of the I-V measurement from the I-V setting by selecting this radio button. Other measurement settings are similar to the I-V Curve settings set from the advanced operation mode. The default values are as follows:

Clock:	Fast
Lamp direction:	Automatic
Source signal:	Linear current
Preamplifier gain:	0.10 V/nA
Number of accumulation:	1
Measurement points:	128

- I-V setting button

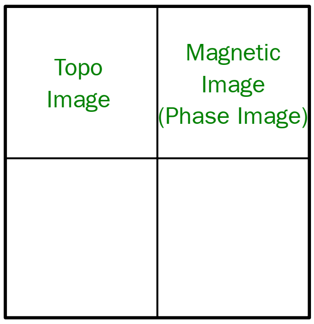
  This button opens the I-V Curve setting dialog that sets the bias-voltage change-width and number of accumulations when you perform I-V Curve measurement. This button is operable only when you select the I-V Curve radio button or the CITS radio button.

● Magnetic Force measurement tab window



- Source signal

  Since the source signal of the Magnetic Force measurement tab window is set for measuring the magnetic force, you need not set it. The measurement pixels are fixed at 256×256. When measurement starts, the images appear as follows:



✍ You can confirm the scan mode and source-signal settings at magnetic force measurement from the Magnetic Force measurement tab window by moving directly to the advanced setting tab window.

Scan mode:	4 Inputs (at P_Lift) or 2 Inputs (at L_Lift)
Measurement mode:	P_Lift or L_Lift
Source signal 1:	Phase
Source signal 2:	Topography
Source signal 3:	Topography
Source signal 4:	Phase

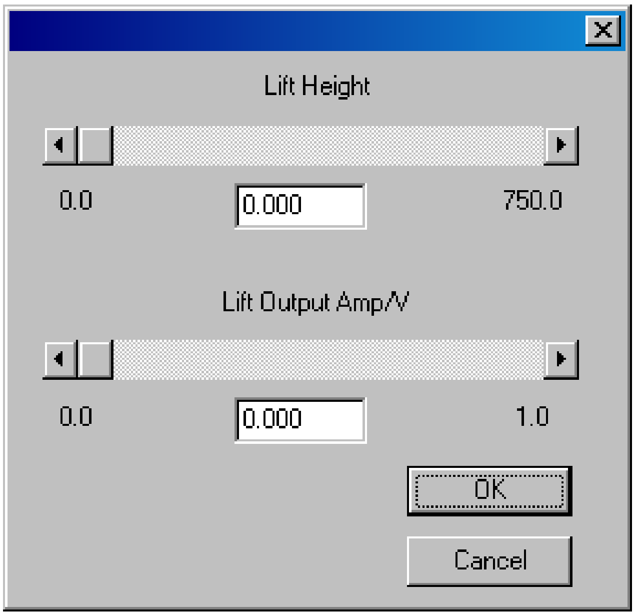
✍ While you use the Point by Point lift mode, the scan mode becomes 4 Inputs and the system displays the topographic image as the average of source signals 2 and 3, and the magnetic force image as the average of source signals 1 and 4.

• Source Gain

The same as that in the AC-AFM tab window.

• Lift setting button

This button opens the setting dialog that sets the amount of the Z scanner control at lift up and the cantilever-oscillation voltage at lift up.



• Lift Height

Set how much to move up (lift up) the tip during timing of the lift scan.

• Lift Output Amp/V

You can obtain a clear MFM image by changing the oscillation voltage to the cantilever while you lift it up. Here you set oscillation voltage to the cantilever (Output Voltage (V) in the Cantilever Adjustment window). This setting works only while you lift up the cantilever.

• Point by Point / Line by Line

This selects the Lift mode that is pivotal in Magnetic Force measurement. The WinSPM software supports 2 kinds of lift-up operations, as follows:

• Point by Point Lift mode

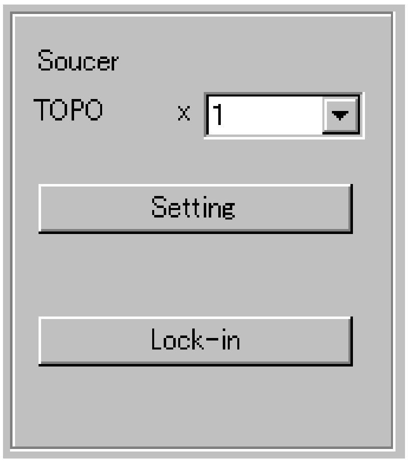
This lift mode performs lift-up operation for every measurement point. Since the up and down movements of the tip are performed too often, even the measurement of topography images in vacuum has the drawback that it is liable to become unstable.

• Line by Line Lift mode

This lift mode performs the lift-up operation for every scan line. Since the up and down movements of the tip are performed for every scan line, you can obtain the stable shape and magnetic force images.

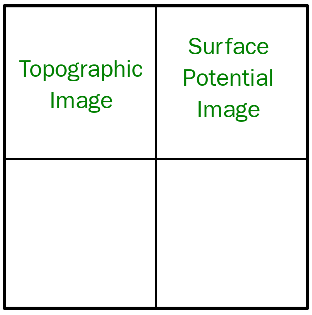
✍ You cannot use the Line by Line radio button if the Digital Control MFM unit is not installed or, even if it is installed, when you do not set it by using the Device Setup dialog.

● Surface Potential measurement (KFM) tab window



- Source signal

  Since the source signal of the Surface Potential measurement tab window is set for measuring surface potential, you need not set it. The measurement pixels are fixed at 256×256. When the measurement starts, the images appear as follows:



✍ You can confirm the scan mode and source-signal settings at surface potential measurement from the Surface Potential measurement (KFM) tab window by moving directly to the advanced setting tab window.

Scan mode:	2 Inputs
Measurement mode:	KFM
Source signal 1:	Topography
Source signal 2:	CPD (Aux3)

- Source Gain

  The same as that in the AC-AFM tab window.
- Setting button

  This button opens the KFM setting dialog that is used for measuring surface potential.
- KFM Feedback on

  If you check this check box, KFM feedback of the bias voltage starts. When KFM feedback starts, the CPD signal is output from the AFM amplifier, which enables KFM measurement.

• CPD Polarity Reverse

If you check this check box, the CPD signal from the AFM amplifier is output, reversing its polarity. Change the polarity depending on the situation that the bias voltage applies to the tip or specimen.

• Lock-in-AMP signal

Change the reference signal, which is necessary for feedback, to the Lock-in amplifier.

A–B/A+B:	Outputs the A–B/A+B signal to the Lock-in amplifier.
FMD:	Outputs the frequency detection (FMD) signal to the Lock-in amplifier.

• Filter/kHz

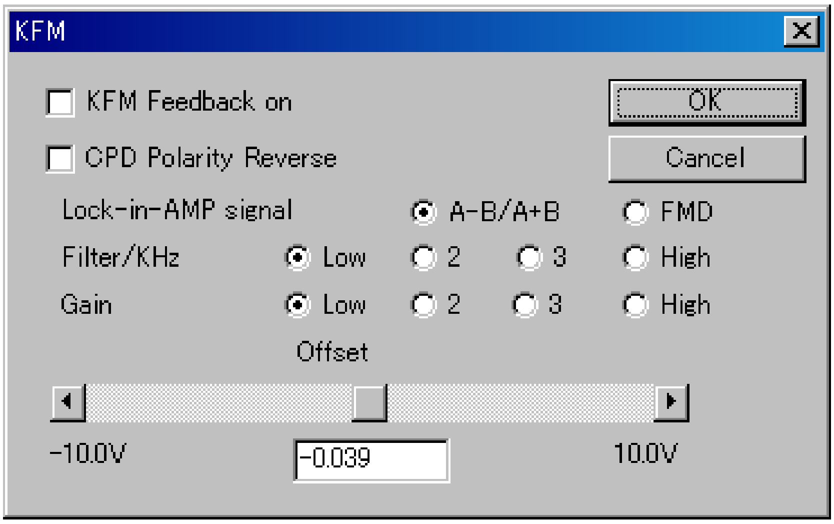
Set the feedback filter for the KFM feedback.

• Gain

Set the gain (loop gain) for the KFM feedback.

• Offset

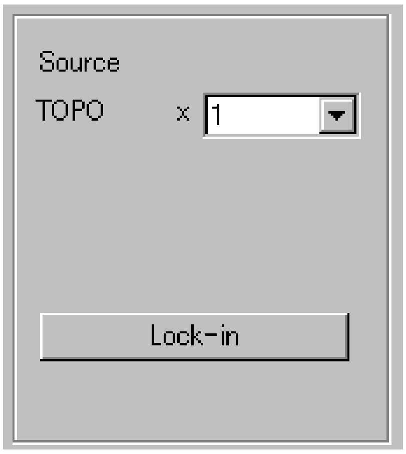
Set the DC offset voltage that is applied to the tip.



• Lock-in amplifier setting button

This button opens the Lock-in Amplifier Control window, which sets the extended lock-in amplifier that is necessary for measuring surface potential. Details on setting the lock-in amplifier will be provided later.

● Viscoelasticity measurement tab window



• Source signal

Since the source signal of the Viscoelasticity measurement tab window is set for measuring viscoelasticity, you need not set it. The measurement pixels are fixed at 256×256. When measurement starts, the images appear as follows:

Topography (Topo Image)	Acosϕ (Elasticity Image)
Asinϕ (Viscosity Image)	

✍ You can confirm the scan mode and source-signal settings at viscoelasticity measurement from the Viscoelasticity measurement (KFM) tab window by moving directly to the advanced setting tab window.

Scan mode:	4 Inputs
Measurement mode:	VE-AFM
Source signal 1:	Topography
Source signal 2:	LIA1 (Aux1)
Source signal 3:	LIA2 (Aux2)
Source signal 4:	Topography

✍ Although the scan mode is 4 Inputs during viscoelasticity measurement, the source signal 4 is ignored, and the system actually acquires 3 images simultaneously.

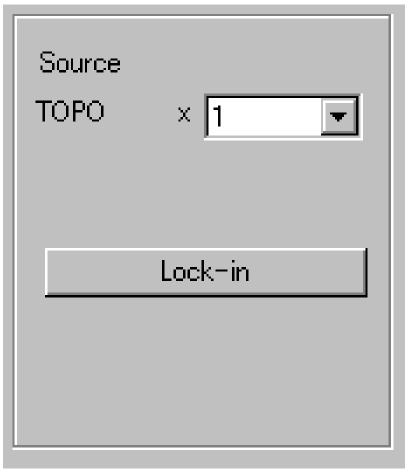
• Source Gain

The same as that in the AC-AFM tab window

• Lock-in amplifier setting button

This button opens the Lock-in Amplifier Control window, which sets the extended lock-in amplifier that is necessary for measuring viscoelasticity. Details on setting the lock-in amplifier will be provided later.

● Lateral-Modulation FFM measurement tab windows



- Source signal

  Since the source signal of the Lateral-Modulation FFM measurement tab window is set for measuring lateral-modulation FFM, you need not set it. The measurement pixels are fixed at 256×256. When measurement starts, the images appear as follows:

Topography (Topo Image)	Acosϕ
Asinϕ (Friction Image)	

  You can confirm the scan mode and source-signal settings at lateral-modulation FFM measurement from the Lateral-Modulation FFM measurement tab window by moving directly to the advanced setting tab window.

Scan mode:	4 Inputs
Measurement mode:	VE-AFM
Source signal 1:	Topography
Source signal 2:	LIA1 (Aux1)
Source signal 3:	LIA2 (Aux2)
Source signal 4:	Topography

  Although the scan mode is 4 Inputs during lateral-modulation FFM measurement, source signal 4 is ignored, and the system actually acquires 3 images simultaneously.

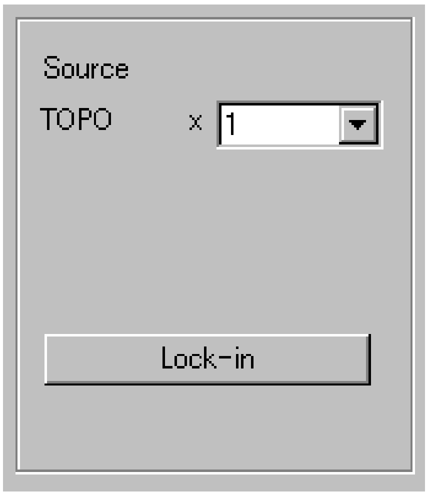
- Source Gain

  The same as that in the AC-AFM tab window.

- Lock-in amplifier setting button

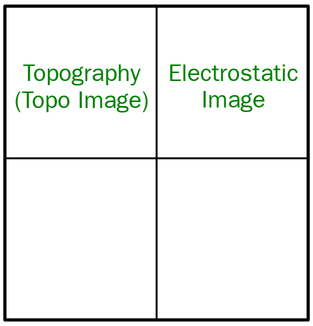
  This button opens the Lock-in Amplifier Control window, which sets the extended lock-in amplifier that is necessary for measuring lateral-modulation FFM. Details on setting the lock-in amplifier will be provided later.

● Electrostatic Force measurement tab window



• Source signal

Since the source signal of the Electrostatic Force measurement tab window is set for measuring electrostatic force, you need not set it. The measurement pixels are fixed at 256×256. When measurement starts, the images appear as follows:



✍ The source signal settings at the electrostatic force measurement are as follows:

Scan mode:	2 Inputs
Source signal 1:	Topography
Source signal 2:	LIA1 (Aux1)

• Source Gain

Same as that of the AC-AFM tab window

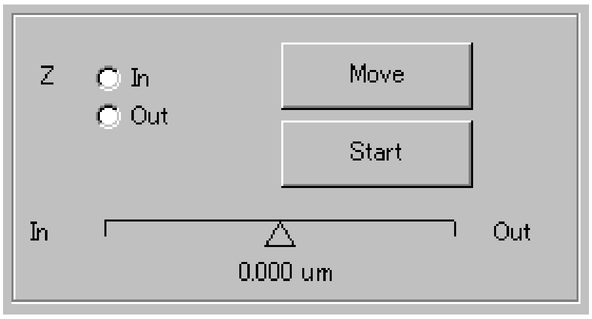
• Lock-in amplifier setting button

This button opens the Lock-in Amplifier Control window, which sets the extended lock-in amplifier that is necessary for measuring electrostatic force. Details on setting the lock-in amplifier will be provided later.

■ Z Stage control

This controls the Z stage axis. Use this if you need to adjust the Z stage-axis position manually when retracting the tip at the end of measurement.

✍ This operation, contrary to the approach movement, does not stop the stage automatically even when the tip approaches the specimen. When you bring the tip close to the specimen, move the stage carefully while watching the Z piezoelectric position indicator.



- Z direction

  Select a direction in which you want to move the Z stage.

  In : Approaches the tip to the specimen.

  Out: Separates the tip from the specimen.
- Move

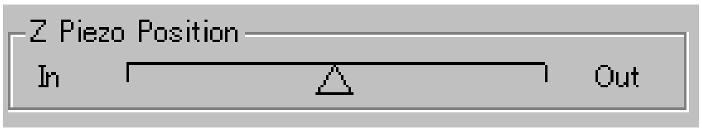
  The Z stage moves to the selected direction only while you are pressing the button.
- Start

  When you click on this button, the Z stage starts to move in the selected direction. During movement, the button changes to Stop; so if you click on the button again, the stage stops.
- Z stage indicator

  This displays the current Z stage position. Use this to confirm whether the Z stage position lies within the approachable range.

■ Z piezo position indicator (Z Piezo Position)

This displays the current Z piezo scanner position. This indicator is effective only while the scan stops. The In side shows the direction in which the piezo scanner stretches, and the Out side shows the direction in which the piezo scanner contracts. During the tip is retracted, this indicator shows the position of the tip at the end of the Out (right) side. When you cancel tip retraction, if this indicator moves to the end of the In (left) side, it shows that the approach has not been completed. On the contrary, when you cancel tip retraction, if this indicator does not move from the end of the Out side or extremely closes to the Out side, adjust the distance between the tip and specimen by moving the Z stage to the Out direction because the tip is too close to the specimen.

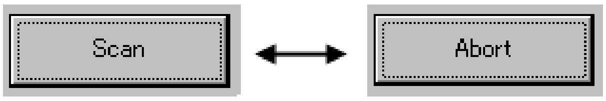


■ Operation buttons

These are operation buttons concerning SPM measurement. They change depending on the SPM mode or instrument model.

● Scan/Abort

Click on this button when you start measurement. When measurement starts, the indication on the button changes to Abort. When you click on the button again under this condition, measurement stops.

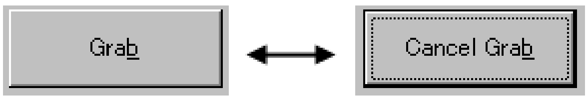


Indication while measurement stops **Indication while measurement is progressing**

✍ This button appears gray while the tip is retracted.
✍ If you stop measurement using this button, be careful that measurement data is not recorded.

● Grab/Cancel Grab

If you click on this button after starting measurement, the current measurement data is recorded after completing the measurement (reserved recording state). In the reserved recording state, the indication on the button changes to Cancel Grab. When you click again under this state, the reserved recording is canceled (canceled reserved recording state). In the canceled reserved recording state, the measurement continues to repeat unless you stop the measurement.



Indication at canceled reserved recording state **Indication at reserved recording state**

✍ This button appears gray while the measurement is not started.
✍ This button also remains gray if the Auto record is not checked.

● Auto Grab

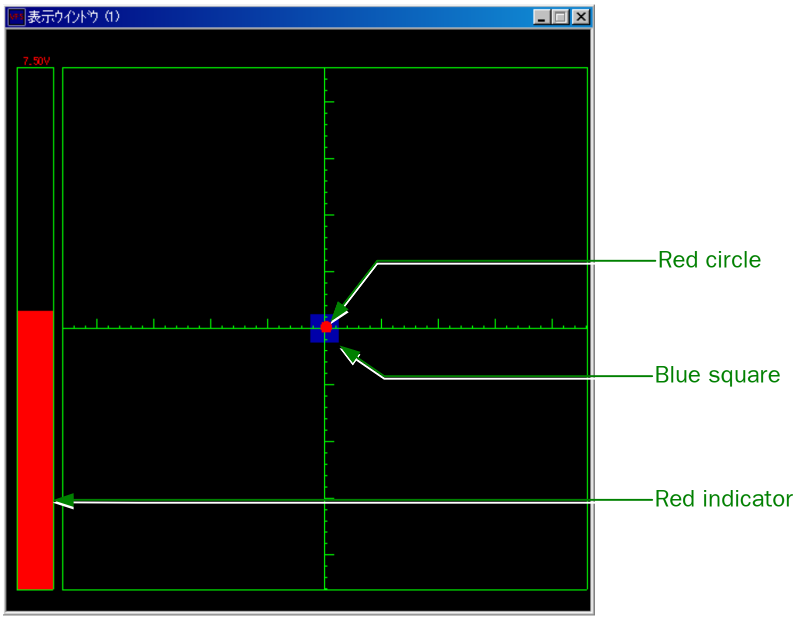
While this checkbox is checked, the measurement data is recorded without fail after measurement (always measure under the reserved recording state). Since it takes a fairly long time to acquire one image in the JSPM−5200/JSPM−5700, you can prevent yourself from forgetting to record the measurement data when you carry out measurement with this check box checked.

When you want to measure continuously, as when searching the optimal values of the measurement parameters or waiting until the creep and thermal drift ceases in the scanner, carry out the measurement leaving this check box unchecked.

✍ You cannot change the checkbox during measurement.

● Adjust PD (used other than STM mode)

Clicking on the Adjust PD button displays the position of the photodiode (PD) position indicator used in the PD position adjustment when you carry out the axis adjustment of the cantilever.



The red indicator on the left side of the Display Window shows the SUM value (the intensity of the incident laser beam onto the photodiode). Adjust the laser beam incident position on the cantilever and the photodiode position so that you can obtain a high enough value.

The red circle is the position that the laser beam is irradiating. Adjust the position of the photodiode so that this red circle coincides with the square part (target position for the PD adjustment) displayed in blue. Be careful that the target positions for the PD adjustment are different from each other between the AC AFM mode and Contact AFM mode.

● Tuning (used only for AC AFM)

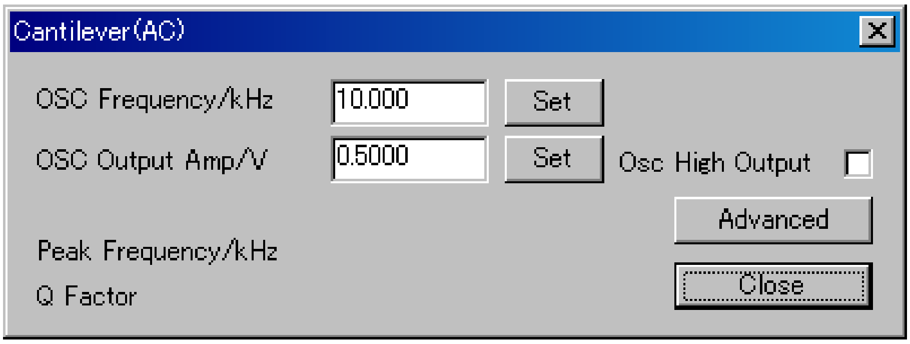
This starts the cantilever-position adjustment sequence. The kind of sequence differs depending on the AFM mode setting (AC/FM) in the operation parameters.

● Cantilever (used only for AC AFM)

This displays the Cantilever setting dialog in which you set the oscillation condition for the cantilever. The content of the displayed dialog differs depending on the AFM mode setting (AC/FM) in the operation parameters.

- When AFM mode is AC

  This opens the Cantilever (AC) dialog in which you set the oscillation signal in the cantilever.



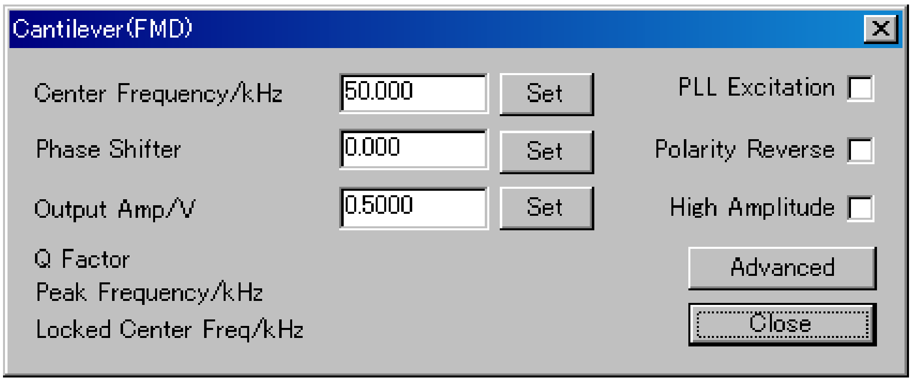
- OSC Frequency/kHz
  Enter an oscillation frequency. The settable frequency range is 1 to 1000 kHz. The oscillation waveform is a sine wave.
- OSC Output Amp/V
  Enter a voltage to apply to the piezoelectric oscillator. The settable voltage range changes according to the OSC High Output setting.
- OSC High Output
  Check this box when you need a large voltage to oscillate the cantilever, as when you observe the specimen in a liquid or when you use a cantilever that is hard to oscillate. Output voltage range changes as follows:
  ☐ OSC High Output···0 to 1.0 V
  ☑ OSC High Output···0 to 10 V
- Q Factor/Peak Frequency/kHz
  The software carries out the frequency scan, detects the resonance frequency (peak frequency) and Q factor, and displays their values.
- Advanced
  Click this button when you must set the resonance frequency of the cantilever manually, and open the Cantilever adjustment dialog that enables you to perform more detailed settings.

✍ For detailed operations, refer to the reference for the Cantilever adjustment button in the Advanced operation mode.

✍ Close
Clicking this button closes the dialog.

- When AFM mode is FM

  This opens the Cantilever (FMD) dialog. The frequency detection in the FM mode is performed by means of the frequency detection circuit using the Phase Locked Loop (PLL) in the AFM AMP. Set here the parameters for this frequency detection:



- Center Frequency/kHz

  Enter a center frequency to perform frequency detection. The frequency detection circuit detects a frequency shift based on the frequency that is set here. Usually, enter here the resonance frequency (peak frequency) of the cantilever.

- PLL Excitation

  This sets the oscillation method of the cantilever when performing FM detection. Check PLL Excitation and perform measurement if the scan speed is high or the specimen surface is uneven.

  Normal oscillation utilizes the self-oscillation of the cantilever. However, since the amplitude of this self-oscillation is minute, re-oscillation becomes difficult if the oscillation stops due to contact of the cantilever with the specimen's surface during the scan.

  When you check PLL Excitation, the oscillation excitation of the cantilever changes from self-oscillation to the external-oscillation using the oscillator installed on the PLL (Phase Locked Loop) circuit. This makes re-oscillation of the cantilever easy due to excitation from the PLL oscillator, even if oscillation stops when the cantilever contacts with the specimen surface. As the PLL tries to maintain the frequency and phase to the set values, the principle involved does not change compared with that of usual self-oscillation.

  Once you have completed FM detection adjustment, when you change the settings, you must retry FM detection adjustment, because the oscillation conditions of the cantilever may change.

- Phase Shifter

  This controls the Phase Shifter. You can enter a phase in the range of ±130°. For the Phase Shifter, set the RMS signal (amplitude of the cantilever) so that it attains a maximum when you set the oscillation frequency to the cantilever resonance frequency.

- Polarity Reverse

  Usually, the Phase Shifter circuit cannot rotate the phase through 360° linearly by its characteristics, but causes a discontinuous point anywhere in the control. The Phase Shifter installed on the AFM amplifier solves this problem. If you check this box, the polarity of phase detection reverses, making the phase that Phase Shifter controls rotate 180° from the present value. This processing is performed by the hardware without changing the set phase-rotation value on the software.

- Output Amp/V

  Enter the voltage amplitude for the oscillation signal to the cantilever. The oscillation voltage in the FM mode becomes very small compared with that in the AC mode.
- High Amplitude

  This is the same as the High Amplitude in the Cantilever (AC) dialog.
- Q Factor/Peak Frequency/kHz

  The software carries out the frequency scan, detects the resonance frequency (peak frequency) and Q factor, and displays their values.
- Advanced

  Click this button when you must set the resonance frequency of the cantilever manually, and open the Cantilever adjustment dialog that enables you to perform more detailed settings.

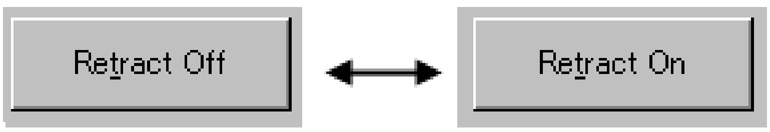
  ☞ For detailed operations, refer to Section 5.10.3 "■ Cantilever ."
- Close

  Clicking this button closes the dialog.

● Retract Off/Retract On

This retracts the tip and cancels the tip retraction.
When the button reads Retract Off, the Z piezoelectric device is in the most contracted state by force (tip retracted state). If you click on the button under this state, the tip retraction is canceled and the indication on the button changes to Retract On. The tip-retracted state is used when you temporarily separate the tip from the specimen (when you change the image field or move stage).

When the button reads Retract On, the tip is in the position that follows feedback control along the surface topography (tip retracted canceled state). If you click on the button in this state, tip retraction is performed and the indication on the button changes to Retract Off. Approach and measurement actions are performed only when the button reads Retracted Off.



Tip retracted state **Tip retracted canceled state**

● Approach On

This starts the approach action. The approach is performed based on the parameters (reference, filter and loop gain) set on the current dialog.

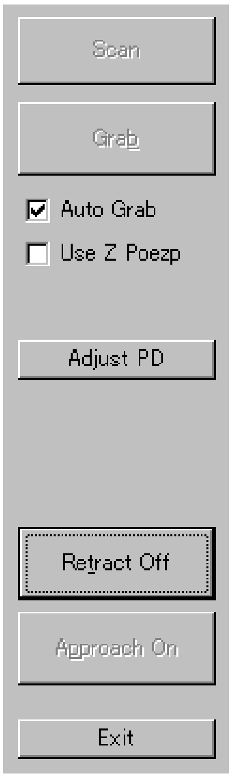
☞ For detailed approach action, refer to Section 5.10.3 "■ Tip."

● Exit

Clicking this button closes the SPM Parameter window.

● List of related operation buttons

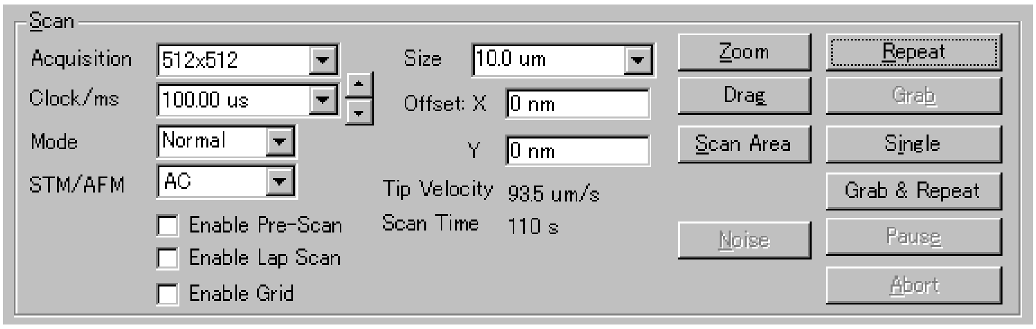
These are the list of related operation buttons that appear on the SPM Parameter window when you open it, just after starting up WinSPM. There are some buttons that do not appear, depending on the SPM instrument or SPM mode.



5.10.3 SPM Parameters (Advanced)

In this section, the Advanced Control window that appears when you select the General Advanced Control measurement mode is explained as an example. There are functions that some Advanced Control tab windows appear in gray or do not appears except in the General Advanced Control measurement mode. These functions cannot be utilized in the selected measurement mode, or they can be used only for other SPM instruments.

■ Scan



● Size

Specify the scanning area in this selection box. Two methods are provided:

◆ Click on the ▼ button in the selection box and select a scanning area from the pull-down menu showing some scanning areas.

◆ Enter a value in the selection box using the keyboard. Then, the nearest scanning area value is selected.

✍ The selected scanning area value is not always the same as the one entered because the value is rounded.
The maximum scanning area depends on the scanner calibration value selected in the SPM Calibration··· window.

✍ You can also enter the following units:
nm: 10^{-9} m
um: 10^{-6} m
For example, when you have entered 3.000 um, the scanning area is 3.0 μm. If you have not entered a unit, the previously displayed unit is applied.
The value displayed in the Scan–Size selection box will differ a little from the value that you entered, because of torsion correction and voltage resolving power.

● Offset

The WinSPM software defines the center position of the total scan area of the scanner as the image-offset coordinates (0, 0). Here the image-offset coordinates in X and Y directions appear.

When you change the setting coordinates, you can move the scan-center position to the specified image-offset coordinates. This operation is the same as the function in the Scan Area setting.

● Clock/ms

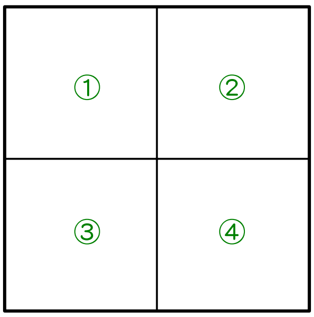
Specify scanning speed in this selection box selecting the time per pixel. You can set speed from 5 μs/point to 200 s/point. Usually you can select a clock from only some of clocks. You can change scan speed during scanning.

- Changing the clock list
  In the pull-down menu, only some of the clock speeds that can be set appear. To display all the clock speeds, select the Long List at the bottom of the menu. To return to the original menu, select the Short List at the bottom of the menu when all the clock speeds appear.
- Scan speed and Scan time
  Under the selected scanning speed, the relative speed between the tip and specimen, and the required time for scanning one image appear in Scan speed and Scan time, respectively.

● Acquisition

Specify the scanning method in this selection box.

- 1024×1024
  Scanning is performed using 1024×1024 pixels. With compression to 512×512 pixels, one image appears in the Display Window. When one image's scanning completes, the currently displayed image is replaced with the new image.
- 512×512
  Scanning is performed using 512×512 pixels. One image appears in the Display Window. When one image's scanning completes, the currently displayed image is replaced with the new image.
- 256×256
  Scanning is performed using 256×256 pixels. Four images are displayed in the Display Window as shown in the figure below in the order of ①→②→③→④.



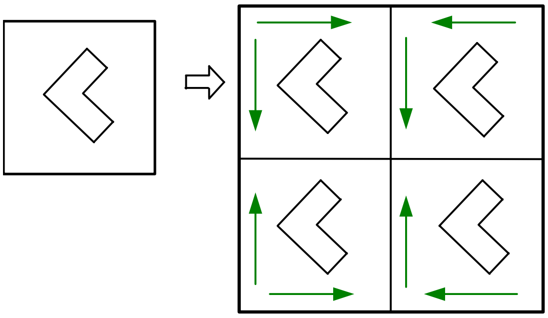
After four images are displayed in the Display Window, the displayed images are updated with subsequent scanning in the order of ①→②→③→④→①→②⋯.

- 128×128
  Scanning is performed using 128×128 pixels. Sixteen images are displayed in the Display Window as shown in the figure below in the order of ①→②→③⋯⑮→⑯.

①	②	③	④
⑤	⑥	⑦	⑧
⑨	⑩	⑪	⑫
⑬	⑭	⑮	⑯

After sixteen images are displayed in the Display Window, the displayed images are updated with subsequent scanning in the order of ①→②→③···⑮→⑯→①→② →③→.

• Mirror
Scanning is performed using 256×256 pixels. One image appears for left-to-right movement, and a separate image appears for right-to-left movement. Scan starts with the top line and proceeds to the bottom line. When the resulting scan is complete, a new scan begins with the bottom line and proceeds to the top line.



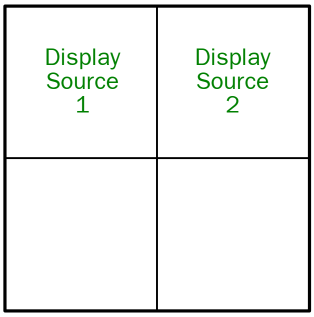
When Mirror is selected, the bias voltage automatically changes between left-to-right movement and right-to-left movement.

In the case of images displayed on the left side in the Display Window, the bias voltage specified in Bias is applied. In the case of the images displayed on the right side, the bias voltage specified in Back Scan is applied.

If the same voltage is specified for Bias and Back Scan, you can check each scanning hysteresis and tip shape for left-to-right movement and for right-to-left movement.

If a different voltage is specified for Bias and Back Scan in the STM mode, you can observe STM images with two different bias voltages by one scanning.

• 2 Inputs (512)
Two different kinds of data are acquired and displayed simultaneously. Scanning is performed to acquire one image in 512×512 pixels. With compression to 256×256 pixels, the image appears during scanning. Specify source signals in the 1 and 2 boxes of the Display Source. Two images are displayed in the following order in the Display Window.



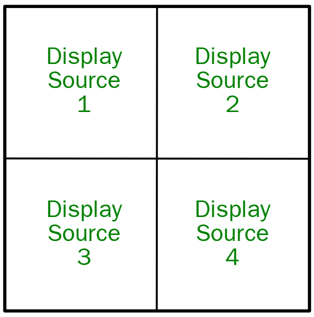
When the images are grabbed using this mode, they are separately grabbed as different images.

• 2 Inputs

The function of this 2 Inputs is the same as that of 2 Inputs (512), except for having 256×256 pixels.

• 4 Inputs

Four different kinds of data are acquired and displayed simultaneously. Scanning is performed to acquire one image using 256×256 pixels. Specify source signals 1 to 4 boxes of the Display Source. Four images are displayed in the following order in the Display Window.



When images are grabbed using this mode, they are separately grabbed as different images.

• Line Scan 128, Line Scan 256, Line Scan 512 and Line Scan 1024

In these modes, you can acquire data only by using the X-direction scanning and stopping the Y-direction scanning to display data in the Display Window. These modes are useful for dynamic observation of time-varying phenomena on the specimen surface such as step edge swaying.

Specify the Y (line) position on which the data is acquired by using the Position button in the Tip window. Scanning is performed only on this line in the X direction.

• Montage

In this mode, divide a specified observation area on a specimen surface into many small scanning areas to obtain images; then compose a montage image. Specify parameters such as observation range for montage in the Montage window. After setting montage parameters and selecting Montage in the Acquisition selection box, click on the Repeat button. Then, scanning starts and a montage image can be grabbed.

- Single SPS

  You can perform various kinds of SPS (Scanning Probe Spectroscopy) measurement. Specify the kind of SPS measurement to perform and the parameters for the measurement using the SPM Parameters window.
- SPS Mapping

  You can perform SPS Mapping measurement. The specified SPS measurement is performed at every pixel in one frame (Topography) scan. Specify the kind of SPS measurement to perform and the parameters for the measurement using the SPM Parameters window. The number of pixels is 128×128 in the SPS Mapping scan mode.

  If you specify I-V for SPS measurement, the CITS (Current Imaging Tunneling Spectroscopy) scan will be performed. The images displayed during scanning are as follows:

Topo image	Current image	〃	〃
Current image	〃	〃	〃
〃	〃	〃	〃
〃	〃	〃	〃

● STM/AFM

Specify the scanning mode. Strictly speaking, specify the kind of signal to use for Z-direction feedback in this selection box.

- STM

  This is the STM mode. The logarithmic value of the tunneling current is used for the feedback signal.
- Contact

  This is the Contact mode in the AFM mode. The Force signal is used for feedback.
- AC

  This is the AC mode in the AFM mode. The RMS (Root-Mean-Square) of the frequency-amplitude signal of the cantilever oscillation is used for feedback.
- FM

  This is the AC mode in the AFM mode. The frequency signal (FMD signal) of the cantilever oscillation is used for feedback.
- Phase

  This is the AC mode in the AFM mode. The Phase signal of the cantilever oscillation is used for feedback.

● Mode

You can use the following modes when optional attachments are installed to perform Viscoelasticity measurement (VE-AFM), Lateral-Modulation measurement (LM-FFM), Surface Potential measurement (KFM) and Magnetic Force measurement (MFM; P-Lift, L-Lift). However, you need the optional Viscoelasticity Lateral-Modulation FFM attachment (Lock-in Amplifier) for using VE-AFM, LM-FFM and KFM. You also need the optional Digital Controlled MFM Unit for using L-Lift.

- Normal

  Select this mode when you perform ordinary measurement (surface shape measurement).
- VE-AFM

  Select this mode when you perform Viscoelasticity measurement, which is possible in the AC AFM and Contact AFM modes.
- LM-FFM

  Select this mode when you perform Lateral-Modulation FFM measurement, which is possible in the Contact AFM mode.
- KFM

  Select this mode when you perform Surface Potential measurement, which is possible in the AC AFM mode.

  When you actually perform Surface Potential measurement, there are other parameters you need to set.

  ☞ For more detail, refer to Section 5.10.3 "■ KFM."
- P-Lift

  Select this mode when you perform observations such as Magnetic Force measurement using the Point-by-Point Lift mode. Magnetic Force measurement is possible in AC AFM mode.

  When you actually perform the Magnetic Force measurement, there are other parameters you need to set.

  ☞ For more detail, refer to Section 5.10.3 "■ Lift."
- L-Lift

  Select this mode when you perform observations such as Magnetic Force measurement using the Line-by-Line Lift mode. Magnetic Force measurement is possible in AC AFM mode.

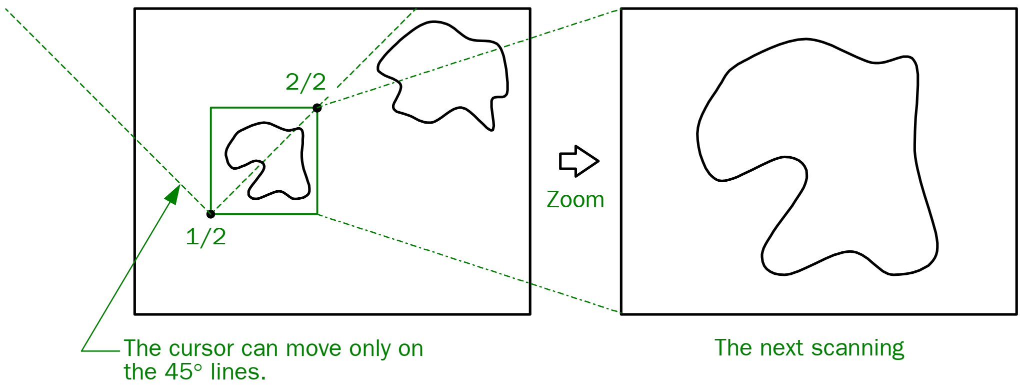
  When you actually perform Magnetic Force measurement, there are other parameters you need to set.

  ☞ For more detail, refer to Section 5.10.3 "■ Lift."

● Zoom

The area that you specify in the displayed image will be scanned as a new scanning area. This operation can change the scan size and scan area at the same time.

1. Click on the Zoom button; then move the cursor to the Display Window.
   The cursor will change to the **+** mark.
2. Specify a new scanning area by moving the curser from one point to another diagonally, as shown below.



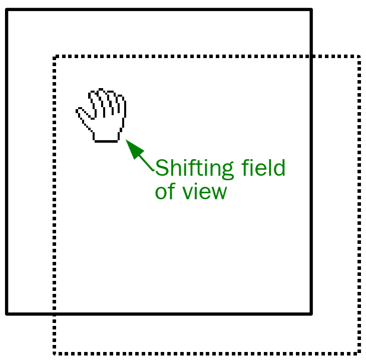
The new scanning area appears in the Size and Offset boxes.

✍ You cannot carry out this operation during scanning. Stop scanning by clicking on the Abort button; then specify a new scanning area.

● Drag

You can shift the center point of the scanning area in the image to measure. This operation is convenient when you wish to shift the field of view by a very small amount during measurement.

1. If you move the mouse curser in the Display Window while pressing and holding down the left mouse button, the center point of the scanning area will shift by exactly the distance through which you dragged the mouse curser. You can shift the field of view continuously by repeating this operation.
2. To end this operation, click on the right mouse button.

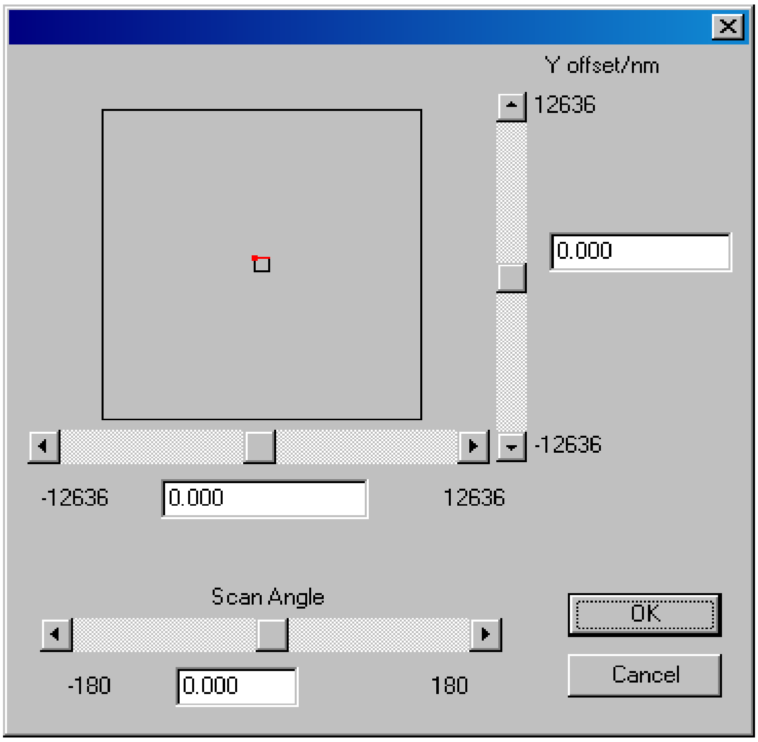


✍ The field of view shifts in real-time, so shift it slowly.

● Scan Area

WinSPM software defines the center position of the total scan area of the scanner as the image-offset coordinate (0, 0). It also defines the scan angle with ±180 degrees by setting 0 degrees as the origin.

Here you specify the image-offset coordinate and the scan-rotation angle, and display the current state of the image offset and the scan-rotation angle.



✍ In this window, the current scanning area appears.
The large square shows the total scan area of the scanner, and the inside square shows the current scanning area in the total scanning area. The shape and position of the inside square change according to the scan size, the amount of image shift and the scan rotation angle.

- Setting the Amount of Image Offset

  There are 3 methods for setting the amount of image shift, as follows:
- Dragging

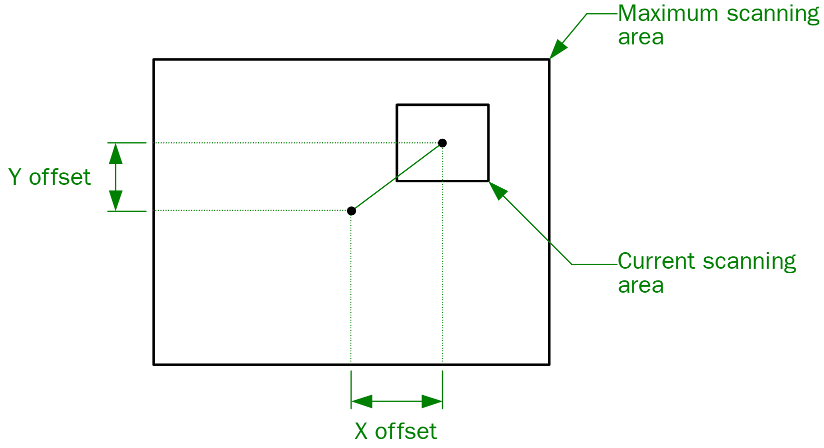
  Move the cursor to the current scanning area. The cursor will change to the **+** mark. Then, drag the cursor to the desired position.

  ✍ The scanner shifts in real-time with the movement of the cursor during dragging, so shift it slowly.
- Using the Offset input boxes

  Enter the offset values directly into the Offset input boxes using the keyboard.

  ✍ When performing scanning immediately after using the Scan Area, the image may sometimes become distorted due to hysteresis or creep on the scanner. In the case of creep, it may take several minutes until image distortion disappears.

• Using the scroll bar
Move the current scanning area by using the scroll bar. This method is useful for a tiny scanning area such as for observing an atomic image.



✍ The scanner shifts in real-time with the positional change of the scroll-bar, so shift it slowly.

• Setting the Scan Rotation Angle
Specify the scan-rotation angle by moving the scroll-bar on the Scan Angle or by inputting the rotation angle in the text box. You can specify a rotation angle from –180° to +180°.

Even if you change the scan-rotation angle, any action involving scanner movement such as change of the scanner coordinate does not arise because only the scan direction changes at the start of the scan. However, when you start the scan after changing the scan-rotation angle, since the scanner moves to the different direction from the previous one, the image may sometimes become distorted due to creep of the scanner for a short while after starting the scan.
✍ Usually, use 0 degrees.

● Enable Pre-Scan

If you check the left side check box, a pre-scan will be performed before scanning. The measurement-signal source gain and the offset value will be adjusted automatically. Concerning how to set scan for pre-scan, refer to Pre-scan Setting in the SPM Setting Menu.

● Enable Lap Scan

If you check the left side check box, the unidirectional scan mode from top to bottom will be changed to the bi-directional scan mode from top to bottom.

● Enable Grid

If you check the left side check box, the four markers that you can move will appear on the Display Window. The marker indicates the same coordinate point of each image when multiple images appear on the Display Window.
You can drag the position of the marker using the mouse.

- **Repeat**

Clicking on this button starts scanning in the mode specified in Acquisition. Scanning repeats continuously.
If you want to store the image, click on the Grab button during scanning. Then the data that is being scanned will be stored in the computer memory.
✍ Usually use Repeat for observing images.
✍ When you perform SPS measurement involving movement of the Z scanner such as FC measurement, set the number of scans once, using Single instead of Repeat, to prevent repeated collisions between the tip and the specimen.

- **Grab**

When you click on this button during scanning, Grab Frame appears in the SPM Status window, and the image data is stored in the computer memory when scanning is complete. As Enter image title will be displayed at this moment, enter a title for the image using the keyboard; then click on the OK button. This title is used only for data storage in the memory and not for image saving on the disk. If you do not want to save the image on the disk, click on the Cancel button. Then the image data is cleared.
After you click on the Grab button, scanning remains in suspension. To restart the scan, click on the Repeat button.
If you click on the Grab button during scanning, Cancel Grab will appear. If you click on the button again, the grab command will be cancelled and return to Grab again. However, scanning continues.

- **Single**

When you click on this button, scanning is performed only once with the mode specified in Acquisition, and the image is automatically grabbed in the computer memory. Use this button to acquire data only once. It proves useful in cases such as Force Curve measurement where repeated scanning might damage the specimen or the tip.

- **Grab & Repeat**

Clicking on this button enables you to continuously measure up to 99 images, and to automatically save them in a file.
You cannot perform continuous measurement in the 2 Inputs, 4 Inputs, Montage, Single SPS or SPS Mapping mode.
Since you can display the images measured by the Grab & Repeat function continuously using the Play back function in the File menu when the observation object changes time-sequentially, it is suitable to watch the object change.
✍ When you scan the specimen using the Repeat function, specify the name and destination for saving the file. A serial measurement number is automatically attached to the filename. Refer to the procedure below.
✍ In this measurement, the measured images are not recorded in memory. In order to look at the measured images, you must read the saved image files from the disk.

The setting procedure is as follows:

1. Click on the Grab & Repeat button.

   A file operation dialog box appears.

2. Select the folder in which you wish to save the measurement image (if necessary, make a folder and select it), and then enter the filename.

✍ Continuously measured images are automatically stored in the selected folder.
A serial measurement number is automatically attached to the filename.
Example: Filename test → test00.tif, test01.tif...

3. The Grab & Repeat dialog box appears. Enter the number of continuous measurements (up to 99 measurements).
4. Click on the OK button.
   Continuous measurement starts.

● Noise

Clicking on this button measures the voltage input to the AC converter 5,000 times a second, and displays the minimum, maximum and mean values of the voltage. This function is applicable only when the Status Display window, which is also a signal monitor of the AD converter, appears. During noise measurement, the scanner stays at the present position without performing measurement operations involving the scanner movement.

The measurement procedure is as follows:

1. Click on the Status button in the Display Source frame of the SPM Parameters window.
   The SPM Status window opens.
2. Select a source signal to the AD converter from source signals 1 to 4 in the Display Source frame.
3. Click on the Noise button in the Scan frame of the SPM Parameters window.
   The SPM Status window displays the result of noise measurement of the signals specified in the Display Source signal input boxes.
4. If you want to stop noise measurement, click on the Abort button.

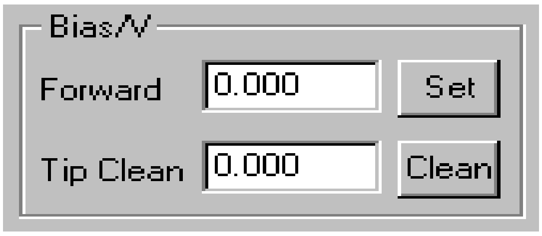
● Pause

When you click on this button, scanning is temporarily stopped and the tip stays at the present position. To restart scanning, click on the Repeat or Single button. Scanning restarts from that position.

● Abort

When you click on this button, scanning is stopped and the tip returns to the initial position.

■ Bias/V



● Forward

Specify the bias voltage in this input box. The voltage specified in the Forward input box is always applied to the specimen. After clicking on the Set button, specify the bias voltage using the slider. You can specify the bias voltage up to ±10 V.

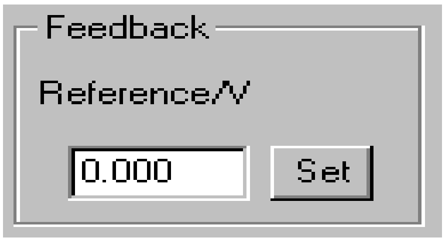
● Tip Clean

Use his control only when you use STM mode in the ultra-high vacuum SPM instrument and when you use AC-AFM (FM) mode. While you perform STM observation, when you change the bias voltage temporarily or slightly touch the tip on the specimen using AC-AFM (FM), sometimes the tip condition can show improvement and the image becomes clearer. So, this function often serves to improve the tip condition

Only while you are pressing the Clean button, the bias voltage changes to the voltage specified in Tip Clean when you use the STM mode and the feedback reference value changes to the voltage specified in Tip Clean when you use the AC-AFM (FM) mode. Enter the bias voltage for cleaning the tip in the Tip Clean box, using the keyboard.

■ Feedback

Set a target value (reference value) for the reference signal that is used in the feedback. The feedback circuit of the SPM controller operates around the set value for the reference signal, which differs depending on the measurement mode.



● When STM is selected: Current/nA

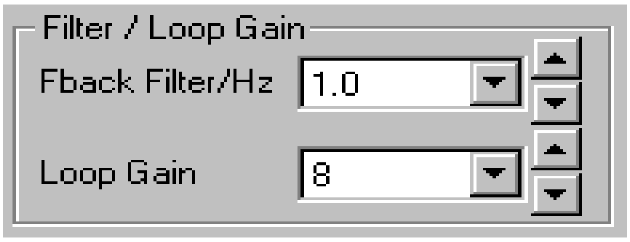
Enter the tunneling current flowing between the tip and the specimen in this input box.

● When AFM is selected: Reference/V

Enter the reference voltage in this input box. Be careful that the reference signal differs depending on the AFM mode. The setting voltage range also differs (☞ Refer to the STM/AFM of Scan in Sect. 5.10.3, SPM Parameters).

■ Filter/Loop Gain

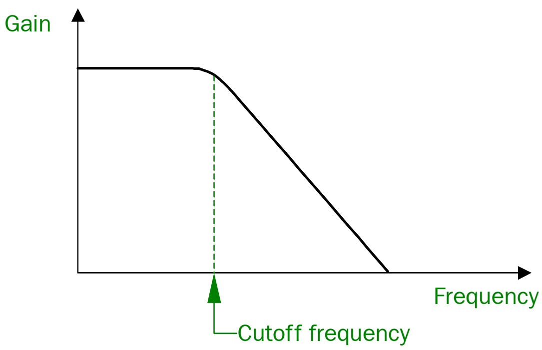
This sets the filter and gain amplifier for the feedback signal.



● Filter [Hz]

Specify the cutoff frequency of the feedback loop in this selection box. You can select from 16 frequencies between 0.01 Hz and 5 Hz when you click on the " " button. Response of the feedback loop becomes slower when a smaller frequency is selected, and vice versa. In ordinary topography observation, select as high a frequency as possible. Too high a frequency causes the feedback circuit to be prone to oscillation. In the case of the current image and the force image, on the other hand, select a lower frequency than that used for topography observation.

The filter used in this system is a low-pass filter. Cutoff frequency indicates the starting frequency that the gain decreases. Its characteristics are shown below:



Sensitivity decreases gradually as the frequency becomes higher than the cutoff frequency.

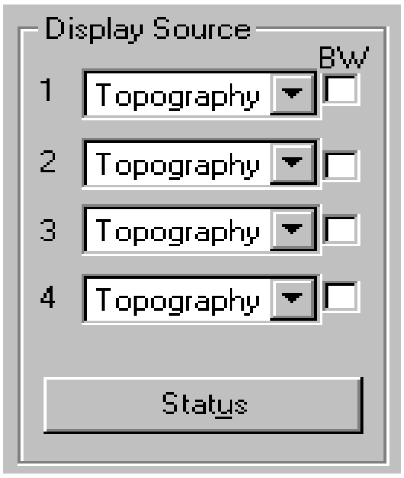
● Loop Gain

Specify the loop gain of the feedback circuit. The gain becomes higher as the number becomes larger. Usually, select a higher number (8 to 64) for the AFM mode, and select a lower number (4 to 32) for the STM mode. Loop Gain and Fback Filter/Hz are closely related to each other. Even if Loop Gain is small, a large Fback Filter/Hz (faster response) causes the feedback circuit to be prone to oscillation. Even if Loop Gain is large, a small Fback Filter/Hz (slower response) causes the feedback circuit not to be prone to oscillation.

During image observation, select about "8" for Loop Gain; adjust Fback Filter/Hz; then select a one-step larger number for Loop Gain if no oscillation occurs. When setting Loop Gain to 1, make sure that the Z position is near zero volts. If the Z position is far from zero, the tip may collide with the specimen or go far away from the specimen surface, because the Z position can follow only within ±20 V to ±30 V, when the Loop Gain is 1.

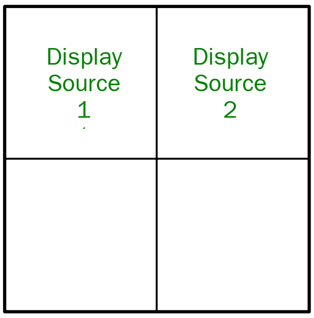
■ Display Source

This sets the display sources for image grabbing:

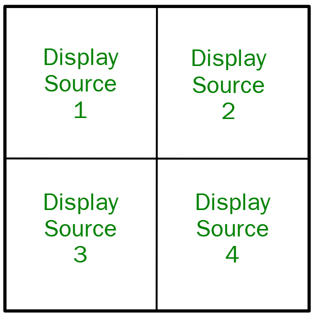


● Display Source 1, 2, 3, 4

Select the signal for the image to display on the Display Window. In ordinary image grabbing, the scanning image appears with the signal specified in Display Source 1. When grabbing images using 2 Inputs or 4 Inputs, the source signals (display sources) are assigned as follows:



2 Inputs



4 Inputs

● BW

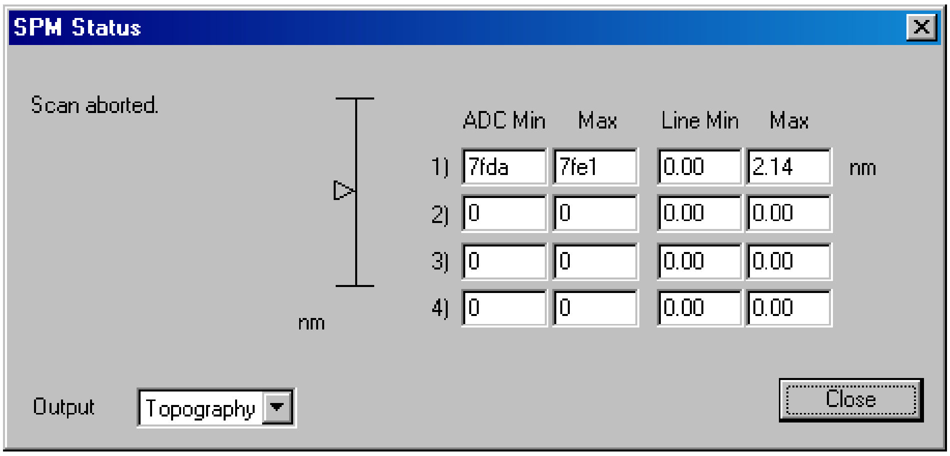
Usually, the source signal that is obtained by performing the forward scan (left-to-right scan) on the specimen is used to display the image. However, if you have checked the BW check box, the source signal will be obtained by performing the backward scan (right-to-left scan) on the specimen.

If you select Topography for Display Source 1 and 2 for measurement, for example, and you check the BW check box (backward scan) to a display source, and you do not check it (forward scan) to the other display source, then you can obtain the forward scan image and the backward scan image at the same time.

✍ You can set a bias voltage for the backward scan on the Bias Voltage tab window in the Detailed Setting window. However, be careful that this bias voltage is only applied for the backward scan in the Mirror scan and is not applied for measuring the backward scan signals.

● Status

Click on the Status button in the Display Source frame. The following SPM Status window opens:



- Status indication

  The present state is indicated by the following messages:

  - SPM inactive at present

    This message shows that the SPM CONTROL unit is ready to operate. When this message appears, you can start scanning by clicking on the Repeat or Single button.

  - Scan in progress

    This message shows that scanning is in progress.

  - Scan aborted

    This message shows that the Abort button has been clicked on during scanning and that scanning has been forced to stop. You can restart scanning from the beginning by clicking on the Repeat or Single button even while this message appears.

  - Scan paused

    This message shows that the Pause button has been clicked on during scanning and that scanning has been stopped temporarily. Scanning will restart from the present point if you click on the Repeat or Single button.

  - Grab frame

    This message shows that the Grab button has been clicked on so that the image under scanning is grabbed in the computer memory.

  - Subtract background

    This message shows that the image has been grabbed and the signal level has been normalized.

- Received Line and Processed Line

  In this system, the analog image signal sent from the SPM CONTROL unit is converted to the digital signal, which is sent by DMA to the computer. The computer normalizes the received signal, line by line, correcting the tilt. Then it displays the normalized signal on the screen. Therefore, the number of scanning lines under the receiving signal is not always the same as that of the scanning lines under the displaying signal, because data processing does not catch up with the image displaying. The actual scanning line is indicated with the Received Line and the displayed scanning line with the Processed Line.

- Scale

  The triangle arrow marks, which show values input to the A/D converter, indicate the signal levels averaged line by line. The positions of the arrow marks show the values obtained after both source signal gain and offset value have been calculated. If the arrow marks are positioned at the top (positive) or bottom (negative), it means that the input voltages to the A/D converter (±10 V if source gain is 1) are outside the range of the A/D converter, and that the image on the Display Window becomes only white or black, reflecting the fact that the image data has not been correctly acquired.

  The arrow mark on the left side shows the value corresponding to the source signal specified in Display Source 1. The arrow mark on the right side shows the value corresponding to the source signal specified in Display Source 2 together with the unit used for conversion.

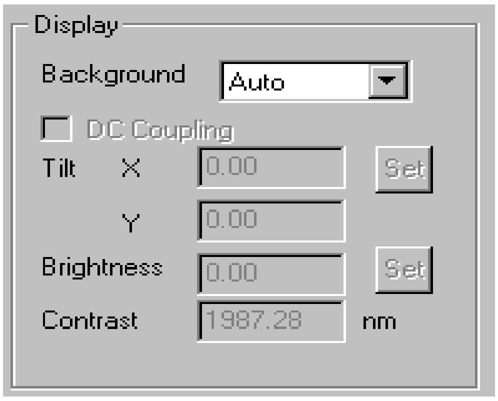
  Only the left arrow mark appears when scan mode other than 2 Inputs or 4 Inputs are selected in the Acquisition selection box.

- ADC Min Max, Line Min Max

  The input values specified for 1 to 4 of the Display Source appear.
  ADC Min Max is input to the AD converter one line at a time. The maximum and minimum values of the converted values are displayed in their initial hexadecimal form, and Line Min and Max are displayed as converted values according to the meaning of the source signals.

  The input values specified for Display Source 1 to 4 are displayed in the boxes. For the AD Min Max boxes, the minimum and maximum values of those that are input and converted for each line are displayed in hexadecimal. For the Line Min Max boxes, the values converted according to the definition of the source signals are displayed.

■ Display



● Background

This item is used to specify the method for displaying measured images on the Display Window. You can display the image using one of the following three methods:

- Auto

  The image appears after the tilt, brightness and contrast of the image for measurement are automatically adjusted. Normally, use this display method.
- No ASB (Auto Subtract Background)

  The image appears after the brightness and contrast of the image for measurement are automatically adjusted, but the tilt of the image for measurement is not adjusted. Use this display method when you wish to know the tilt of the surface for measurement.
- Manual

  All of the automatic adjustment functions are canceled, enabling you to manually adjust tilt, brightness and contrast.

● DC Coupling

Since the piezo scanner used in the SPM creates a structure combined with multiple drive axes, the movement of the X- and Y-axes may interfere with each other. Therefore, when the scan range is large, a tilt in the X direction interferes with the Y-axis scanner (the scanner moves as if a tilt also exists in the Y direction). Such a phenomenon is called DC coupling.

When the Background is Manual, if the scanning-plane tilt remains in the Y direction even if you have corrected the scanning-plane tilt in only the X direction, not only does the specimen-plane tilt in the Y direction but also the effect of DC coupling can be considered. In such a case, check the DC Coupling check box to enable the tilt correction in the Y direction.

● Tilt X, Y

The software corrects the tilt in the scanning plane. This becomes effective only when the Background is set to Manual. Tilt Y is in effect only when the DC Coupling check box is checked.

● Brightness and Contrast

You can correct image brightness and contrast.

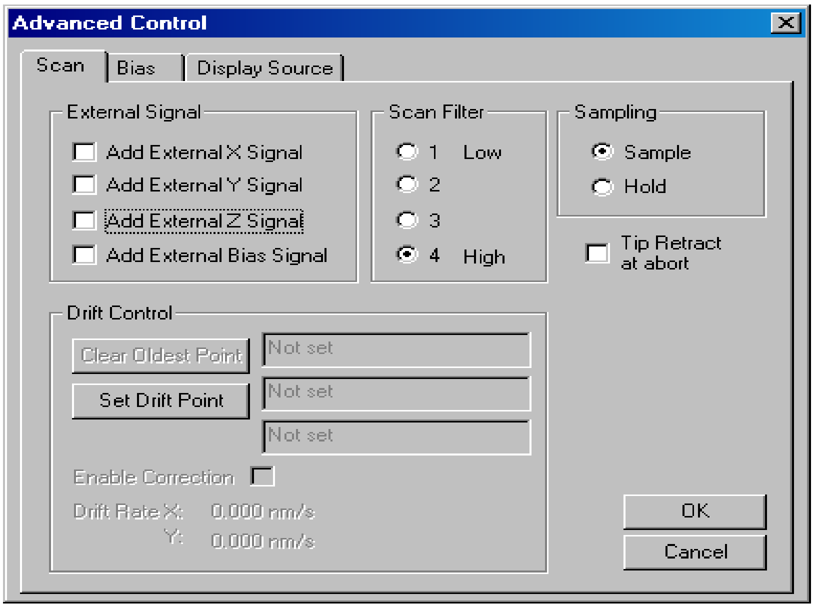
■ Advanced Control

When you click on the Advanced Control button, the Advanced Control window opens. The Advanced Control window includes some parameters that are not often used, and other parameters that are necessary to perform optional measurements.

The Advanced Control window has three tab windows in which you can specify detailed parameters.

● Scan tab window

Specify detailed parameters that are necessary for a scan.



- External Signal

  This controls ON or OFF for the signals that enter the SPM CONTROL unit.

  - Add External X Signal

    When this check box is clicked on, the signal input from the ADX terminal on the rear of the SPM CONTROL unit is added to the X-axis scanning signal. The signal input from the ADX terminal is increased to a signal 20 times greater in voltage through the piezo-drive high-power amplifier. That is, inputting a ±1 V sine wave to the ADX terminal outputs ±20 V.

    The maximum input rating of the ADX terminal is ±10 V. However, if the sum of the input voltage and X-axis scanning voltage exceeds the power-supply voltage of the SPM CONTROL unit, the maximum X-axis scanning voltage is saturated at the power-supply voltage.

  - Add External Y Signal

    When this check box is clicked on, the signal input from the ADY terminal on the rear of the SPM CONTROL unit is added to the Y-axis scanning signal. The signal input from the ADY terminal is increased to a signal 20 times greater in voltage through the piezo-drive high-power amplifier. That is, inputting a ±1 V sine wave to the ADY terminal outputs ±20 V.

    The maximum input rating of the ADY terminal is ±10 V. However, if the sum of the input voltage and Y-axis scanning voltage exceeds the power-supply voltage of the SPM CONTROL unit, the maximum Y-axis scanning voltage is saturated at the power-supply voltage.

- Add External Z Signal

  When this check box is clicked on, the signal input from the ADZ terminal on the rear of the SPM CONTROL unit is added to the Z-axis scanning signal. The signal input from the ADZ terminal is increased to a signal 20 times greater in voltage through the piezo-drive high-power amplifier. In other words, inputting a ±1 V sine wave to the ADZ terminal outputs ±20 V.

  The maximum input rating of the ADZ terminal is ±10 V. However, if the sum of the input voltage and Z-axis scanning voltage exceeds the power-supply voltage of the SPM CONTROL unit, the maximum Z-axis scanning voltage is saturated at the power-supply voltage.

- Add External Bias Signal

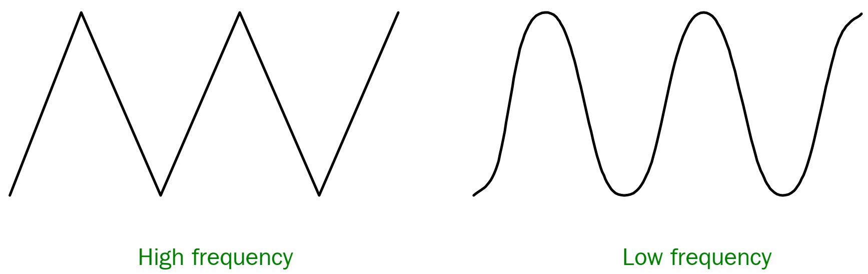
  When this check box is clicked on, the signal input from the ADB terminal on the rear of the SPM CONTROL unit is increased to the bias voltage. Unless this check box is checked, the signal input from the ADB terminal is not added.

  When the bias-voltage output setting from the SPM CONTROL unit is Normal Output, the signal input from the ADB terminal is added as it is. When the Bias-voltage output setting from the SPM CONTROL unit is High-voltage Output, the signal is increased to a signal 20 times greater in voltage.

  The maximum input rating of the ADB terminal is ±10 V. However, as the maximum bias voltage is about ±12 V, the total added scanning voltage is saturated at ±12 V even if the signal input to the ADB terminal exceeds ±12 V. For the high-voltage output, if the sum of the input voltage and the bias voltage exceeds the power-supply voltage, the maximum bias voltage is saturated at the power-supply voltage, because the maximum bias voltage becomes equal to the power-supply voltage.

- Scan Filter

  Specify the filter for the scanning waveform using this button. When Scan Filter is specified, the scanning waveform looks like as shown below.



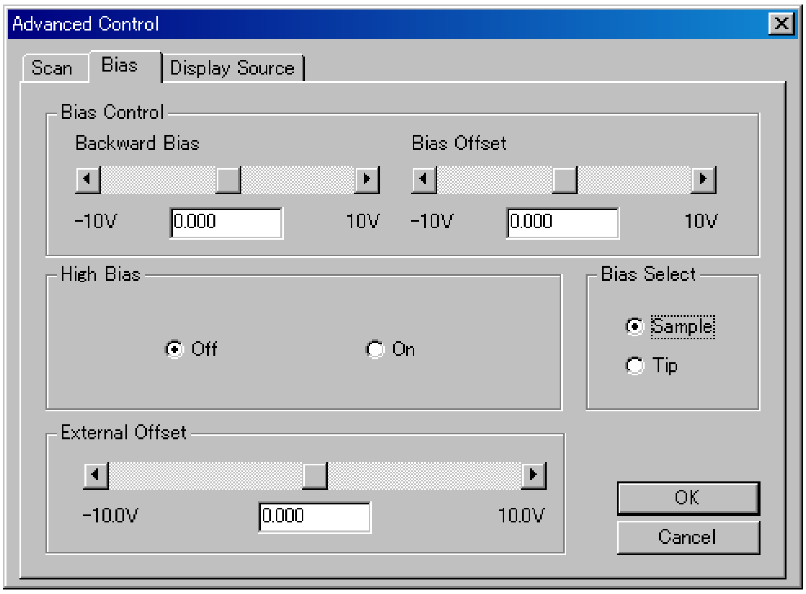
When a high scanning speed is selected, vertical streaks sometimes appear on the image. This is because vertical streaks are created by mechanical vibration of the scanner due to acceleration at the top point of the triangular waveform. If such a phenomenon occurs, the most effective remedy is to change the scanning speed to a low speed. If the image quality deteriorates due to the change in scanning speed, set this Scan Filter to a lower number.

- Drift Control
  These parameters are set for correcting the drift.
  - Set Drift Point
    You can set the reference points for computing the drift speed. You can specify up to three points.
  - Clear Oldest Point
    You can erase the oldest of the set reference points.
  - Enable Correction
    You can select this item if two or more reference points are set. While Enable Correction is checked, the center point of measurement shifts precisely the amount of drift correction each time measurement is performed.
  - Drift Rate
    The computed drift speed appears. The drift speed is computed by a first order approximation based on the least squares method.
- Sampling
  Selecting the radio button in the Sampling frame turns the feedback on or off.
  If you click on the Sample radio button, the feedback becomes active. If you click on the Hold radio button, the feedback becomes inactive and the Z scanner voltage is held at the present Z position.
  When observing the image, turn the Sample radio button on. When performing measurements such as I-V and Focus Curve, keep the Sample radio button on, since the system switches the feedback between on and off automatically.
- Tip Retract at abort
  If you click on the Abort button in the SPM Parameters window during scanning, the scanning stops and the tip immediately returns to the initial position. Therefore, if the specimen is uneven, the tip is likely to touch it. When the Tip Retract at abort button is checked, the tip first retracts during scanning, and then returns to the initial position; then tip retract is cancelled. This prevents damages to the tip and specimen.

  ✍ Usually, use the instrument keeping Tip Retract at abort off. If you keep it on when observing the even specimen, the obtained image may become bright or dark at the beginning of the next scan due to the creep characteristics of the Z scanner.

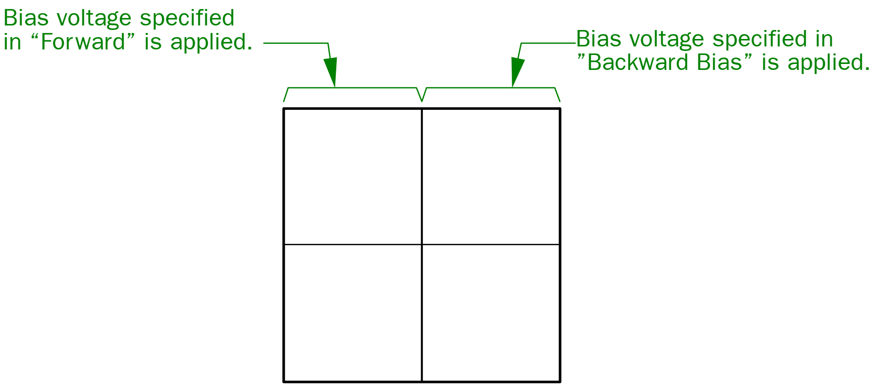
● Bias tab window

Specify detailed parameters concerning the bias voltage in the Bias tab window.



- Bias Control
  - Backward Bias

    This slider enables you to specify the bias voltage to be applied in backward scanning when Mirror is selected in the Acquisition selection box.



✍ Backward Bias is in effect only when Mirror is selected in the Acquisition selection box. If any other scanning method is specified, the bias voltage that is specified in Forward is applied in both forward (left-to-right) and backward (right-to-left) scanning, even though different voltages are specified in Forward and Backward Bias.

  - Bias Offset

    When you perform STM observation while directly heating the specimen using the optional 4-terminal Specimen Holder, the power supply for heating is used with an electrically floating condition. With the STM tip positioned just in the center of the specimen, the actual bias voltage is:

    Voltage specified in the Forward input box – heating-power voltage/2

Therefore, if you input a numerical value in the Bias Offset input box so that you do not mistake the bias voltage actually applied, the bias voltage displayed in the Forward box will be: Bias voltage – Bias offset voltage.

✍ Bias Offset is used only as a marker. The voltage output from the SPM CONTROL unit is the same as the Forward voltage displayed when the Bias Offset voltage is 0 V.
This function is in effect when heating the specimen using a current. You cannot use it when indirectly heating the specimen by using the optional Indirect Heating Holder.

- High Bias

The HV-AMP with 20 times greater gains is installed in the bias voltage source line. The usual bias voltage is ±10 V. However, by using the HV-AMP, the bias voltage can be made 20 times greater.

When the Off radio button is selected, if you click on the On radio button, a warning message will appear. If you have no problem, click on the Yes button. To return the output bias voltage to normal, click on the On radio button.

✍ Whenever you change the output bias voltage, the probe is automatically retracted.

✍ In the SPM instrument that applies the bias voltage to the probe, you cannot use High Bias to prevent damaging or shorting the probe due to the concentration of the electric field at the probe tip by applying high voltage on the probe.

✍ If you click on the On radio button, the displayed maximum value of the bias voltage will be changed to ±200 V. However, since the power voltage is ±150 V in some SPM instruments, the actual output voltage is limited to ±150 V.

- External Offset

Using External Offset electrically gives the offset voltage to the Friction Force. When the optional Vacuum Evacuation System is installed, External Offset can correct the bending of the cantilever that occurs in evacuation. Though in JSPM−5200, you can correct the Force value from the outside using the photodiode Y-axis adjusting knob, since you cannot correct the Friction Force value, use External Offset for adjustment.

First, correct the Force value using the photodiode Y-axis adjusting knob. Then correct the Friction Force value. However, if the shift of the Friction Force value is larger than ±10 V even after the Force value is corrected, you could not probably obtain any correct data even if you could correct the value. In such a case, vent the vacuum and adjust the Friction Force value again.

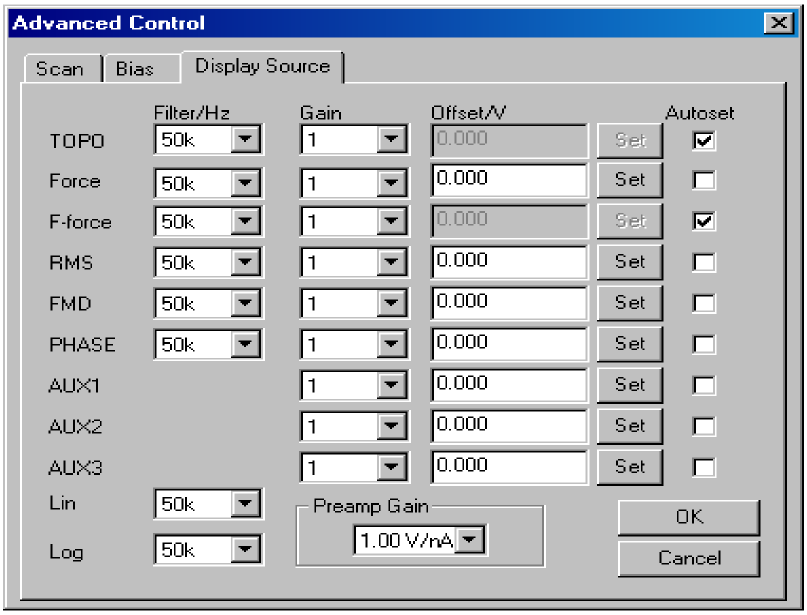
- Bias Select

Depending on the SPM instrument, you can change the destination to which the bias voltage is applied between sample and tip. Select either Sample or Tip in the radio buttons to apply the bias voltage.

✍ When you select Tip for the destination to which the bias voltage is applied, the radio button of the High Bias automatically turns Off.

● Display Source

Specify detailed parameters to each source signal for measurement in the Display Source tab window. The source signal is the one used for measurement after feedback. Settings here do not influence the feedback operation.



• Filter/Hz

Each input source has a filter circuit. You can specify the filter selecting its cutoff frequency from the eight steps that exist from 10 Hz to 50 kHz in the Filter/Hz selection box. These filters, having nothing to do with the feedback, are added to the measurement signal after feedback as a low-pass filter before performing A/D conversion.

When the image includes a lot of high-frequency components such as noise, and you cannot remove them by using Feedback Filter, Loop Gain and Current/Reference, then select a lower frequency. Remember that this filter is used just as an auxiliary means. This filter is not provided to the exterior display sources AUX1, AUX2 and AUX3. Usually, select 50 kHz.

• Gain

Set a gain to each source signal, selecting it from the six steps 1 to 32. Gain is useful for very low contrast images such as the atomic image. If you specify a high gain for observing a wide area or an uneven-surface specimen, the image contrast may become saturated. Usually, observe images using a low gain; but if you cannot obtain enough contrast, use a high gain.

✍ If the Enable Pre-Scan check box is checked, the system will automatically obtain the optimum gain from the results of Pre-Scan.

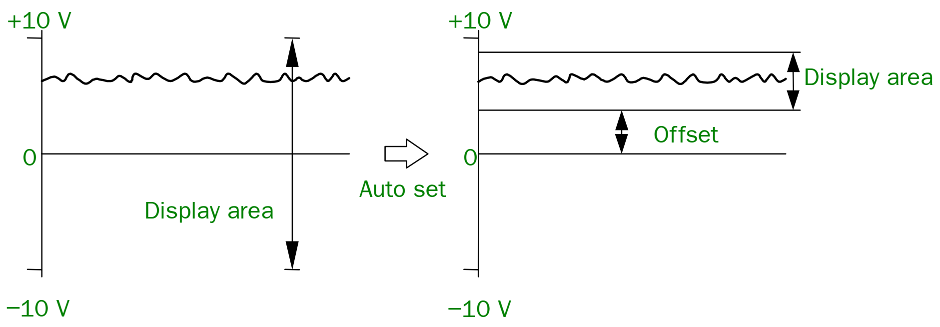
✍ When you change the gain during measurement, the signal might become saturated unless you readjust the offset.

• Offset/V

Specify the offset voltage to each source signal in this input box. Offset/V is in effect only when the Autoset check box is not checked. Use this when you have changed the gain during measurement and the signal has become saturated.

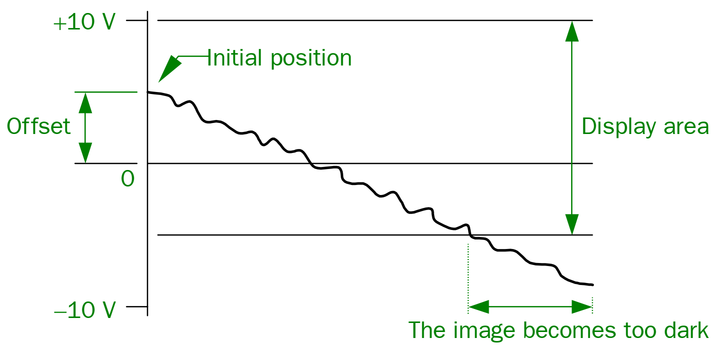
• Autoset

When the Autoset check box is checked for source signal, the offset voltage is automatically applied so that the input voltage at the initial position becomes zero volts. If the voltage of the source signal is positive (+), an offset voltage is added so that the voltage at that positive position becomes 0 V. Usually, check the Autoset check box for use.



Because of this, the display area starting from the initial position (usually, the upper-left corner of the image) attains a maximum.

If the initial position is extremely high or low, or if the specimen is tilted, the image could become white or black during scanning. In such a case, set Offset/V manually.



✍ If the Enable Pre-Scan check box is checked, and the Autoset check box is checked for the source signal, the software will automatically adjust the offset so as to obtain the optimum gain from the result of Pre-Scan.

✍ Even if the Enable Pre-Scan check box is not checked, if the Autoset check box is checked for the source signal, the software will automatically adjust the offset so as to obtain the optimum gain from the result of Pre-Scan.

• Preamp Gain

Concerning the tunneling current signals (Current and Log current), specify the gain for the tunneling current preamplifier in this selection box instead of specifying the source gain. Three gains are provided, as shown below:

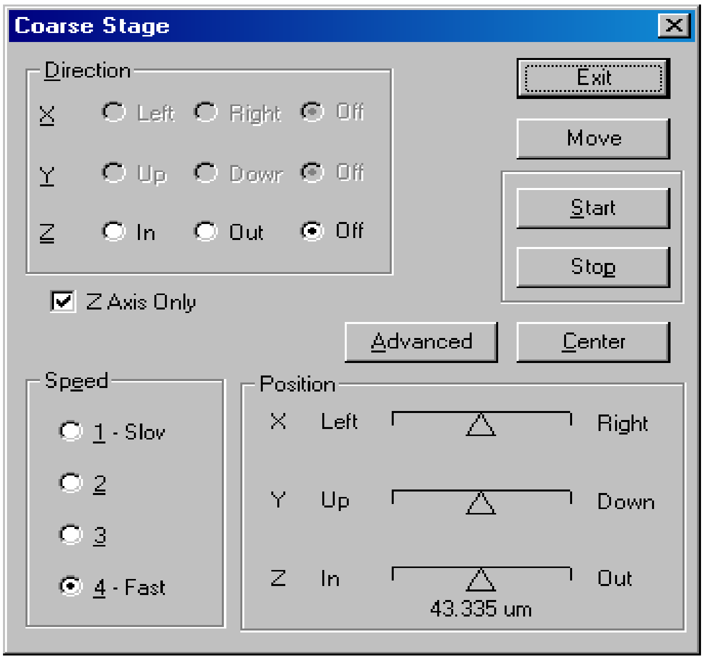
Gain	Tunneling current
1 V/nA	0 to 10 nA
0.1 V/nA	0 to 100 nA
0.01 V/nA	0 to 1 μA

Usually, select 1 V/nA for the ordinary STM mode, but if a tunneling current exceeds 10 nA in the I-V measurement, or if a contact current exceeds 10 nA in the contact current measurement in the AFM Contact mode, select 0.1 V/nA or 0.01 V/nA.

✍ In the contact current measurement, if the current is too large, the cantilever tip and the specimen could be damaged by Joule heat. Be careful not to set too large a bias voltage.

■ Stage

This opens the stage control window for controlling the coarse motor drive.



● Direction

Y-Left:
Y-Right:
Y-Off:
Y-Up: Do not use JSPM-5200
Y-Down:
Y-Off:

Z-In: Specimen surface approaches the tip.
Z-Out: Specimen surface moves away from the tip.
Z-Off: Specimen stage does not move.

✍ There is a play of about 3/10 turns due to the rotation-shaft detaching mechanism when you change the moving direction.

— CAUTION —

When you move the tip close to the specimen using the Coarse Stage window, the tip never stops even if a tunneling current or atomic force is actually detected.

- **Z Axis Only**

  Check this box when you do not use the X and Y motor drive. Use the instrument with this box checked except when you use the ultra high vacuum SPM instrument.

- **Speed**

  Specify the motor driving speed for each axis. Usually you use 4-Fast.

- **Position**

  This indicates the X, Y and Z positions in each movement range. If the △ mark is at the either side of the end positions, the driving motor does not move any more.

- **Move**

  The driving motor works while this button is being pressed.

- **Start/Stop**

  Once you click the mouse on the Start button, the motor continuously works even if you release the mouse button. To stop the motor, click on the Stop button.

- **Centre**

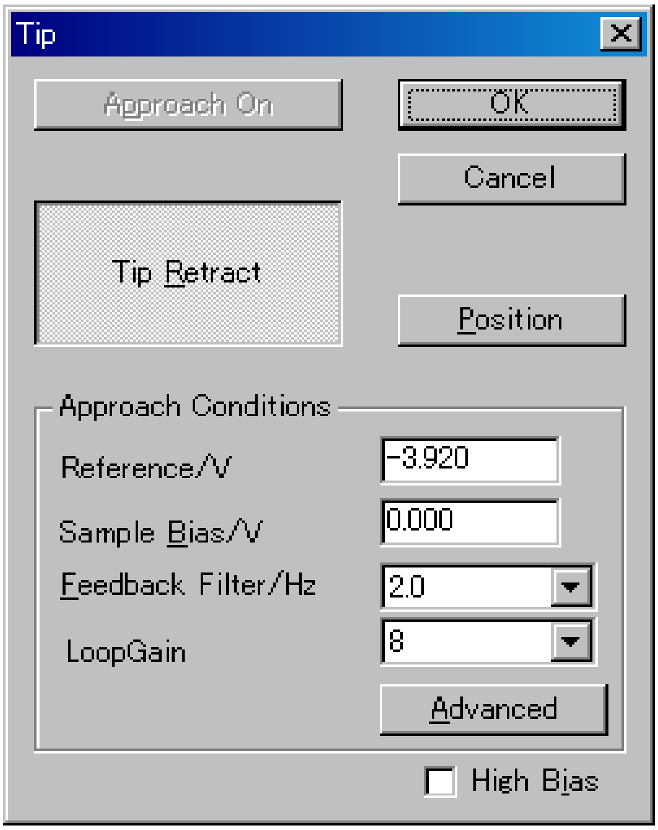
  The X and Y motor drives return to the center position automatically. This button is used when you exchange the specimen.

- **Advanced (Only an administrator can operate this)**

  Enter the calibration value of the Z-stage position. The calibration value is set before factory shipment.

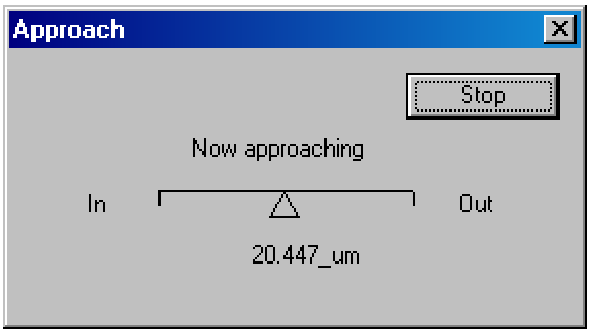
■ Tip

This opens the Tip dialog that performs the tip control operations such as approach control and tip retract.



● Approach On

Clicking on the Approach On button starts the approach according to the conditions specified in the Approach Conditions frame in this window. The Approach dialog box showing approach conditions will appear.



When the Tip Retract box is checked, you cannot use the Approach On button.

● Tip Retract

When you check this button, the Z-piezoelectric element shrinks most. This check box is used to retract the tip from the specimen temporarily when you change the field of view or move the stage.

● High Bias

This is the same function as High Bias on the Bias tab window in the Advanced Control window.

● Position

This specifies the initial position to perform the SPS measurement.

☞ For detailed operations, refer to the measuring procedure in the SPM mode (I-V,S-V,I-S,FC,FFC).

● Approach Conditions

Specify approach conditions in this frame. When the Approach On button is clicked on, approach is performed according to the conditions specified in this frame.

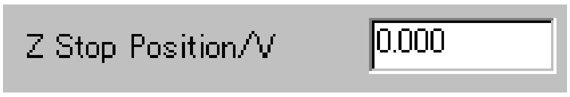
STM mode	AFM mode
Current/nA	Reference/V
Feedback Filter/Hz	Feedback Filter/Hz
Sample Bias/V	

• Advanced button

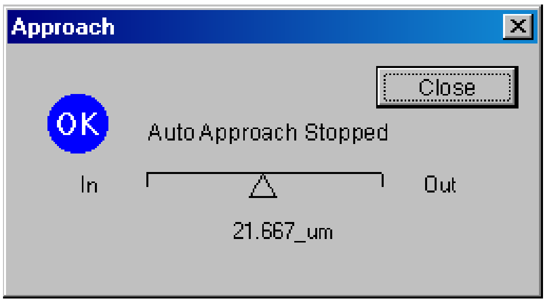
There are two ways to conduct the approach operation. One is approach by software control, and the other is approach by hardware operation. Clicking on the Advanced button displays the Tip Advanced window, in which you can specify detailed settings.

• Approach by software control

The JSPM−5200 and JSPM−5700 perform approach by software control.
Enter the Z scanner voltage (usually 0 V) in the Z Stop Position/V input box in the Tip Advanced window.



In approach by software control, once the approach conditions that are specified in the Tip Advanced window are complete, the Approach dialog box will change to the following state:



Approach and processing have automatically stopped.

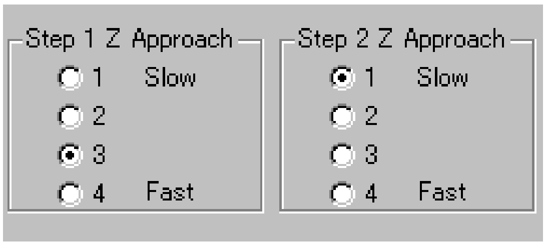
This state shows that approach by software control has automatically stopped, and that the Z-scanner position is in the value specified in the Z Stop Position/V input box since the Z motor drive position has been adjusted. All of these operations are performed by software control.

- Approach by hardware control

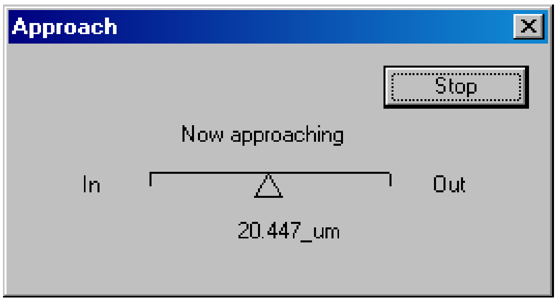
The following function is not usually used for the JSPM-5200.We describe outline the summary of this functionbelow.

Approach is fully controlled by the SPM CONTROL unit. When performing approach, specify the motor-drive speeds for Step 1 Z Approach and Step 2 Z Approach. In Step 1 Z Approach, specify the motor-drive speed until the tip arrives near the specimen; in Step 2 Z Approach, specify the motor-drive speed after the tip arrived near the specimen. The relation between step 1 speed and step 2 speed should be: step 1 > step 2.

Set the corresponding motor speeds for Step 1 Z Approach and Step 2 Z Approach, respectively, in the Tip Advanced window (Normally, set 3 for Step 1 Z Approach and 2 for Step 2 Z Approach).



In this approach, even when the approach finishes, the software does not automatically finish. When you click on the Stop button in the Approach dialog box, all the conditions specified by the software will terminate.

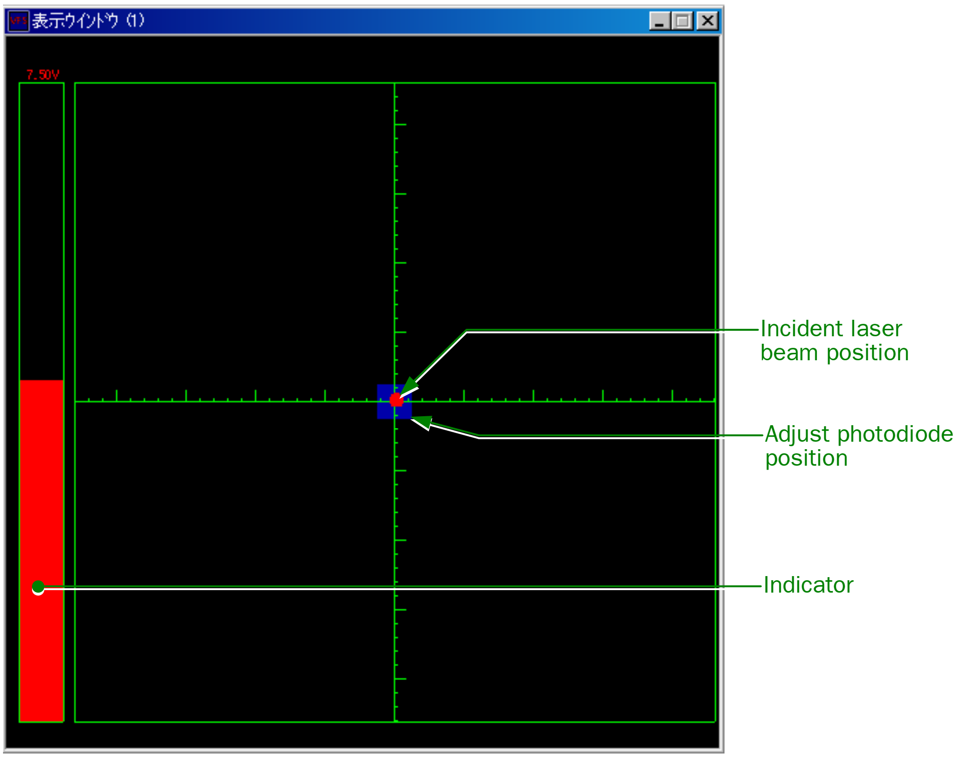


Approach has finished but processing has not finished.

The SPM CONTROL unit judges whether or not it finish the approach from the voltage applied to the scanner. When starting approach or during approach, if the scanner voltage should change by electrical noise or other accidents, the approach stops. In such a case, even though the voltage of the Z scanner returns to the previous +150 V, approach cannot be performed automatically. Click on the Stop button to finish the approach; then click on the Approach On button again.

■ Adjust PD

Clicking on the Adjust PD button opens the Display Window that displays the position of the laser beam irradiating the photodiode.



The red indicator on the left side of the Display Window shows the SUM value (the intensity of the incident laser beam projected on the photodiode. Adjust the laser beam incident position on the cantilever and the photodiode position so that you can obtain the requested value.

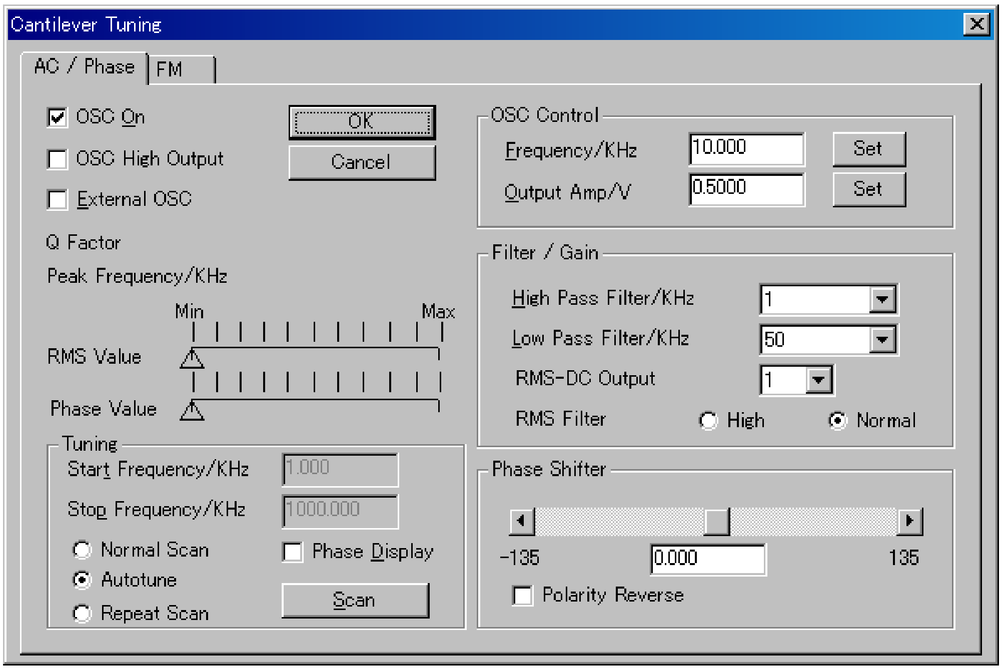
The red circle marks the position that the laser beam is irradiating. Adjust the position of the photodiode so that this red circle coincides with the part displayed in blue.

■ Cantilever

When you perform observation in the AC mode or the AFM mode, open the Cantilever Tuning window to specify parameters used for cantilever oscillation. The Cantilever Tuning window has two tab windows; one is the AC/Phase tab window for the AC mode and Phase mode, and the other is the FM tab window for the FMD mode.

● AC/Phase tab window

When performing measurements in the AC mode or Phase mode, specify parameters for cantilever oscillation.



• OSC On

When the OSC On check box is checked, oscillation voltage is applied to the piezoelectric element for cantilever oscillation.

• OSC High Output

The check box is used to specify the range of oscillation voltage.

☐ OSC High Output··· 0 to 1.0 V
☑ OSC High Output··· 0 to 10 V

• External OSC

When you want to use an external oscillator without using the internal oscillator, check this check box.

Connect the external oscillator to the EXT terminal on the rear of the AFM AMP. Set the output of the oscillator to 0 to 1.0 V.

Adjust the frequency of the oscillator with the oscillator, but adjust voltage amplitude using the software.

- Q Factor/Peak Frequency/kHz
  When you have performed a frequency scan, if the resonance frequency (peak frequency) of the cantilever and Q factor are detected, each detected value will appear here.
- RMS Value/Phase Value indicators
  The outputs of the present RMS and phase signals will appear. The displayed values are the same as those that appear on the LCD of the AFM AMP front panel.

- Tuning
  The parameters in the Tuning frame are used for searching for the resonance frequency of the cantilever.

  - Start Frequency/kHz
    Specify the start frequency of the frequency sweep in this input box.

  - Stop Frequency/kHz
    Specify the stop frequency of the frequency sweep in this input box.

  - Phase Display
    Checking the Phase Display check box acquires and displays phase data during frequency scanning.

  - Normal Scan/Autotune/Repeat Scan
    When Normal Scan is selected:
    Clicking on the Scan button performs one frequency sweep from the start frequency to the stop frequency. The detected peak frequency and the Q value appear after measurement.

    When Autotune is selected:
    Select this button when you control and adjust the Q value using the optional Q controller (TM−26060).
    Clicking on the Scan button performs frequency sweep repeatedly from the start frequency to the stop frequency. Detected peak frequency and the Q value appear at the end of every scan. Adjust the Q controller by referring to the change of Q values. The scan finishes by pressing the ESC key on the keyboard.

    When Repeat Scan is selected:
    Clicking on the Scan button starts the automatic adjusting sequence.
  - Scan
    Starts frequency scan using the method selected from the above scan types.
- OSC Control
  Specify the oscillation signal to the cantilever.

  - Frequency/kHz
    Specify the oscillation signal in this input box. The range in which you can select the frequency is between 1 and 1000 kHz. The output signal is a sine wave.
  - Output Amp V
    Specify voltage applied to the piezoelectric element for oscillation. The voltage depends on the value set to OSC High Output.

- Filter/Gain

  Specify the filter gain in the RMS signal circuit.

  - High Pass Filter/kHz

    Specify the cutoff frequency of the high-pass filter in this selection box for the input Force signal. Before you click on the Scan button, select a cutoff frequency lower than that selected in the Start Frequency/kHz selection box.

    After you have finally determined the oscillation frequency, you have to set the cutoff frequency to the value nearest to but lower than that specified in the Frequency/kHz selection box.

  - Low Pass Filter/kHz

    Specify the cutoff frequency of the low-pass filter in this selection box for the input Force signal. Before you click on the Scan button, select the cutoff frequency higher than that selected in the Start Frequency/kHz selection box.

    After you have finally determined the oscillation frequency, you have to set the cutoff frequency to the value nearest to but higher than that specified in the Frequency/kHz selection box.

  - RMS-DC Output

    Specify amplifier gain for the signal that has passed through the high-pass and low-pass filters. Usually, set it to 10.

  - RMS Filter

    This filter is used for the signal that has passed through the high-pass and low-pass filters. Usually, set it to Normal.

- Phase Shifter

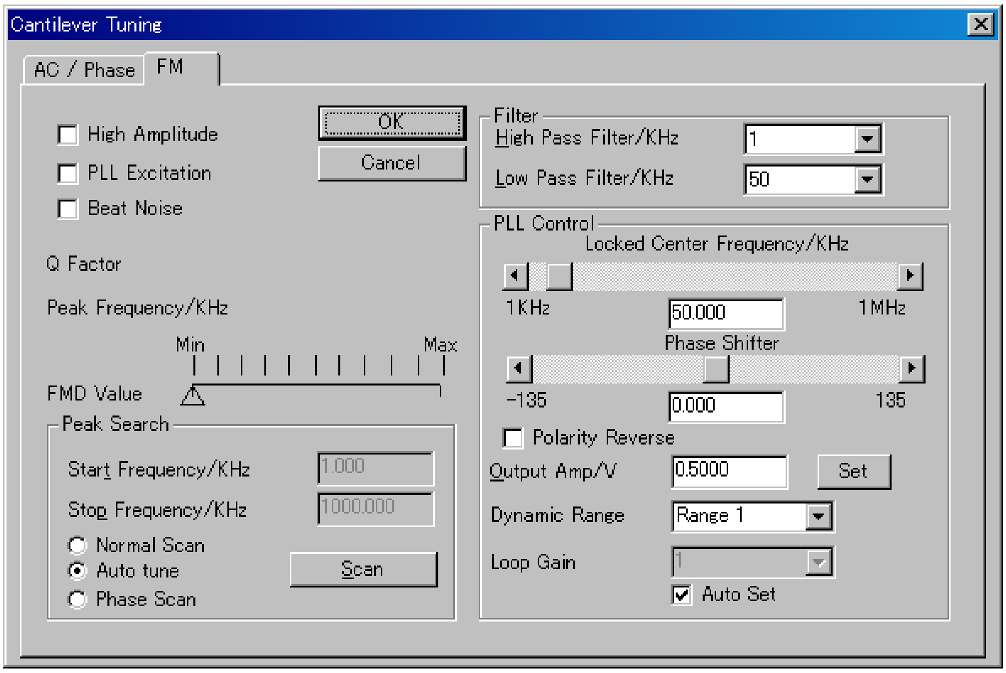
  The Phase Shifter slider enables you to control the phase, which can be set in the range of ±130°.

  - Polarity Reverse

    If this box is checked, the phase rotates by 180° from the present angle. Since the operation is performed by the hardware, the preset value of phase rotation on the software does not change at all.

● FM tab window

When performing measurements in the FM mode, specify the parameters for cantilever oscillation.



• High Amplitude

This check box has the same function as the OSC On check box on the AC/Phase tab window. This is used in such case as require high voltage to oscillate the cantilever when you observe a specimen in a liquid or use a cantilever that is difficult to oscillate.

• PLL Excitation

Set the oscillation-excitation method of the cantilever when you perform FM measurement. When the scanning speed is rapid, or the specimen surface is topographical, check the PLL Excitation box for measurement.

Though self oscillation-excitation of the cantilever (oscillation in the resonance frequency) is used in ordinary oscillation-excitation, the cantilever comes into contact with the specimen surface during scanning and its oscillation stops, since its amplitude is very small.

When PLL Excitation is checked, the ordinary self oscillation-excitation of the cantilever changes to oscillation-excitation by the oscillator installed in the PLL (Phase Locked Loop) circuit. Then even if oscillation stops when the cantilever comes into contact with the specimen surface, re-oscillation of the cantilever will be easier due to the excitation of the PLL oscillator. Since the PLL oscillator tries to maintain the values that have been set to the frequency and phase, the principle involved is essentially the same as in ordinary self oscillation-excitation.

When you have changed the PLL Excitation after you had once finished adjusting the FM measurement, the oscillation conditions of the cantilever change. So you must readjust the FM measurement.

- Beat Noise

  Frequency detection in the FM mode is executed in the frequency-detection circuit of AFM AMP using PLL (Phase Locked Loop). In the PLL circuit periodical noise with relatively low frequency (of 1 kHz or less) occurs due to the correlation between the signal frequency and the characteristic frequency of the frequency detection system (PLL).

  In such a case, checking the Beat Noise check box will remove the beat noise by slightly changing the characteristic frequency of the frequency detection system (PLL).
- Q Factor/Peak Frequency/kHz

  When you have performed a frequency scan, if the resonance frequency (peak frequency) of the cantilever and Q factor are detected, each detected value will appear here.
- FMD Value indicator

  The outputs of the present FMD signal (FM detection signal) will appear. The displayed value is the same as that appears on the LCD of the AFM AMP front panel.
- Tuning

  The parameters in the Tuning frame are used for searching for the resonance frequency of the cantilever.

  - Start Frequency/kHz

    Specify the start frequency of the frequency sweep in this input box.
  - Stop Frequency/kHz

    Specify the stop frequency of the frequency sweep in this input box.
  - Phase Display

    Checking the Phase Display check box acquires and displays phase data during frequency scanning.
  - Normal Scan/Auto tune/Phase Scan

    When Normal Scan is selected:

    Clicking on the Scan button performs the frequency sweep once from the start to the stop frequency. Detected peak frequency and the Q value appear after the measurement.

    When Autotune is selected:

    Clicking on the Scan button starts the automatic adjusting sequence.

    When Phase Scan is selected:

    Clicking on the Scan button performs the phase scan, and adjusts the phase control of the frequency detection circuit to the optimal condition for performing frequency detection.
  - Scan

    Starts frequency scanning using the method that is selected from the above scan types.
- Filter
  - High Pass Filter/kHz

    High Pass Filter/kHz has the same function as that of the AC/Phase tab window.
  - Low Pass Filter/kHz

    Low Pass Filter/kHz has the same function as that of the AC/Phase tab window.

- PLL Control

  Frequency detection in the FM mode is executed in the frequency-detection circuit of AFM AMP using PLL (Phase Locked Loop). Specify parameters for frequency detection.

  - Locked Center Frequency/kHz

    Specify the center frequency for frequency detection. The frequency detection circuit detects the shift of frequency based upon the frequency specified here.

    Usually, enter the value near to that of the resonance frequency (peak frequency) of the cantilever.

  - Phase Shifter

    The Phase Shifter slider enables you to control the phase, which can be set in the range of ±130°. Set the Phase Shifter so that the RMS signal (amplitude of the cantilever) becomes a maximum under the condition that the frequency is set to the resonance frequency of the cantilever.

  - Polarity Reverse

    Usually, the Phase Shifter circuit cannot uniformly rotate the phase by 360° in its characteristics but always has discontinuous point somewhere in control. The Phase Shifter installed on the AFM amplifier resolved this problem by reversing the polarity of phase detection. If this check box is checked, the phase rotates by 180° from the present angle. Since the operation is performed by the hardware, the preset value of phase rotation on the software does not change at all.

  - Output Amp/V

    Specify the voltage amplitude of the oscillation signal to the cantilever. Oscillation voltage in the FM mode is much smaller than that in the AC mode.

  - Dynamic Range

    Specify the dynamic range (frequency detection range) of the frequency detection circuit. If the dynamic range is small, the detection sensitivity becomes better. However, the detectable frequency amplitude becomes smaller. If the dynamic range is large, the result will be reversed. If you select Range 1 in the Dynamic Range selection box, the dynamic range will be the smallest. If you select Range 4 in the Dynamic Range selection box, the dynamic range will be the largest.

Range1:	Range width 76 Hz
Range2:	Range width 76 Hz
Range3:	Range width 305 Hz
Range4:	Range width 610 Hz

  - Loop Gain

    Specify the loop gain in the PLL movement. If the dynamic gain is the same, the smaller loop gain set in the Loop Gain selection box will improve the resolving power for detecting the frequency. Usually, set the Loop Gain as follows:

Dynamic range Range1:	Recommended Loop Gain 30
Dynamic range Range2:	Recommended Loop Gain 20
Dynamic range Range3:	Recommended Loop Gain 10
Dynamic range Range4:	Recommended Loop Gain 5

● SPS Parameters

Specify various kinds of parameters using the SPS Parameters window. The SPS Parameter window is divided into several tab windows for various kinds of SPS measurements. Set the SPS measurement parameters from each tab window. Moreover, when you perform measurements by setting Acquisition of the SPM Parameters window to Single SPS or SPS Mapping, specify the kind of SPS measurements using the SPS Parameters window.

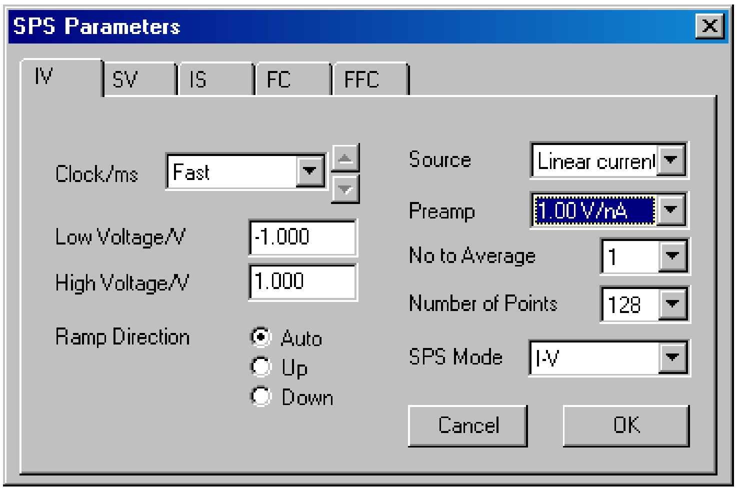
The SPS modes are as shown below. However, it depends on the SPM measurement mode whether you can actually perform measurements under the SPS mode.

- IV

  You can perform IV measurement in the STM, contact AFM, AC or AFM, mode. Usually, perform it in the STM and contact AFM modes. You must use the conductive cantilever when you perform IV measurement in the AFM mode.

  During IV measurement, the feedback control is withheld and measurement is carried out keeping the distance between tip and specimen at a constant. At the Repeat measurement, feedback is sampled between measurements and performs feedback under the conditions specified on the SPS Parameter window.

  The position at which IV measurement is carried out is determined by using the Position function in the Tip window.



- Clock/ms

  Specify the clock speed when performing measurements. This Clock/ms item is independent from that of the SPM Parameters window. It is used only for SPS measurement.

  ✍ If the Number of Points is 128, only Fast (100 μs) and Slow (1.6 ms) are selectable. If the Number of Points is 256 or more, the same number for clock speed as in the SPM Parameters window is selectable in this window.
- Low Voltage/V

  Specify the minimum bias voltage for sweeping in this input box.
- High Voltage/V

  Specify the maximum bias voltage for sweeping in this input box.

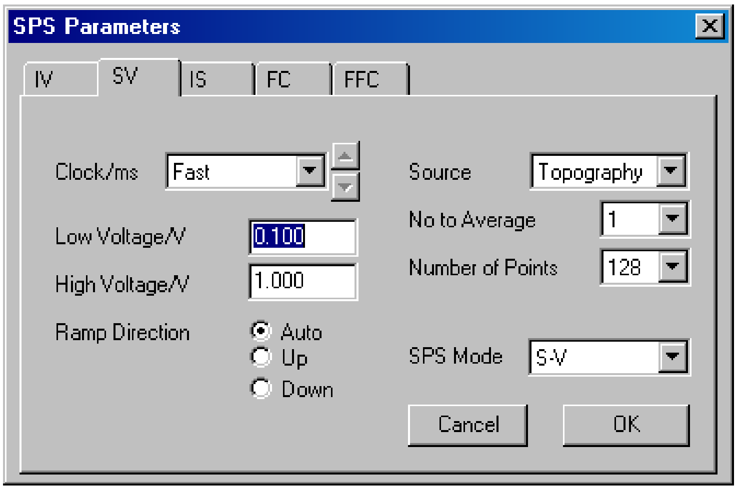
- Ramp Direction
  Specify the direction for scanning the bias voltage using these radio buttons.
  Auto: The bias voltage is scanned from the maximum or minimum voltage, whichever is closer to the currently set voltage.
  Up: The bias voltage is scanned from the minimum voltage to the maximum voltage.
  Down: The bias voltage is scanned from the maximum voltage to the minimum voltage.
- Source
  Specify the source signal. Usually, select Linear Current for IV measurement. If you change the source signal, you can perform various measurements.
- Preamp
  Specify the preamplifier gain.
- Number to Average
  Specify the number for averaging the measurement. You can obtain the measurement result whose data the software has averaged after performing the specified number of sweeps.
- Number of Points
  Specify the number of measurement points in a sweep. The measurement interval is obtained by dividing the sweep width by this number of points.
  ✍ In the SPS Mapping measurement, the Number of Points is always set to 128.
- SPS Mode
  When performing the Single SPS or SPM Mapping measurement, select the kind of SPS measurement in this selection box. The displayed SPS mode depends on the settings in the SPM mode.

• SV

You can perform SV measurement only in the STM mode.

In SV measurement, you can measure the change of the distance (S) between the tip and specimen by sweeping the bias voltage with keeping the STM feedback on.

The position at which SV measurement is carried out is determined by using the Position function in the Tip window.



• Clock/ms, Low Voltage/V, High Voltage/V, Ramp Direction, Number to Average, Number of Points and SPS Mode

Specify these items in the same way as for IV.

• Source

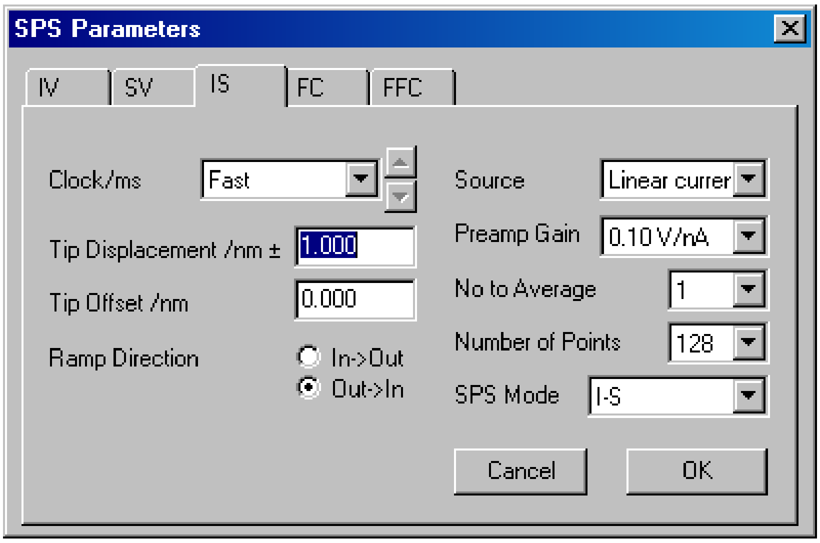
Select Topography for source because you measure the change of the distance between the tip and specimen by sweeping the bias voltage in SV measurement.

• IS

You can perform IS measurement in the STM or contact AFM mode. Usually, perform it in the STM mode. You must use the conductive cantilever when you perform IS measurement in the AFM mode.

In the IS mode, you can measure the change of the tunneling current by sweeping the distance between the tip and specimen. Feedback is automatically turned off during IS measurement.

The position at which IS measurement is carried out is determined by using the Position function in the Tip window.



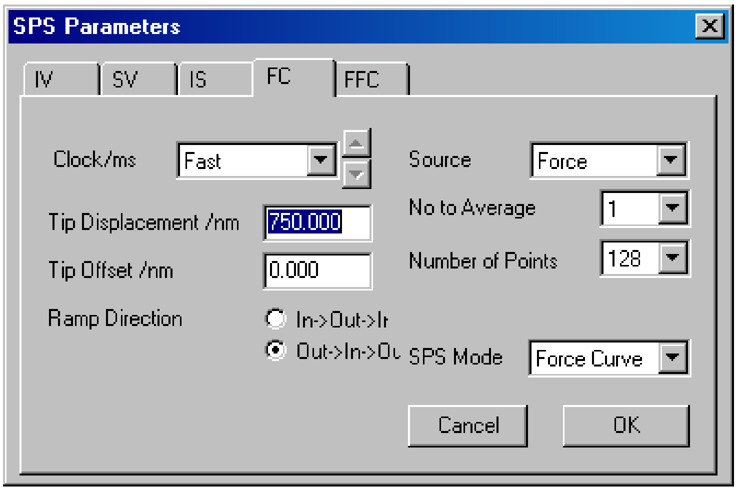
• Clock/ms, Preamp Gain, Number to Average, Number of Points and SPS Mode
  Specify this item in the same way as for IV.
• Tip Displacement/nm±
  Specify the scanning range of the tip in the vertical (Z) direction.
• Tip Offset/nm
  Specify the offset value in the Z direction. The value in Tip Offset/nm will be added to the height before scanning. Usually, specify 0.
• Ramp Direction
  Specify the sweeping direction for the distance between the tip and the specimen.
  In->Out: The tip moves away from the specimen.
  Out->In: The tip approaches the specimen.
• Source
  Select Linear Current for IS measurement because you measure the change of the tunneling current by sweeping the distance between the tip and specimen.

• FC (available only in AFM mode)

You can perform FC measurement in the contact AFM, AC or AFM mode. Usually, perform it in the contact AFM mode.

In the FC mode, you can measure the change of the interatomic force due to the bending of the cantilever by sweeping the distance between the tip and specimen. Feedback is automatically turned off during measurement. FC measurement is carried out in the back and forth sweeping directions, and appears in different colors for the respective sweeps on the same screen.

The position at which FC measurement is carried out is determined using the Position function in the Tip window.



• Clock/ms, Number to Average, Number of Points and SPS Mode

Specify these items in the same way as for IV.

• Tip Displacement/nm, Tip Offset/nm

Specify these items in the same way as for IS.

• Ramp Direction

Specify the sweeping direction for the distance between the tip and the specimen.

In->Out->In:	First, the tip moves away from the specimen, and then it approaches the specimen.
Out->In->Out:	First, the tip approaches the specimen, and then it moves away from the specimen.

• Source

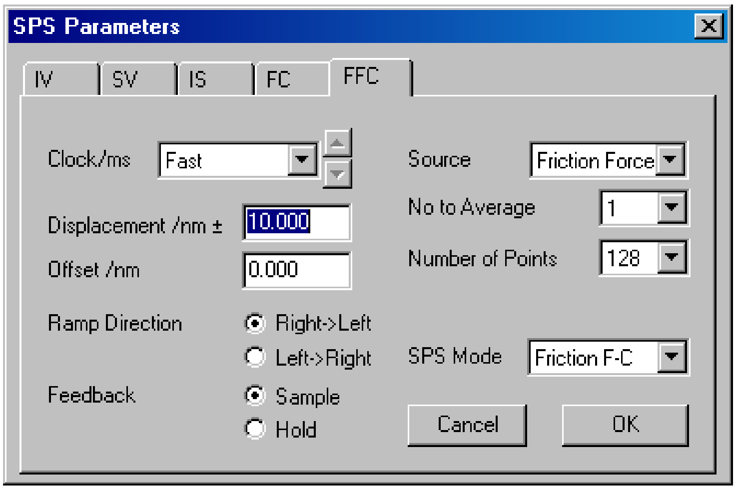
Select Force for FC measurement because you measure the change of the interatomic force when changing the distance between the tip and specimen.

• FFC

You can perform FFC measurement only in the contact AFM mode.

In FFC mode, you can measure the change of the friction force due to the torsion of the cantilever by sweeping the tip in the horizontal (Y) direction The measurement result appears on the screen. The FFC measurement is carried out in the back and forth sweeping directions, and appears in different colors for the respective sweeps on the same screen.

The position at which the FFC measurement is carried out is determined by using the Position function in the Tip window.



• Clock/ms, Number to Average, Number of Points and SPS Mode

Specify these items in the same way as for IV.

• Tip Displacement/nm±

Specify the scanning range of the tip in the Y direction.

• Tip Offset/nm

Specify the offset position in the Y direction. The value in Tip Offset/nm will be added to the position in the Y direction before scanning. Usually, specify 0.

• Ramp Direction

Specify the sweeping direction for the distance between the tip and the specimen.

Right ->Left:	First, the tip sweeps in the right direction, and then it sweeps in the left direction.
Left -> Right:	First, the tip sweeps in the left direction, and then it sweeps in the right direction.

• Feedback

Turn Feedback on or off.

Sample:	Measurement is performed with feedback turned on.
Hold:	Measurement is performed with feedback turned off.

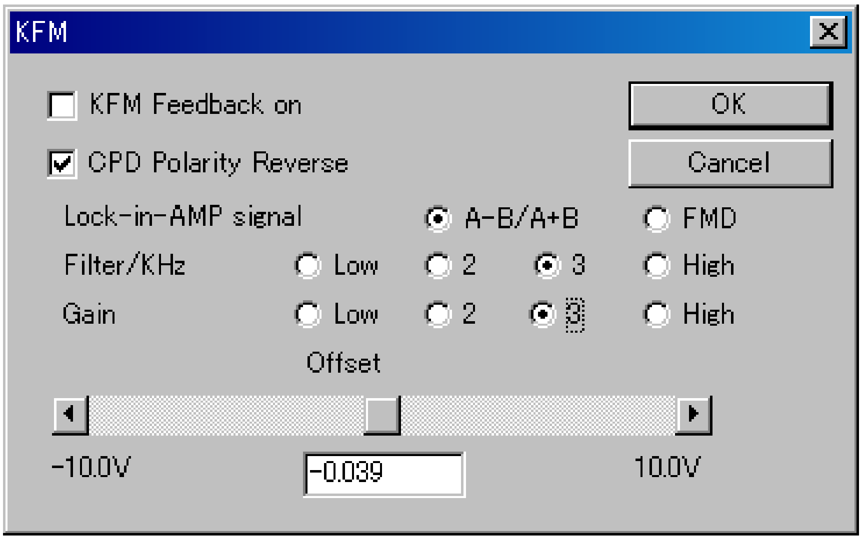
• Source

Select Friction Force for the FFC measurement because you measure the change of the friction force when sweeping the tip in the Y direction on the specimen.

■ KFM

You can perform SKPM measurement when the optional Extended Lock-in Amplifier is installed in the instrument for lateral modulation FFM. Explained here is the setting for SKPM measurement.

✍ The following KFM dialog box will be in effect if you select KFM in the Mode selection box in the Scan frame of the SPM Parameters window.



• KFM Feedback on

When you check this check box, the KFM feedback of the bias voltage will start. Then the CPD signal is output from the AFM AMP unit, and you can perform SKPM measurement.

• CPD Polarity Reverse

When you check this box, the polarity of the CPD signal output from the AFM AMP unit will be reversed. Change this according to whether the bias voltage applies to the tip or to the specimen.

• Lock-in-AMP signal

Select the desired reference signal for the Lock-in Amplifier that is necessary for KFM feedback.

A–B/A+B: Output the A–B/A+B signal to the Lock-in Amplifier.
FMD: Outputs the FMD signal (frequency-detection signal) to the Lock-in Amplifier.
Filter/KHz: Sets the feedback filter to KFM feedback.
Gain: Sets the gain (loop gain) to KFM feedback.
Offset: Sets the DC offset voltage to be applied to the tip.

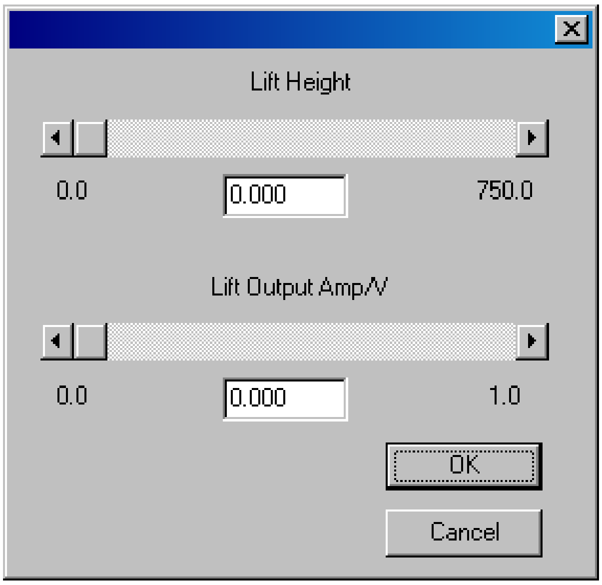
■ Scan Options

When the optional Viscoelasticity Lateral Modulation FFM (Lock-in Amplifier) is installed in the instrument, use the Scan Options dialog box for setting the external instruments. A detailed procedure for setting the Lock-in Amplifier is provided later.

■ Lift

Clicking on the Lift button opens a dialog that you set at the lift operation.

✍ The Magnetic Force measurement is an image acquisition method that acquires magnetic images as well as topographic images by detecting bending caused by the effect of the local magnetic force on the surface of cantilever using the Phase signals that react sensitively with minute signal changes, by separating the specimen from the tip at a greater distance (the distance that causes no bending of the cantilever by the interatomic force) than by measuring topographic images. The process to separate the cantilever from the specimen at that time is called the lift operation.



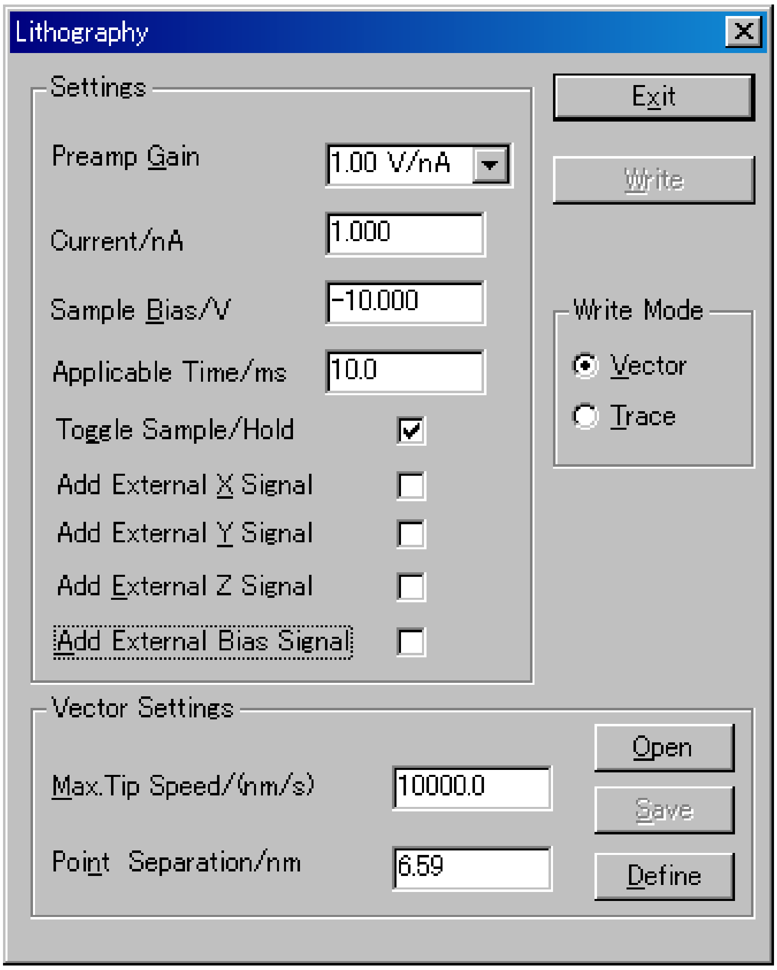
- Lift Height

  Specify the amount to lift up the tip as lift-scan timing.
- Lift Output AMP/V

  When the tip is lifted up, it is necessary to change oscillation voltage to the cantilever in order to obtain beautiful MFM images. Therefore, specify the voltage of the oscillation signal (Output AMP/V of the Cantilever Tuning window) before lifting up the tip. The specification is in effect only when lifting up the tip.

■ Lithography

This opens the Lithography dialog that you should set for applying this instrument to lithography.



● Settings

Specify the parameters for lithography in this frame of the Lithography window:

Parameters	Description
Preamp Gain	Specify the gain for preamplifier in this selection box.
Current/nA (for STM mode)	Specify the tunneling current in this input box.
Reference/V (for AFM mode)	Specify the reference voltage in this input box.
Sample Bias/V	Specify the bias voltage to the sample in this input box.
Toggle Sample/Hold	Select whether or not the feedback circuit should be turned on by checking this box.
Add External X, Y, or Z Signal	Select whether or not the external signal should be added by checking this box.
Time Period/ms	Specify the duration for applying Current/nA or Reference/V in this input box. If 0.0 is specified, Current/nA or Reference/V is applied while pressing the left mouse button. This function is in effect only for Trace mode.

● Vector Settings

Specify parameters for Vector mode in this frame of the Lithography window.

Parameters	Description
Max. Tip Speed/(nm/s)	Specify the speed of the tip movement in this input box.
Point Separation/nm	Specify the step gap for the tip movement in this input box.
Open	A pattern is defined and the data stored in the file is loaded when you click on this button.
Save	The defined pattern is saved in the file when you click on this button.
Define	A designed pattern is defined when you click on this button.

● Write Mode

Select the writing mode for lithography.

Parameters	Description
Vector	When this radio button is selected, the tip moves along the pattern that has already been defined.
Trace	When this radio button is selected, lithography is performed by manual operation of the mouse.

- Vector mode

  After selecting Vector, click on the Write button; then the tip will move along the pattern that has already been defined.

  ✍ Define the pattern using the Open or Define button prior to executing lithography.

- Trace mode

  After selecting Trace, click on the Write button; then execute lithography by moving the mouse on the Display Window while pressing the mouse button.

  ✍ If 0 is specified in Time Period/ms, the same condition is retained while pressing the left mouse-button.

  ✍ The trajectory (pattern) of the mouse movement appears on the Display Window.

● Form of File

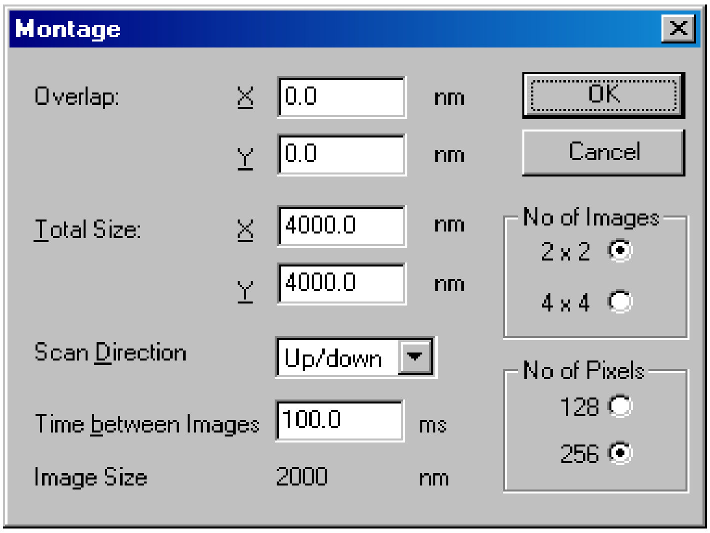
A pattern-definition file is saved in ASCII (American Standard Code for Information Interchange) form, as shown below. This file itself can be edited using the Note pad of Windows98TM.

```
WinSPM Version 4.04
Vector saved on 9/9/1997 at 16:43:15
Vector created on 9/9/1997 at 16:26:02
*
*Start comment lines with a '*'
*
 x1    y1  -  x1    y1:    Bias    Feedback   Gain   Hold   External
165   355    349   250   -10.000    1.000     1.00    1         0
252   437    430   344   -10.000    1.000     1.00    1         0
```

■ Montage

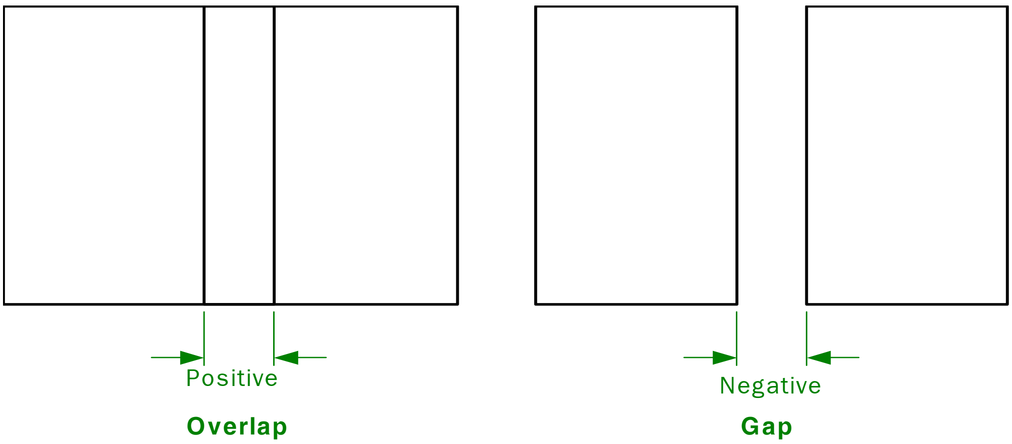
Clicking on the Montage button in the SPM Parameters window opens the Montage window.

✍ In the montage scan, you cannot specify the scan area that exceeds the maximum scan area of your scanner, because the system scans the specified scan area by dividing it.



● Overlap

Continuity between frames is not perfect due to hysteresis and creep in the scanner. Overlap or gap between frames may occur. In such a case, specify the edge-to-edge distance between frames in the X and Y directions in nm. in the Overlap input boxes. You can enter positive and negative values for overlap and gap as shown below independently in the vertical and horizontal directions.

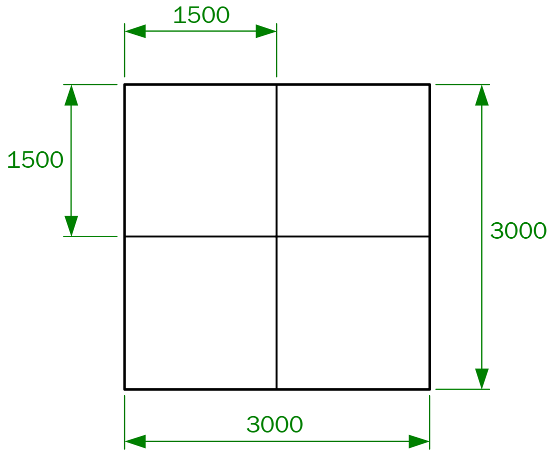


● Total Size

Specify the total scanning area in nm in the Total Size input boxes. The area specified in these input boxes shows the total size of scanning.

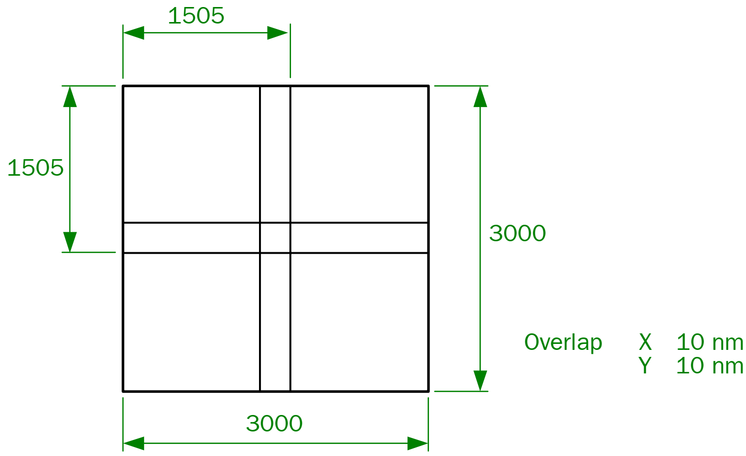
The image will appear as below if the parameters are as follows:

- Number of Images 2 × 2
- Total Size X: 3000 nm, Y: 3000 nm
- Overlap X: 0 nm, Y: 0 nm



The scanning area of an image will appear in the Image Size display position of the Montage window.

If you select Overlap specifying X: 10 nm and Y: 10 nm, the image will appear as below.



In montage scan, this Total Size has priority in determining the scanning range of one frame.

✍ During montage scan, Scan–Size in the SPM Parameters window is not in effect.

● Scan Direction

In this selection box, specify the direction in which the next one-frame-scan moves when the present one-image-scan has finished. Up/down and Left/right are provided in the pull-down menu.

- Up/down

①	⑤	⑨	⑬
②	⑥	⑩	⑭
③	⑦	⑪	⑮
④	⑧	⑫	⑯

4 × 4

①	③
②	④

2 × 2

- Left/right

①	②	③	④
⑤	⑥	⑦	⑧
⑨	⑩	⑪	⑫
⑬	⑭	⑮	⑯

4 × 4

①	②
③	④

2 × 2

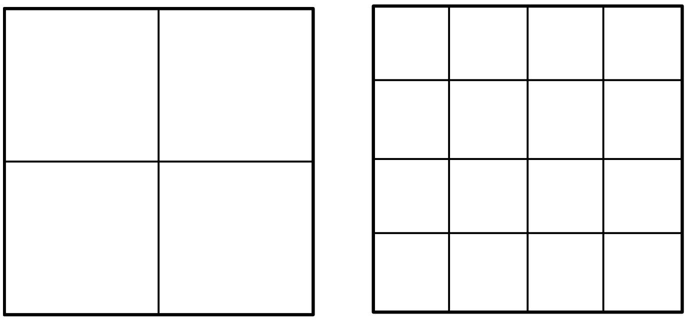
- **Time Between Images**

Specify the waiting time between the one-frame-scan and the next-one-frame scan in this input box. Just after a large shift (frame to frame) of the scanner, drift may occur due to creep in the scanner. In order to decrease the effect of this phenomenon, allow for waiting time.

For obtaining a good montage image, an appropriate setting of Overlap and Time between Images is important and necessary. As these values depend upon Total Size and Clock/ms, try to perform scanning as many times as needed to find appropriate values.

- **Number of Images**

Specify the number of frames on which you want to perform the montage scan. The selections 2×2 and 4×4 are provided. Select one of them by clicking on the radio button. The frame arrangement for each selection is shown below.



2 × 2 4 × 4

- **Number of Pixels**

Specify the number of pixels per scan-frame.

The selections 128 and 256 are provided. Select one of them by clicking on the radio button. When 128 is selected, the one-scan-frame is composed of 128×128 pixels; when "256" is selected, the one-scan-frame is composed of 256×256 pixels.

✍ If 4×4 is selected for No of Images and 256 is selected for No of Pixels, an image appears on the screen as 128×128 pixels, but data is stored in memory as 256×256 pixels.

■ Load

This button is used to recall the parameters saved using the Save button in the SPM Parameters window, and to initialize the SPM CONTROL unit with the parameters.

■ Save

This button is used to save the present parameters specified in the SPM Parameters window in the file.

■ Exit

Clicking on the Exit button terminates the SPM Parameters window.

5.10.4 Setting Lock-in Amplifier

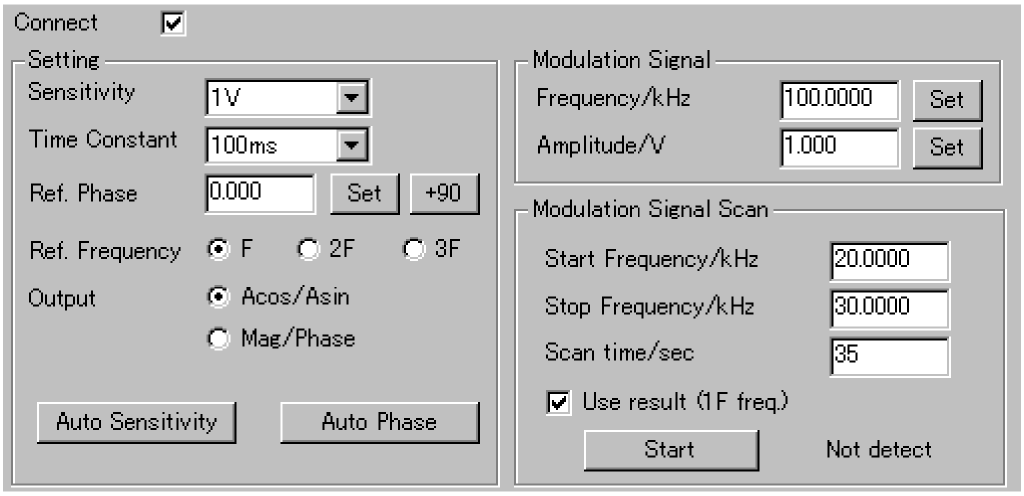
WinSPM supports the following two models in the EG&G INSTRUMENTS lock-in amplifiers.

- Model 7265
- Model 5110

The window contents, with which the WinSPM controls the lock-in amplifier, differ according to the model.

■ Controlling Model 7265

The following items control Model 7265:



● Connect

When you check this, the system starts to connect with the lock-in amplifier using RS232C. Since initialization processing of the lock-in amplifier is performed during its connection with the PC, it takes a little time before the processing completes. If the connection completes normally, a backlight on the front display panel of the lock-in amplifier lights up. If the connection cannot complete normally, an error dialog appears. In such a case, confirm the RS232C cable connection, the power supply of the lock-in amplifier, and the communication settings.

✍ The PC communicates with the lock-in amplifier using the communication port 1 (COM1). So you must connect the RS-232C cable with COM1 port of the lock-in amplifier.

● Setting

This sets signal inputs for the lock-in amplifier.

- Sensitivity

  This sets signal-input sensitivity for the lock-in amplifier. The signal-input sensitivity determines the signal amplitude that can input into the lock-in amplifier. However, if you set too large sensitivity, output-signal precision from the lock-in amplifier decreases. Usually, change the setting from a large value to a small value during use, and set the largest possible value unless the input signal becomes saturated.

  On WinSPM, set the input sensitivity within the range of 100 nV to 1 V.
- Time Constant

  Set a time constant when you perform a detection operation on the lock-in amplifier. The smaller the time constant, the higher the frequency signal at which you can perform the detection operation.

  On WinSPM, set the time constant within the range of 5 ms to 500 ms.
- Ref. Phase

  In order to use the detection operation on the lock-in amplifier, you must make equal the phases of the reference signal and input signal. You use this control to adjust the phases of these signals. By clicking on the Set button, you can set the phase of the reference signal in the range of ±180°. Moreover, if you click on the +90 button, the reference signal is set at the phase rotated 90° from the current phase.
- Ref. Frequency

  For the frequency of the reference signal, set the frequency component of the input signal that you want to detect and output. Let the period of the reference signal be ω, if F is set, the lock-in amplifier locks and outputs the ω component of the input signal. If 2F is set, the lock-in amplifier outputs the 2ω component, which has a double period, as the output signal. Similarly, if 3F is set, the lock-in amplifier outputs the 3ω component, which has a triple period.
- Output

  Set the kinds of output signals from the lock-in amplifier. Since the lock-in amplifier can output two kinds of output signals, set two signals in pairs.

  If you select Acos/Asin, the detection signals in the lock-in amplifier are decomposed and output into the cos component and sin component, respectively.

  If you select Mag/Phase, the amplitude and phase of the detection signals in the lock-in amplifier are output.
- Auto Sensitivity

  When you click on this button, the lock-in amplifier sets an appropriate input sensitivity for the current input signal by using the automatic sensitivity adjusting function of the lock-in amplifier. However, if the amplitude of the input signal changes after you had adjusted the sensitivity, you must readjust it.
- Auto Phase

  Just the same as Auto Sensitivity, when you click on this button, the lock-in amplifier sets an appropriate reference phase so that the reference phase agrees with the input signal phase by using the automatic phase adjusting function of the lock-in amplifier.

● Modulation Signal

To operate the lock-in amplifier, the reference signal is required for locking the input signal. Usually, a signal from the oscillator, which the lock-in amplifier itself has, is used for this reference signal.

Here you set the oscillator of the lock-in amplifier.

- Frequency/kHz

  Set the signal frequency that is output from the oscillator in kHz order. You can also set this by clicking on the Set button using the slider bar.

  On WinSPM, you can set this in the range of 0 to 250 kHz.

- Amplitude/V

  Set the signal amplitude that is output from the oscillator in V order. You can also set this by clicking on the Set button using the slider bar.

  On WinSPM, you can set this in the range of 0 to 5 V.

● Modulation Signal Scan

When you specify the frequency component to detect by means of the Ref. Frequency control such as in measuring the static electric force, you must set the modulation signal frequency so that the lock-in amplifier can perform signal detection with maximum efficiency.
Use this field to find the modulation frequency at maximum efficiency by scanning the modulation signal from the amplifier of the lock-in amplifier and by plotting the output signal from the lock-in amplifier at that time.

- Start Frequency/kHz

  Set the start frequency in kHz order when you perform the modulation-signal scan.

- Stop Frequency/kHz

  Set the stop frequency in kHz order when you perform the modulation-signal scan.

- Scan time/sec

  Set the total time required to perform the modulation-signal scan. The modulation-signal scan takes 35 s in the most rapid scan. You can set 600 s (10 min) as the maximum value.

- Use result (1F freq)

  If you check this box, the system sets the 1F component of the frequency, at which the detected signal of the lock-in amplifier becomes maximum as a result of scanning the modulation signal, to the Frequency/kHz in the Modulation Signal frame.

  The detected frequency also appears to the right of the Start button.

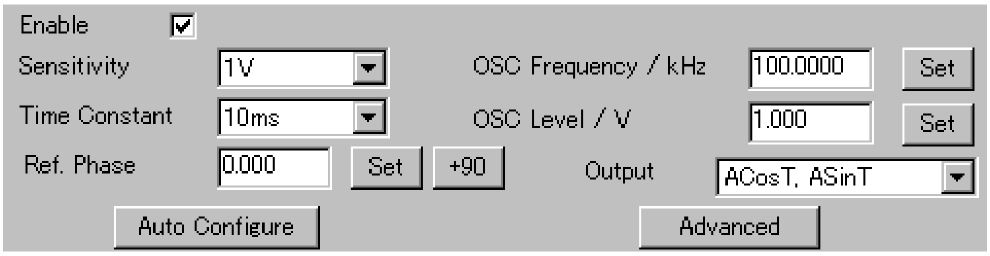
  ✍ In the undetected state, Not detect appears there.

- Start

  This starts the-modulation signal scan.

■ Controlling Model 5110

The following items control Model 5110.



● Enable

When you check this, the system starts to connect with the lock-in amplifier using the RS232C. Since the initialization processing of the lock-in amplifier is performed during its connection with the PC, it takes a little time before the processing completes. If the connection cannot complete normally, an error dialog appears. In such a case, confirm the RS232C cable connection, the power supply of the lock-in amplifier and the communication settings.

✍ The PC communicates with the lock-in amplifier using the communication port 1 (COM1). So you must connect the RS-232C cable with the COM1 port of the PC.

● Sensitivity

This sets the signal-input sensitivity for the lock-in amplifier. The signal-input sensitivity determines the signal amplitude that can input into the lock-in amplifier; however, if you set too large sensitivity, the output-signal precision from the lock-in amplifier decreases. Usually, change the setting from a large value to a small vale while you use it, and set the largest possible value unless the input signal becomes saturated (the OVLD indicator lights up).

● Time Constant

Set a time constant when you perform the detection operation on the lock-in amplifier. The smaller the time constant, the higher the frequency signal at which you can perform the detection operation.

● Ref. Phase

In order to use the detection operation of the lock-in amplifier, you must make equal the phases of the reference signal and input signal. You use this control to adjust the phases of both signals. By clicking on the Set button, you can set the phase of the reference signal in the range of ±180°. Moreover, if you click on the +90 button, the reference signal is set at the phase rotated 90° from the current phase.

● OSC Frequency / kHz

To operate the lock-in amplifier, the reference signal is required for locking the input signal. Usually, a signal from the oscillator, which the lock-in amplifier itself has, is used for this reference signal.

Set the signal frequency that is output from the oscillator in kHz order. You can also set this by clicking on the Set button using the slider bar.

● OSC Level / V

Set the signal amplitude that is output from the oscillator in V order. You can also set this by clicking on the Set button using the slider bar.

● Output

Set the kinds of output signals from the lock-in amplifier. Since the lock-in amplifier can output two kinds of output signals, set two signals in pairs.

If you select ACosT, ASinT, the detection signals in the lock-in amplifier are decomposed and output into the cos component and sin component, respectively.

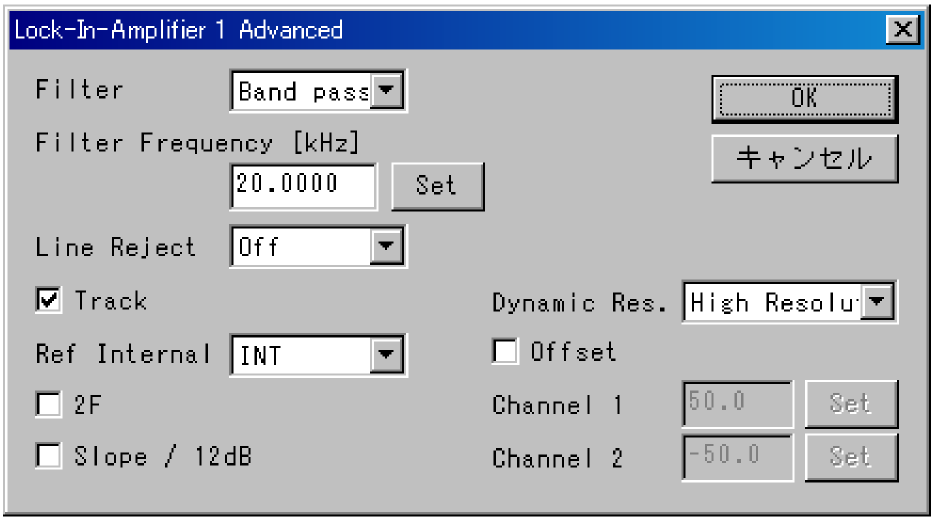
If you select Amplitude, Phase, the amplitude and phase of the detection signals in the lock-in amplifier are output.

● Auto Configure

When you click on this button, the lock-in amplifier sets an appropriate input sensitivity for the current input signal and reference phase so that the reference phase agrees with the input signal phase by using the automatic adjusting function that the lock-in amplifier itself has.

● Advanced

This displays a dialog that enables you to perform a more detailed setting for the lock-in amplifier.



• Filter

This sets a filter for the input signal. Usually, select Band Pass.

Flat   Do not apply a filter.
Low Pass   Apply a low pass filter.
Band Pass   Apply a band pass filter.

• Filter Frequency [kHz]

In the Filter selection, this sets the cutoff frequency if you select Low Pass or Band Pass.

- Line Reject

  This reduces the power-supply noise by applying a filter for the power-supply (AC 100 V) frequency that enters the input signal. Usually, select Off.

Off	Do not use Line Reject.
F	Apply a filter for the power-supply frequency.
2F	Apply a filter for the double harmonic frequency of the power-supply frequency.
F + 2F	Apply a filter for both the power-supply frequency and its double harmonic frequency.

- Track

  This sets whether you apply the filtering frequency band to the reference signal. Usually, check this box.
- Ref Internal

  Select which signal do you use as a reference signal that is used for the lock-in amplifier. Usually, select INT.
  - INT Use the internal oscillator of the lock-in amplifier.
  - TTL Use the TTL level input-signal for the locking operation.
  - EXT Use an external oscillator for the locking operation.
- 2F

  This selects which frequency components of the input signal do you detect and output for the reference signal frequency. Usually, do not check this box.

  Let the period of the reference signal be ω, the lock-in amplifier locks and outputs the ω component of the input signal. If this box is checked, the 2ω component, which has a double period, is output as the output signal.
- Slope / 12dB

  This specifies the filtering for the output signal. Usually, do not check this box.
- Dynamic Res.

  This sets the Dynamic Reserve mode. Usually, set Normal or High Resolution.
- Offset

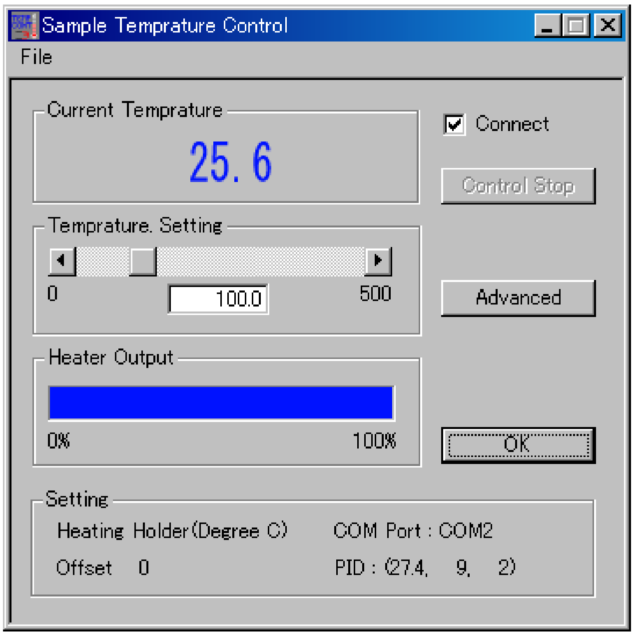
  Check this box when you set the offset for the output signal. Usually, do not check this box.
- Channel 1 / Channel 2

  Set the offsets for both output channels 1 and 2. You cannot use this when the Offset is not checked.

5.10.5 Controlling Specimen Temperature

■ Sample Temperature Control dialog

This is a dialog for controlling the specimen temperature.



● Current Temperature

This displays the current temperature read by a temperature sensor, which is attached to the specimen holder.

- When the temperature display appears in red

  This shows that the current temperature is more than 1 ℃ higher than the set temperature.

- When the temperature display appears in green

  This shows that the current temperature is within ±1 ℃ of the set temperature.

- When the temperature display appears in blue

  This shows that the current temperature is more than 1 ℃ lower than the set temperature.

● Temperature Setting

This sets a desired specimen temperature you want. You can set the temperature in 0.1 ℃ unit:

- When you use a heating holder

  You can set the temperature from 0 ℃ to 500 ℃ (273.1K to 773.1K). When you use a heating holder, control the temperature by heating the specimen from room temperature using a heater. Be careful that the actually controllable temperature range and the required time to reach the set temperature differ depending on the specimen.

- When you use a cooling holder

  You can set the temperature from −199 ℃ to 50 ℃ (74.1K to 323.1K). When you use a cooling holder, control the temperature by heating the specimen from the cooled state using a heater. Be careful that the actually controllable temperature range and the required time to reach the set temperature differ depending on the specimen.

● **Heater Output**

This displays the output to the present heater as a percentage. The maximum current of the direct-current power-supply of the temperature controller basic unit determines the actual output voltage. For example, when you set the maximum current of the direct-current power-supply to 1 A, about 0.5 A is output to the heater if the indicator is positioned near the middle of its scale.

The temperature controller controls the temperature using the PID control; but generally you can accomplish stable temperature control when the temperature reaches an equilibrium state near the set temperature and the heater output becomes roughly 50%. Since the setting temperature differs according to an observation object or purpose, adjust the maximum current of the direct-current power-supply depending on the setting temperature.

✍ When you change the output voltage during temperature control, temperature control worsens owing to the change of the output voltage. It takes a little time to recover from such an unfavorable situation.

● **Setting**

This shows setting conditions for the current temperature control. You can change the setting from the Advanced Temperature Control dialog.

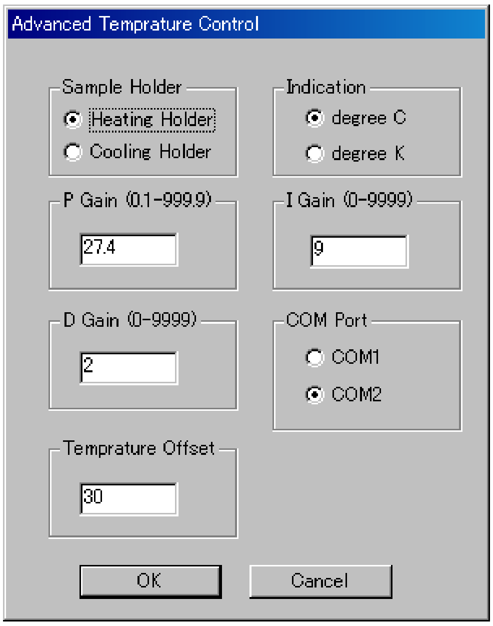
● **Control Stop**

This stops the temperature control under the present state, and holds the heater output under the present state. Use this button when the specimen temperature becomes stable near the set temperature and the heater-output change becomes small. Click on this button before you start SPM measurement for preventing the heater-output change from affecting the measurement. The indication on the button during the control suspension changes to Control Start.

● **Advanced**

This displays the Advanced Temperature Control dialog for setting such as the holder type and PID parameters.

■ Advanced Temperature Control dialog



● Sample Holder

Select the holder type attached to the instrument.

● Indication

Select which temperature to display, Celsius or Fahrenheit.

● COM Port

Specify the communication-port (COM port) number of the PC with which the temperature controller communicates. Usually, use COM1 for communicating with the lock-in amplifier, and COM2 for communicating with the temperature controller.

Connect the RS-232C cable, with which the temperature controller connects, to the specified COM port of the PC. The RS-232C communication settings are as follows:

Communication speed:	9,600 bps
Data length:	7 bit
Parity:	Even
Stop bit:	1 bit

● P Gain / I Gain / D Gain

These set the PID parameters for controlling temperature. Although the exact parameter values differ depending on the unevenness of the holder, specimen size and specimen temperature, the default values are as follows:

P Gain:	27.4
I Gain:	9
D Gain:	2

☞ For more details on the PID control, refer to the instruction manual or other explanatory books.

● Temperature Offset

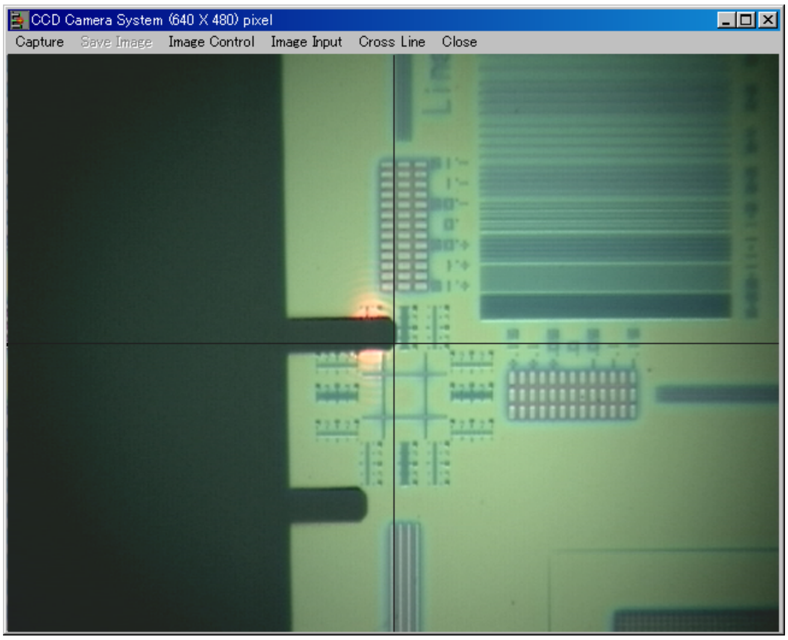
The temperature measurement is performed by measuring the resistance of the temperature sensor (platinum thin-film resistance pair). The resistance sometimes increases a little owing to the contact resistance of screws attached to the holder, cable resistance or other resistances. This causes the sensor to display a higher temperature on the dialog than the actual temperature. Set an offset to correct this error.

When the actual temperature of the specimen is 20 ℃ (the temperature is measured before heating or cooling), if the indicated temperature on the dialog under Offset 0 appears 25 ℃, set −5 for Offset.

✍ The temperature offset applies for both display temperature and setting temperature.

5.10.6 CCD Camera

This displays images from the CCD camera. You can adjust the image size to display it depending on the window size. You can change the image size from 640×480 pixels to 256×192 pixels. However, the image size changes based on its width so that the ratio of length and width remains constant.



● Display of title bar

The current display size of the CCD image appears on the title bar.

● Functions of menu bar

The menu on the top of the window acts like buttons on which you click to execute its functions.

- Capture

  This controls stop and restart of CCD image acquisition (Capture). While Capture is stopped, the display of the title and menu bars changes as follows.

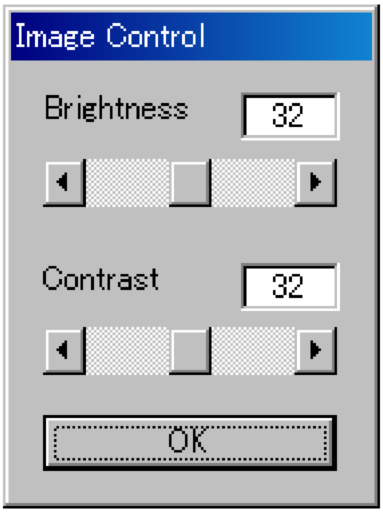
- Save Image

  This is used only while Capture is stopped. You save the CCD image (still image), while Capture is stopped, on a file as a BMP image with the same size as the display size.
  When you click on this, the Save as dialog appears. Specify the destination directory and file name to save the image.

- Image Control

  This adjusts the brightness and contrast of the CCD image. The image adjustment is performed on the video capture board after image acquisition. So you cannot perform image adjustment while Capture is stopped.

  When you click on this, the following dialog appears. Adjust brightness and contrast while watching the image. You can change the brightness and contrast parameters in the range of 0 to 63; the standard value is 32.



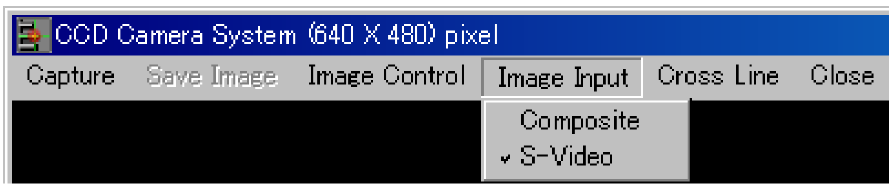
  - Brightness

    The image is darkest at 0, brightest at 63; the standard value is 32.
  - Contrast

    Image contrast is lowest at 0, highest at 63; the standard value is 32.

- Image Input

  This selects an input terminal when you input the image from the CCD camera into the video capture board, FlashBus MV. Select Composite when you input the image from the camera using the BNC terminal, or select S-Video when you input the image from the camera using the S-VIDEO terminal.



- Cross Line

  This changes whether you display a cross line or not on the CCD image. It changes every time you click on this. The cross line appears on the center of the image.
- Close

  This closes the CCD camera window.

6

ANALYSIS OPERATION

6.1 PROCESS MODE 6-1
6.2 IMAGE PROCESSING AND DATA PROCESSING FUNCTIONS 6-2
6.3 EXAMPLE OF PROCESS FUNCTION 6-4
6.3.1 Example of Using the Image Processing Function 6-4
6.3.2 Example of Using the Data Processing Function 6-11
6.3.3 Arranging the Measured Data 6-14
6.4 FILE MENU 6-17
6.5 EDIT MENU 6-25
6.6 PROCESS MENU (IMAGE PROCESSING FUNCTION) 6-26
6.6.1 Filter 6-26
6.6.2 Edge Enhance 6-29
6.6.3 Differentiate 6-30
6.6.4 Normalise 6-30
6.6.5 Normalise S.D. 6-30
6.6.6 Median 6-31
6.6.7 Subtract Background... 6-32
6.6.8 Single Math 6-33
6.6.9 Double Math 6-34
6.7 ANALYSE MENU (IMAGE PROCESSING FUNCTION) 6-35
6.7.1 Profile 6-35
6.7.2 Measure 6-45
6.7.3 Zoom 6-47
6.7.4 Trim 6-48
6.7.5 FFT (Fast Fourier Transformation) 6-49
6.7.6 Particle Analysis 6-56
6.7.7 Draw Mesh 6-60
6.7.8 Roughness 6-61
6.8 GEOMETRY MENU (IMAGE PROCESSING FUNCTION) 6-63
6.8.1 Translate 6-63
6.8.2 Rotate 6-63

6.8.3 Mirror.......6-64
6.8.4 Resize.......6-65
6.8.5 Pad Points.......6-66
6.8.6 Drift Correction.......6-67
6.8.7 Average Unit Cell.......6-67
6.8.8 Extract Area.......6-68
6.8.9 Replace Area.......6-69
6.9 LUT (HEIGHT INFORMATION).......6-70
6.9.1 Brightness/Contrast.......6-70
6.9.2 Set Window.......6-71
6.9.3 Histogram.......6-72
6.9.4 Display Image LUT.......6-73
6.9.5 Linearise Image LUT.......6-74
6.9.6 LUT Math.......6-75
6.9.7 Fix Z scale.......6-75
6.10 DISPLAY MENU (IMAGE PROCESSING FUNCTION).......6-78
6.10.1 Display.......6-78
6.10.2 Display Parameters.......6-78
6.10.3 Full Display.......6-81
6.10.4 3D Display.......6-82
6.10.5 Display Colours.......6-87
6.10.6 Clear Memory (FS).......6-88
6.10.7 Grab from Memory (FS).......6-89
6.10.8 Change Parameters.......6-90
6.10.9 Display SPS Measurement Position.......6-91
6.11 MAPPING MENU (IMAGE PROCESSING FUNCTION).......6-92
6.11.1 Display Parameters.......6-93
6.11.2 Special Displays.......6-94
6.11.3 SPS Mapping Select.......6-95
6.11.4 Edit SPS Mapping Data Set.......6-96
6.11.5 Average Images.......6-99
6.11.6 Duplicate Data Set.......6-99
6.11.7 Extract Spectra.......6-99
6.12 PROCESS MENU (DATA PROCESSING FUNCTION).......6-101
6.12.1 Smooth.......6-101
6.12.2 Math X, Math Y.......6-102
6.12.3 2 Spec Math.......6-103
6.12.4 Differentiate.......6-104
6.12.5 Remove DC Bias.......6-104
6.13 ANALYSE MENU (DATA PROCESSING FUNCTION).......6-105
6.13.1 Fit Polynomial.......6-105
6.13.2 Zoom.......6-105
6.13.3 Measure.......6-106
6.13.4 Group Plot.......6-107
6.13.5 Show FFT.......6-108
6.14 DISPLAY MENU (DATA PROCESSING FUNCTION).......6-109
6.14.1 Plot.......6-109
6.14.2 Plot Parameters.......6-109

6.15 SELECT MENU 6-111
6.16 WINDOW MENU 6-112
6.17 SPM SCAN MENU 6-113
6.18 HELP MENU 6-117

6.1 PROCESS MODE

The WinSPM system has two modes, a scan mode and a process mode, which are independent of each other. Here, a description is given of the method of operating the process mode.

■ Starting the System in the Process Mode

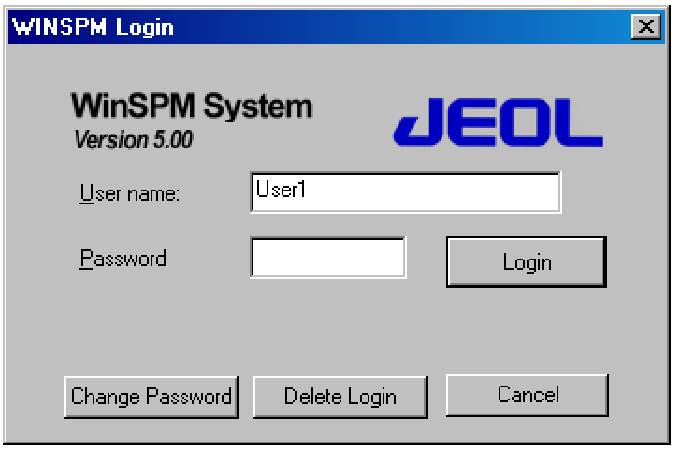
1. Turn ON the POWER switch on the control unit, then turn ON the switch of the computer.

Confirm that power is supplied to both the computer and the display.

✍ There is no need to carry out this operation if power is already being supplied to the computer and Windows has started.

2. When Windows starts, double-click the Analysis icon on the desktop.

The WinSPM software starts in the process mode, and in the same way as when the scan mode starts, the system asks you for your user name and password.



✍ This window will appear even if the software has already started in the scan mode.

3. Enter the user name and password, then click OK with the mouse.

The WinSPM software starts in the process mode.

■ Controlling User Name

☞ Refer to Sect. 5.1.3 " Controlling User Name".

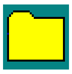
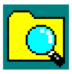
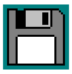
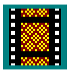
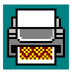
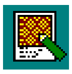
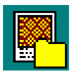
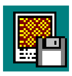
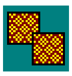
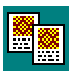
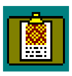
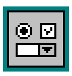
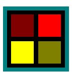
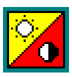
6.2 IMAGE PROCESSING AND DATA PROCESSING FUNCTIONS

Basically, the process mode has two kinds of analysis functions.

■ Image processing function

This is an image processing function that analyzes an SPM image. It can analyze the image being measured, and also carry out image processing. By displaying an SPM image in the image window, the main menu automatically changes to the image processing menu.

● Shortcut icons for image processing

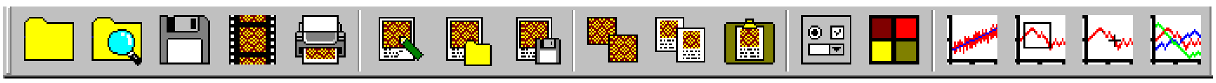
	"Open"	Loads the data file from the disk.
	"Find"	Searches the list of data files.
	"Save As"	Saves data on the disk as file.
	"Replay"	Replays the continuous measurement image by easy movie.
	"Print"	Prints out data.
	"Make Report"	Creates a report.
	"Load Report"	Loads a report from the file.
	"Save Report"	Saves the created report in the file.
	"Copy"	Transfers the displayed image to the clipboard.
	"Copy Data"	Transfers data to the clipboard.
	"Paste Data"	Transfers data from the clipboard.
	"Display Param"	Opens the Display Parameters dialog.
	"Display Colors"	Opens the Display Colors dialog.
	"Brightness/Contrast"	Adjusts the brightness and contrast of the image.

“Subtract Background”	Opens the Subtract Background dialog.
“Filter”	Executes filtering.
“Median”	Eliminates spike-shaped electric noise.
“Single Profile”	Executes cross sectional analysis.
“Multi Profile”	Executes multiple cross sectional analysis.
“Roughness”	Executes surface roughness analysis.
“Multi Image Profile”	Executes cross sectional analysis for multiple images.
“Particle”	Executes particle analysis.
“FFT”	Executes FFT (Fast Fourier Transformation) analysis.
“3D Display”	Executes three-dimensional display.

■ Data processing function

This function can analyze SPS data and also perform arithmetic processing. By displaying the SPS data in the image window, the main menu automatically changes to the data processing menu.

● Shortcut icons for data processing



Functions of the shortcut icons ranging from “Open” to “Display Colors” are the same as those in image processing.

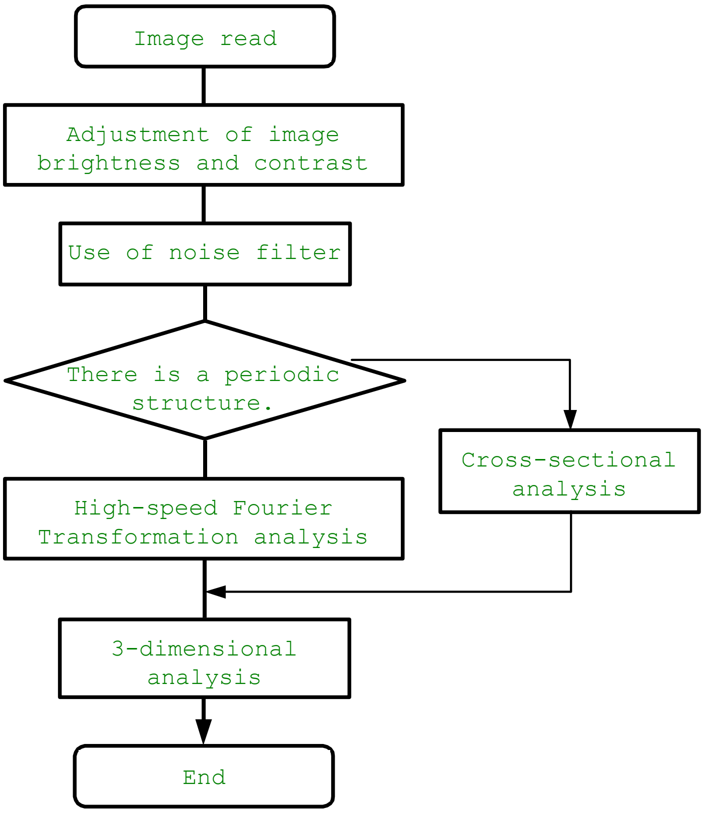
“Fit Polynomial”	Displays a higher order approximation curve and its approximation expression.
“Zoom”	Expands a part of a graph.
“Measure”	Checks numeric values and difference between two points on a graph.
“Group Plot”	Overlays multiple graphs on display.

6.3 EXAMPLE OF PROCESS FUNCTION

We describe the typical example of process functions.

6.3.1 Example of Using the Image Processing Function

Here, a description is given of functions that are often used in the image processing function. The general flow of image processing is shown below.



General image processing

■ Reading an Image

There are two methods of reading an SPM image.

● Transfer the measured SPM image from the scan mode.

This method is useful when you wish to perform image processing while performing measurement.

1. Using the scan mode, display the image to be analyzed in the Display Window.
2. Click on Copy Data shortcut icon.
   The displayed SPM image and the measurement data are copied to the clipboard.
3. Switch over the application to the process mode.
4. Regarding the mode switchover method, refer to the Windows manual. Click on Paste Data shortcut icon.

The SPM image that was copied in the scan mode and also the measured data are transferred to the process mode, and the image is displayed in the "Display Window".

● **Read the SPM image stored in the file.**

Read the SPM image from the file.

1. Click on the Open shortcut icon.

   The Open dialog box appears.

2. Select the file that you wish to subject to image processing, and click on the Open (O) button.

   The specified SPM image is loaded and displayed in the Display window.

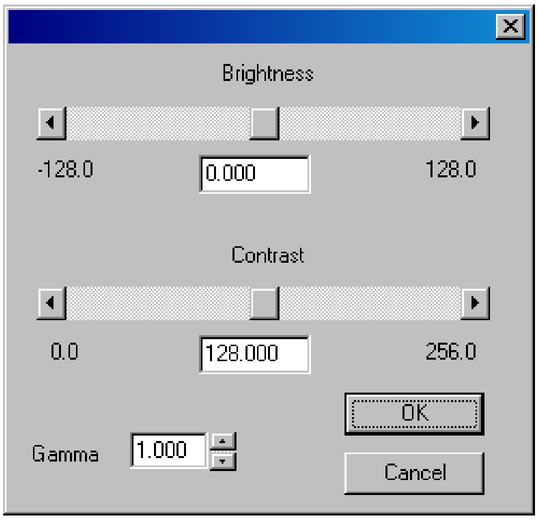
   ✍ The extension of an SPM image file is "tif".

■ Adjusting the Brightness and Contrast of an Image (Brightness/Contrast)

Adjust the brightness and contrast of the image so as to obtain an image that is easy to observe.

1. Click on Brightness/Contrast shortcut button.

   The image appears as 400×400 pixels on the image display, and a bar chart appears on the console display.



2. Adjust the brightness and contrast using the mouse.

   The brightness and contrast of the image changes in real-time, so perform adjustment while observing the image. When you carry out adjustment, use the LUT bar and the histogram bar, both of which are displayed at the left of the image, as a guide in performing adjustment.

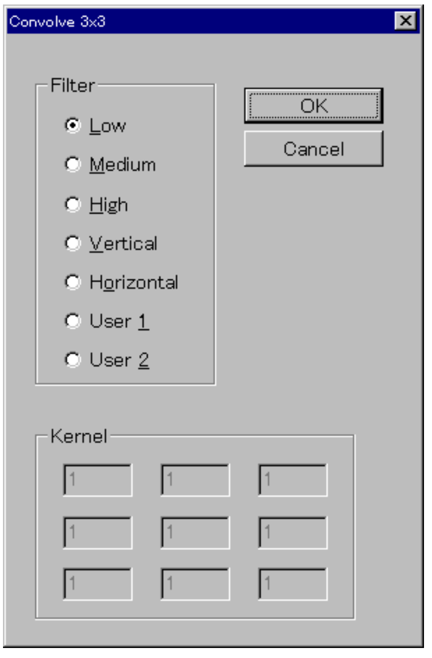
3. Perform adjustment so as to obtain the optimum image, then finalize the adjustment by clicking OK.

   The image returns to its initial size, and is displayed at the changed brightness and contrast.

■ Use of Noise Filter (Convolve 3×3 Low Pass)

The noise filter removes unwanted noise from the image.

1. Click on the Filter shortcut icon.
2. The Filter dialog appears. Click on Convolve 3×3.
3. The Convolve 3×3 window appears.
4. Select Low and click on OK.



Filtering starts, and the filtered image appears on the image display.

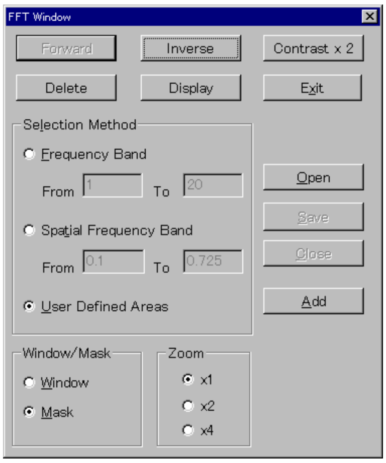
■ High-speed Fourier Transformation Analysis (FFT)

FFT is performed on an image that has a periodic structure, such as a crystal, or a rearranged structure, in order to obtain a diffraction pattern. It is also possible to apply a mark to the acquired diffraction pattern, and perform reverse Fourier analysis of specified components alone.

1. Click on the FFT shortcut icon.

2. Select Forward on FFT Window displayed.

Fourier transformation starts. Upon completion of Fourier transformation, a diffraction pattern appears on the display.



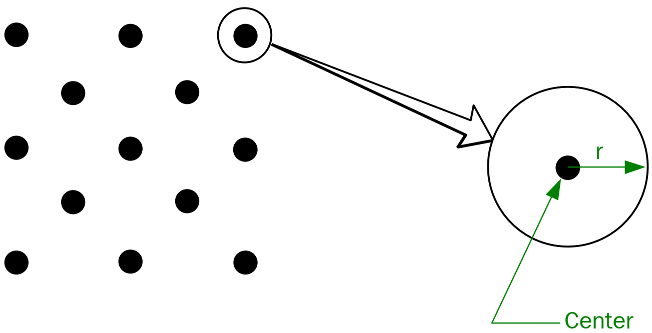
3. If the spots of the diffraction pattern are dark, making them difficult to see, select Contrast×2 to increase the contrast.

✍ Contrast×2 generates double brightness when selected once. You can make this selection any number of times.

If you wish to remove unwanted spots and perform a reverse Fourier transformation, next carry out steps 3 to 6 below.

4. Click on Add.

5. Apply a mask window to a valid spot.



✍ To set a mask window, move the cursor to the center of the spot, and click the left mouse button. Next, move the cursor a distance equal to the radius, then click the left mouse button, and a window appears.

✍ To erase a mask window, set Window/Mask to Window, specify the center point, then move the cursor a distance equal to the radius. Next, click the left mouse button, and an area equal to a circle of the radius through which the cursor was moved will be erased.

✍ To define another mask window, click on Add.

6. Click on Inverse.

A reverse Fourier-transformed image will appear.

7. Click on Exit to finish the FFT process.

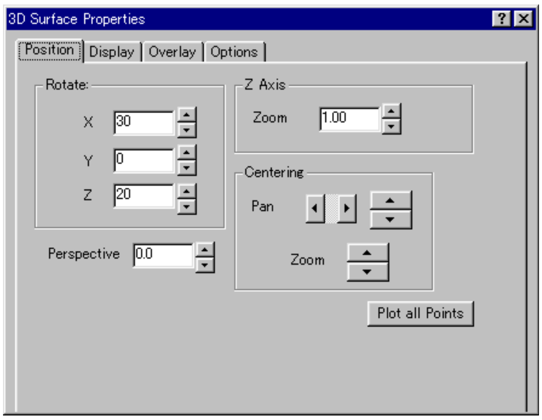
■ 3D Display

By displaying an image in 3-dimensional form, you can intuitively understand the surface structure. This system enables you to display an acquired image in 3-dimensional form.

1. Click on 3D Display shortcut icon.

The 3-dimensional display window 3D Display and the 3D Display Properties control panel appear.

Also, a 3-dimensional image is displayed in simplified form in the 3D Display window.



2. Set the display direction and position of the 3-dimensional display image.

Specify the rotation of a 3-dimensional image using Rotate in the Position tab, the display magnification in the height direction using Z Axis, and the display position using Centering.

3. Set the display direction of a 3-dimensional display image.

Select Alpha overlay from Display Mode in the Display tab. Also, set Alpha Level in the Option tab.

Setting the Alpha Level value to about 0.3 results in a biological surface image that appears to have a wet surface. Setting it to about 0.7 results in a metallic surface image that has luster.

4. Set the surface characteristics of a 3-dimensional display image.

Select the Display tab, then set the surface characteristics of the 3-dimensional image using Surface.

Set Diffuse level to about 0.5, Specular level to about 0.5, and Shininess to about 6.0.

✍ The optimum values of these settings differ depending upon the displayed image.

5. Set the light source of the 3-dimensional display image.

a. Check Display Light Source Vectors in the Display tab.

The position of the light source and the illumination direction with respect to the 3-dimensional image are plotted.

b. You can set a maximum of two light sources, so set the illumination direction of the light and the intensity of the illumination light using Light1 and Light2 in the Display tab, while observing the change in the plotted light source position and the 3-dimensional display image.

✍ When setting two light sources, if you emit a strong beam using Light1, and emit a weak beam using Light2 in the direction so as to cancel the shadow created by the strong beam, you will obtain a clean, 3-dimensional display image.

6. Perform precision computation for a 3-dimensional display.

a. Remove the check from Display Light Source Vectors in the Displaytab.

b. When the light source position display goes out, press the Plot all Points button, and perform precision computation for the 3-dimensional display.

As a result of this computation, you can acquire a precise 3-dimensional display image.

■ Cross-Sectional Analysis (Profile)

When using the SPM, it is important to obtain information concerning the height direction of the acquired image. There are four modes, “Single Profile”, which enables you to select and measure an arbitrary cross-section in the measurement image, “Multi Profile”, which enables you to display up to five cross-sections, “Extra Profile”, which enables you to perform analysis of multiple frequencies simultaneously and “Multi Image Profile”, which enables you to analyze the cross-section of the same line on the up to three different images.

✍ In the case of a sample that has large surface irregularities, stepped parts of the image may sometimes lack sharpness depending upon the shape of the probe tip. For this reason, be careful when interpreting the measurement results.

● Single Profile

1. Click on the Single Profile shortcut icon.

The Single Profile window appears.

2. Specify the measurement position with the mouse.

The measurement position is indicated by the arrow in the preview image of the Single Profile window. You can specify an arbitrary cross-section by dragging the starting and end points of the arrow with the mouse.

The cross-sectional view appears at the bottom of the window.

3. If necessary, move the measurement marker into the cross-sectional view, and perform measurement inside it.

● Multi-Image Profile

1. Display the first of a set of images that you want to analyze in the Display Window.

2. Click on the Multi Image Profile shortcut icon.

The Multi Image Profile dialog appears.

3. Select a set of data that you want to analyze from the list of measurement data and click on the Make button.

   The Multi Image Profile window appears.

4. Specify the measurement position using the mouse.

   The measurement position is indicated by the arrow on the preview image in the Multi Image Profile window. You can specify an arbitrary cross-section by dragging the start and end points of the arrow with the mouse.

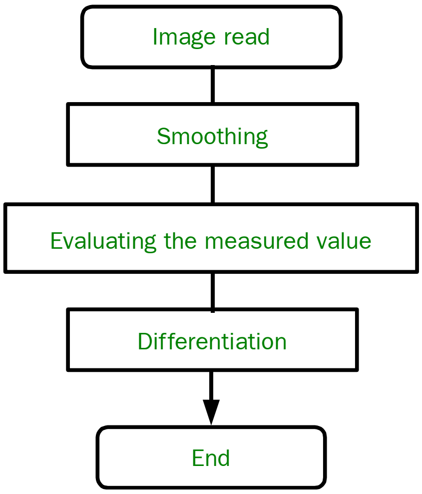
   The cross-sectional view appears at the bottom of the window.

5. Move the measurement marker into the cross-sectional view, if necessary, to measure a length inside it.

6.3.2 Example of Using the Data Processing Function

The WinSPM system has more than 30 kinds of data processing functions.

The general flow of data processing is shown below.



General data processing

■ Data Read

There are two methods of reading SPS data.

● Transfer SPS data measured from the scan mode.

This method is useful for performing data processing while performing measurement.

1. Using the scan mode, display the SPS data that you wish to analyze in the Display Window.
2. Click on Copy Data shortcut icon.
   The displayed SPS data and the measured data are copied to the clipboard.
3. Switch over the application to the process mode.
4. Click on Paste Data shortcut icon
   The SPS data and measurement data copied in the scan mode are transferred to the process mode, and the image appears in the "Display Window".

● Read an SPM image stored in a file.

Read the SPS data from the file.

1. Click on Open shortcut icon.
   The Open dialog box appears.
2. Select the file that you wish to subject to image processing, and press the Open (O) button.
   The specified SPS data is loaded, and displayed in the Display Window.
   ✍ The extension of an SPM image file is "spc".

■ Smoothing (Smooth)

If there is a lot of noise in the graph, carry out smoothing. If there is a small amount of noise over the entire graph, select Average. If there is spike-shaped sporadic noise, select Median.

✍ If you perform smoothing, the data changes from the pre-processed value as a result of the smoothing computation. For this reason, be very careful when evaluating the data after carrying out smoothing.

1. Select Process from the menu, then select Smooth in the pull-down menu.

2. Set Method to Average, specify the number of points to be used for smoothing, then select OK.

Smoothing takes place, and the data is displayed.

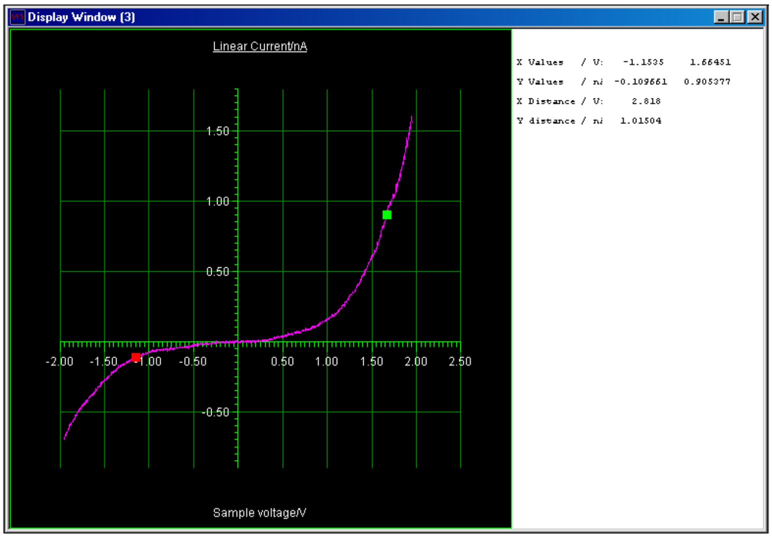
✍ It is recommended that you use between 5 and 7 points. Note that several points at the edge of the graph are not smoothed.

■ Evaluating the Measurement Values (Measure)

You can measure the values at arbitrary points on the graph or the difference between the values at two points.

1. Click on Measure shortcut icon.

The Display Window will appear.



2. Drag the red and green markers on the graph to set the measurement points.

The value at the mark position and the relative value between the red and green markers are displayed on the right of the graph.

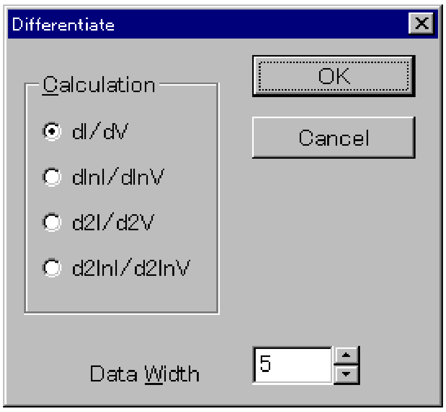
3. Press the right mouse button to exit processing.

You can freely move the marker position until the time when you click on the right mouse button (during the time the mouse courser's shape is fingered).

■ Differentiation (Differentiate)

I-V curves and other parameters are frequently differentiated before being processed. In this system, differentiation is done by one command.

1. Select Analyse from the menu, then select Differentiate from the pull-down menu that appears.



2. Select dI/dV, then select the number of points to use for computing the differential value.

If you select five points, differential coefficients for five points consisting of the point of interest and two points on each of the left and right of it are computed.

6.3.3 Arranging the Measured Data

Arrange the analyzed data in the output sheet format.

■ Creating an output sheet

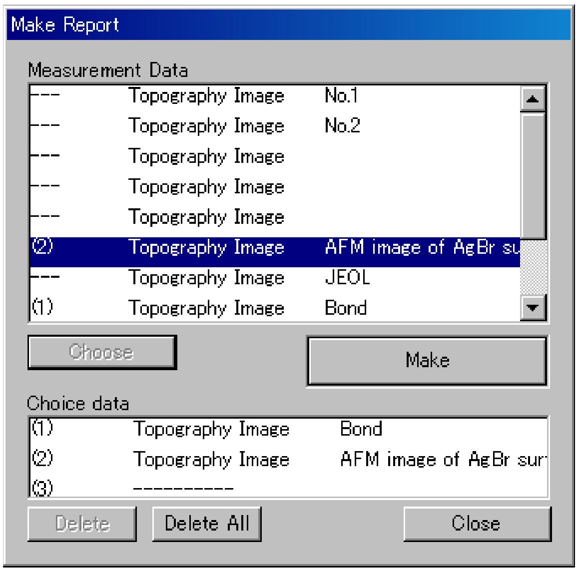
● Arrange the image data and the spectrum data in the output sheet

1. Display the data you wish to display in the Display window.

2. Activating the Display window, click on the Make Report shortcut icon.

The Make Report dialog box appears.

3. The list of both the image and the spectrum data is displayed. Select the data to arrange and click on the Choose button.

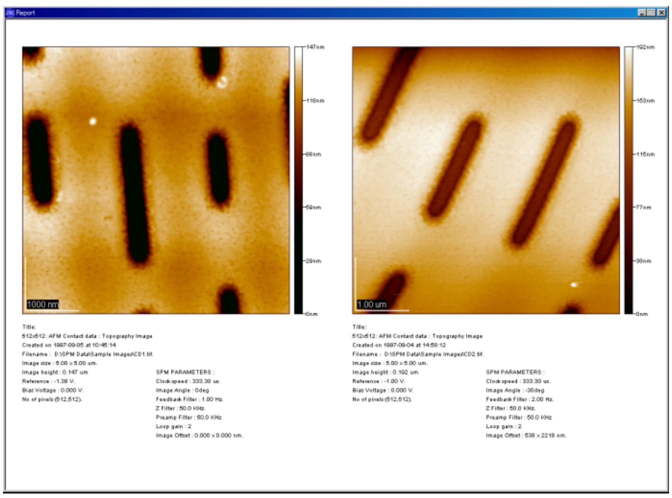


✍ You can select up to three sets of data.

✍ The data displayed in the Display window when you clicked on the Make Report shortcut icon is automatically selected as the first data.

4. When you have finished selecting data, click on the Make button.

The Report window appears.

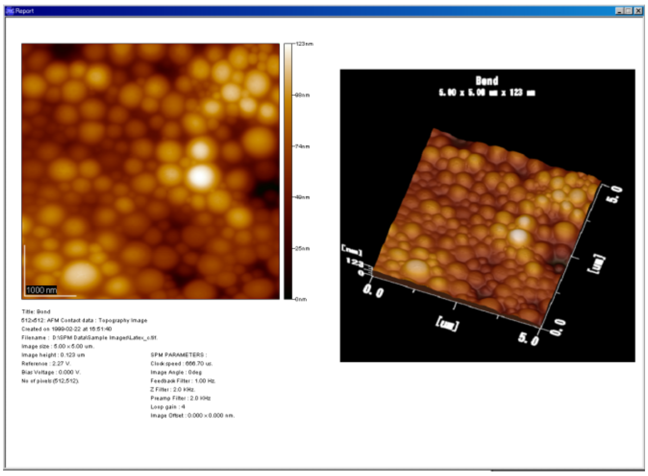


- **Arrange the 3D display image in the output sheet**

1. Create a 3D display image.

2. Activating the 3D Display window, click on the Make Report shortcut icon.

2D and 3D display images are created in pairs in the output sheet and displayed in the Report window.

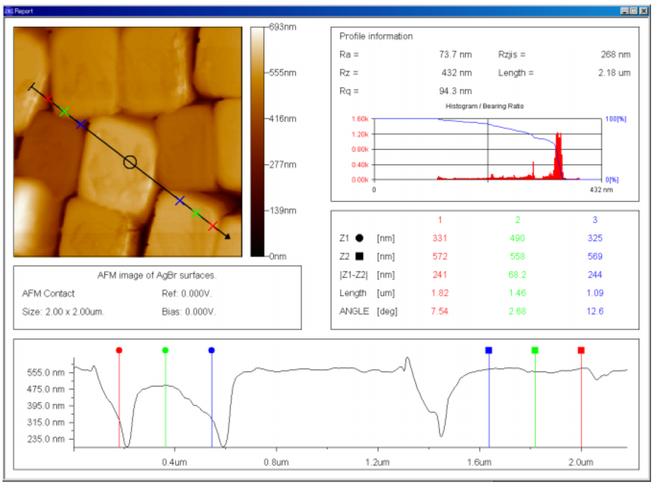


- **Arrange the results of the cross-sectional and roughness analyses in the output sheet.**

1. Perform various kinds of cross-sectional and roughness analyses.

2. Activating each analysis window, click on the Make Report shortcut icon.

Information on each analysis window is created as the output sheet as it is and displayed in the Report window.



■ Saving and printing the output sheet

After having created an output sheet, save and print it.

● Saving an output sheet

You can save an output sheet in the following two types of file.

- Saving it in the WinSPM original file

  Activating the Report window, click on the Save Report shortcut icon to save an output sheet in the file. The extension of the output sheet file is "∗.RPT". By reading the saved output sheet file, you can load the SPM data and the output sheet again in the WinSPM.

- Saving it in the BMP image file

  Activating the Report window, select File – Save BMP Image. The information in the output sheet is saved in the BMP file with the same image size as the original.

  ✍ When you want to use the output sheet in the Windows application other than the WinSPM, save it in the BMP image file.

  ✍ Saving in the BMP image file saves only the images in the output sheet not the SP data.

  ✍ When the output sheet is saved in the WinSPM original file and printed in the WinSPM, the text characters except those in the graph or in the image are output using the True Type font. When the output sheet is saved in the BMP image file, pay attention that the characters are output as a simple bitmap font.

● Printing an output sheet

Activating the Report window, click on the Print shortcut icon. The output sheet will be printed to meet the sheet size specified in the printer driver.

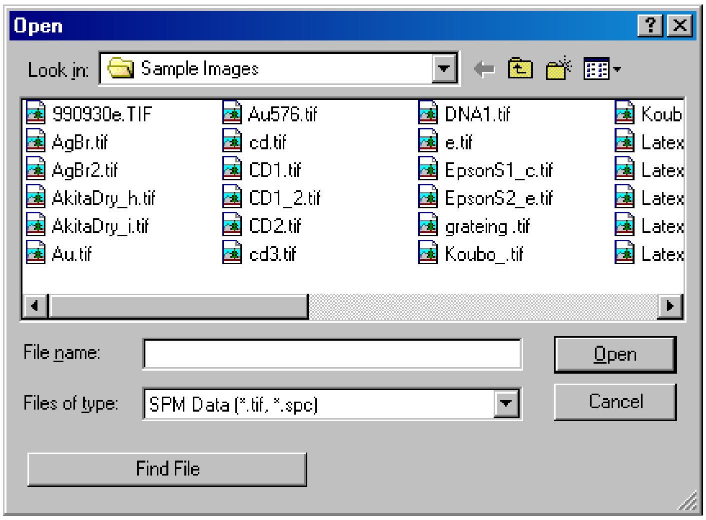
✍ For print settings, refer to the instruction manual for the printer.

✍ Printing quality depends on the printer you use.

6.4 FILE MENU

■ Open (Ctrl+O)

You load data stored on the disk into the memory, and display it on the screen.



● File name

When you enter the filename of the file to load, or select it from the displayed list of filenames, the filename is displayed in this box.

To load all of the displayed files, click on the filename displayed at the end of the list using the left mouse button, while pressing the Shift key on the keyboard.

To load some files from different parts of the list, select each file while pressing the Ctrl key on the keyboard.

After selecting the files that you wish to load, click on the Open button to load the files.

✍ By using a wildcard you can easily use the list of filenames.
A wildcard is something that is used as a substitute for matching characters.

*:	Matches all characters
?:	Matches all characters at one character position.

☞ Examples

.:	All files
*.TIF:	All files with the extension TIF
SI*.TIF:	All files that start with SI and have the extension TIF
SI111_?.TIF:	Files that start with SI111, have one character in the ? part, and have the extension TIF SI111_1.TIF and SI111_A.TIF are both a match, but SI111_AB.TIF is not.

If you click on the Open button after entering a filename using a wildcard, a list of files that match the wildcard will appear.

● Type of File

Specify type for loading files. You can specify the following types of files.

Type	Description
SPM Data (∗.tif, ∗.spc)	Image file and graph file such as I-V data File normally saved with this software
SPM Image (∗.tif)	Image file only
Binary Image (∗.bin)	Image file saved in binary with “Save As”
Binary FFT (∗.bft)	Image file which is FFT-processed spectrum data in binary
ASCII Image (∗.asc)	Image file saved in ASCII code with “Save As”
ASCII FFT (∗.aft)	Image file which is FFT-processed spectrum data in ASCII
Spectrum (∗.spc)	Graph file such as I-V data

● Look in

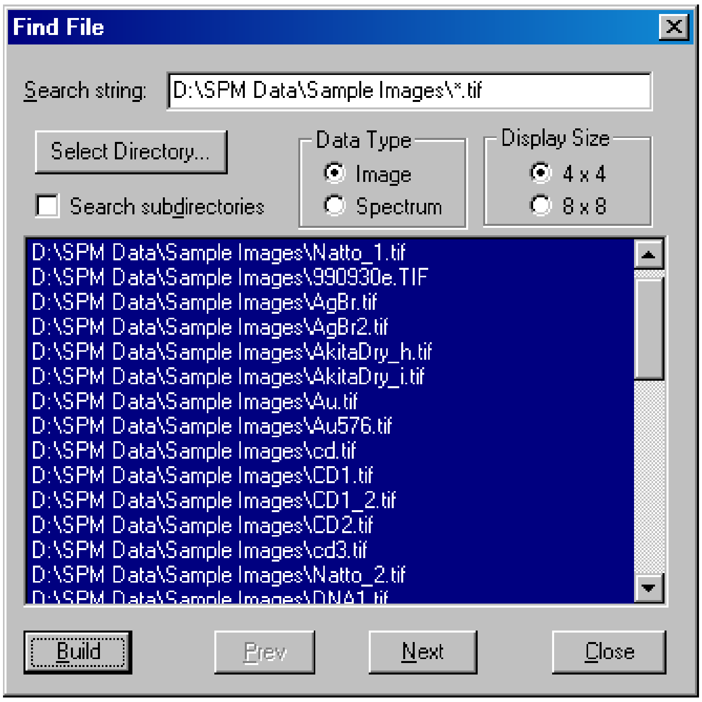
Specify the folder containing saved files.

● Find File

Click on this button to display the list of files saved under the current directory.
☞ For details, refer to next Sect., “Find File”.

■ Find File

You display the list of saved data.



- Search string
  Specify folders that you wish to search for saved files and also filenames. Specify as shown below. You can use a wildcard for filenames.

  Drive name:\Folder name\Folder name\...\Filename
- Select Directory
  Clicking on this button displays the dialog for selecting the desired directory from the tree-structured display.
- Search subdirectories
  When you have checked the Search subdirectories check box, if there is a folder beneath the folders specified using Search string, a search will take place as far as the inside of that folder.
- Data Type
  Specify file types of the files that you want to search. If you select Image, *.tif will be added to the end of filenames in the Look in box. If you select Spectrum, *.spc will be added.
- Display Size
  Specify the size of list of images or spectra to display in the Display Window. If you specify 4×4, 16 files are displayed; if you specify 8×8, 64 files are displayed.
- Build
  If you click the Build button after specifying Search string, a data search starts and the data is displayed.
- Prev
  Selecting the Prev button displays the previous data after Build is executed.
- Next
  After you perform Build, if there is data remaining that cannot be displayed on a single screen, click on this button to display the next data.

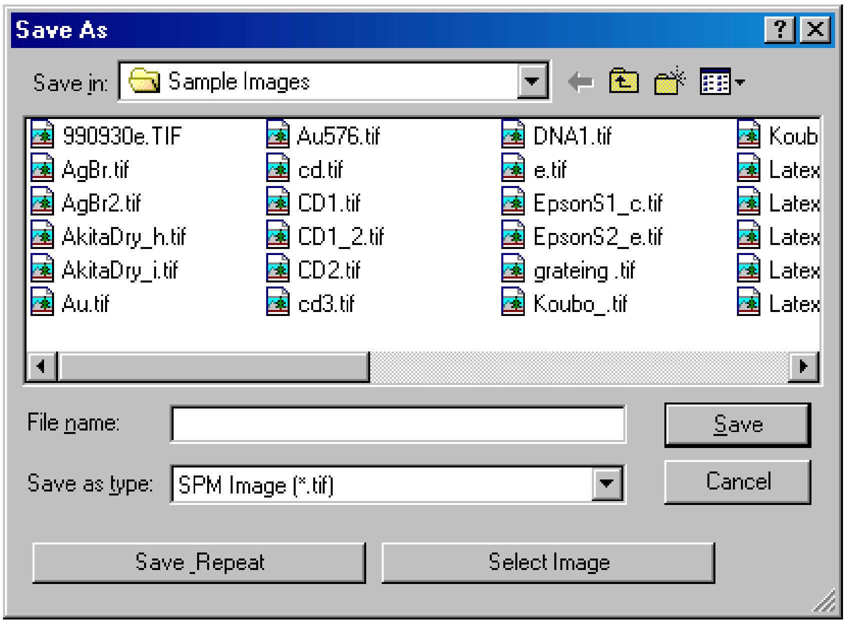
✍ By using the Find File dialog box, to load the data displayed in the Display Window into the memory, move the mouse cursor to the image to load, and then double-click the image. You can load images one after the other by doing this operation.

■ Close (Ctrl+L)

You erase the current image displayed in the Display Window from the memory. If there are other data after the image is erased, the next data will appear in the selection list.
If there is no data after the image is erased, the display will remain, but the main menu display will change to gray.

■ Save As (Ctrl+A)

You save data on a disk. The applicable data is the current data displayed in the Display Window.



- File name
  Enter filename of the file that you want to save.
  When you enter filename and click on the Save button, the data will be saved.
- Save as type
  Specify format for saving data. You can specify the following types of files.

Type	Description
SPM Image (∗.tif)	16-bit TIFF format for saving the SPM image
Compressed Image (∗.tif)	8-bit TIFF format for saving the SPM image This type has compatibility with other application software which cannot handle the 16-bit TIFF format.
Binary Image (∗.bin)	16-bit binary format for saving data
Binary FFT (*.bfc)	16-bit binary format for saving FFT spectrum
ASCII Image (∗.asc)	ASCII format for saving data
ASCII FFT (∗.aft)	ASCII format for saving FFT spectrum
Header (∗.hdr)	ASCII format for saving FFT spectrum Contents of the SPM Data Information window
SPM spectrum (∗.spc)	Format for saving graph data such as I-V
ASCII spectrum (∗.dat)	ASCII format for saving graph data such as I-V The graph data can be read into softwares such as a graph processing software.

- Save in
  Specify a folder containing saved files.
- Save_Repeat
  When multiple sets of data have already been grabbed in the memory, if you wish to save them in the form of a file successively, you can do this by clicking on the Save_Repeat button.

  Click on the Select Image button to select the data you wish to save, and input the filename of the data using the keyboard; then click on the Save_Repeat button.
  The data is saved, and the listing of data you save next is displayed.
  Select the next data you wish to save from the listing of data in the same way as using the Select Image button.
  The selected data is displayed in the Display Window. The serial numbers 01, 02, 03, ... are appended to the ends of filenames automatically.
  After confirming that the filename you input is appropriate, click on the Save_Repeat button. If you wish to change the filename, change it here and then click on the same button.
  ✍ The lists of image data and graph data are displayed independently in the Select Data Item dialog that is displayed by clicking on the Select Image or Save_Repeat button. The contents of the listing are dependent on the current data of the time when you select Save_Repeat.

■ Close All But Current

You erase all data other than the current image displayed in the Display Window from the memory.

■ Close All

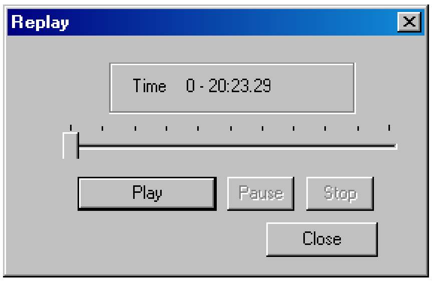
You erase all data in the memory.

■ Replay

You display continuous images measured using the Grab & Repeat function.

◆ Display the Open dialog box by selecting Replay from the File menu. Select one of the saved continuous images, and then click on the Open button.

The Replay control window appears, and the first image of the continuous images appears in the Display Window.



Time:	Indicates the sequence number of the displayed image, and also the time at which it was measured.
Play:	Continuously plays back a series of images.
Pause:	Temporarily halts continuous playback.

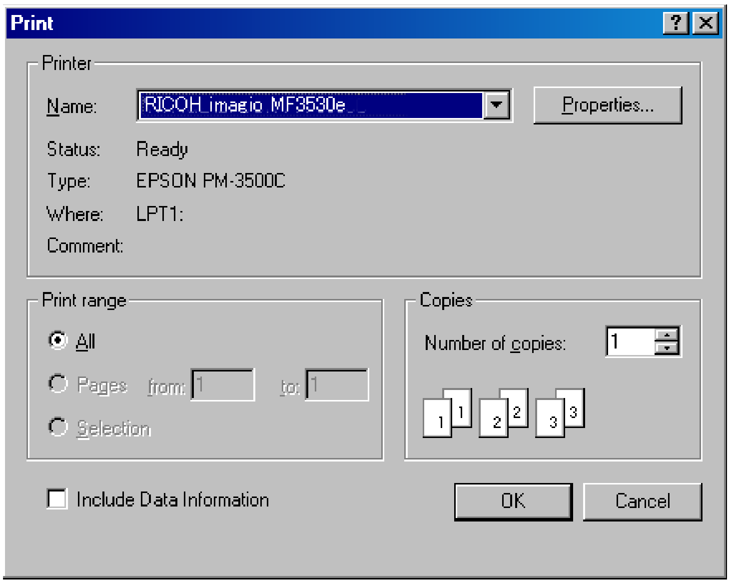
Stop: Stops continuous playback. When playback stops, the displayed image returns to the first image. Also, you can display any desired image by dragging the slider bar.

✍ The selected continuous images are not loaded into the memory.

✍ Unless a series of continuous images exists in the same directory, an error will occur when you attempt to read them.

■ Print (Ctrl+P)

You output data to a printer. For methods such as setting the printer, refer to the instruction manual of the printer.



• Include Data Information

When you have checked this item, the data displayed in the Display Window and also the data displayed in the SPM Data Information window are printed on a single sheet.

■ Make Report (Ctrl+R)

You arrange the data in the output sheet. The output sheet is a template with landscape orientation of an A4 size basically used for displaying the SPM image and the information on acquired data to output them in high quality.

There are three types of output sheets:

• Acquired data sheet

This output sheet is for arranging acquired data such as images, spectra and mapping. You can arrange up to three pieces of data on a single output sheet.

• 3D image sheet

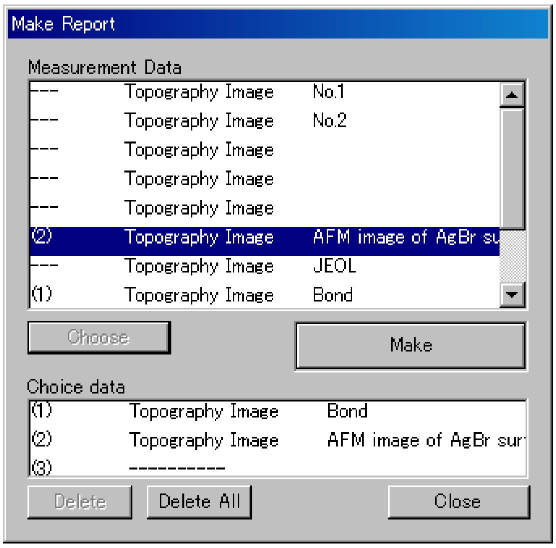
This output sheet is for displaying 2D and 3D images in pairs. You cannot arrange plural 3D images on a single output sheet.

- Analysis result sheet

  This output sheet is the displayed information in each analysis window. You can hardly distinguish this output sheet from the analysis window by their appearance; e.g., you cannot operate the analysis position in the output sheet. You cannot arrange the displayed information in plural analysis windows on a single output sheet.

You can automatically create the 3D image sheet and the Analysis result sheet by clicking on the Make Report shortcut icon, activating each display window.

You can create the Acquired data sheet by clicking on the Make Report shortcut icon, activating the display window. At this time, the following Make Report dialog box appears.



- Measurement Data

  The list of SPM data stored in memory is shown. Select the data you want to arrange from the list. The selected data is displayed in the Display Window.
- Choose button

  Click on the Choose button to select data from the list of Measurement Data. The selected data is displayed in the Choice data area.
- Choice data

  The list of data selected from the Measurement Data area is shown. You can select up to three measurement data to arrange. When you click on the Make Report shortcut icon, the data displayed in the Display Window automatically comes to the top of the Choice data area.
- Delete button

  Deletes the single SPM data selected from the list of Choice data.
- Delete All button

  Deletes all data currently selected in the list of Choice data.
- Make button

  Creates and displays the output sheet, using the SPM data selected in the list of Choice data. Display changes depending on the number of selected data.
- Close button

  Closes the Make Report dialog box and stops creating an output sheet.

■ Load Report

You load and display the output sheet saved in the files. When you select this item, the Open dialog box appears. Select an output sheet file to load. The extension of the output sheet file is "*.RPT". Loading an output sheet file displays the output sheet and stores the original SPM data in memory as well.

■ Save Report

You save the created output sheet in the file. Selecting the item opens the Save As dialog box. Enter the location and a filename to save. The output sheet file is a file that combines the SPM data that are arranged in the output sheets. The file size is almost the same as the sum of the SPM data size to combine.

■ Load BMP Image

You load a BMP image and display it with the same size as the image in the dedicated window. You can load a BMP image only if it is Windows standard.

■ Save BMP Image

You save the displayed information in the currently active window (except for the SPM data information window that displays texts) as a BMP image with the same size. You can load the saved BMP image in common to the Windows application.
When you save an SPM image, an SPS spectrum and a 3D image in a BMP file, the same text data is generated and saved as that for the attached SPM measurement data like header information.

✍ For example, if you put a BMP filename with "Image.BMP", the filename with "Image.TXT" is generated and the header information is saved in it.

■ Store Configuration

You store the parameters to which you set. The parameters that you stored using the Store Configuration item are read and used for settings the next time you start the system.

The parameters that you changed during measurement or observation are not stored until you perform this Store Configuration operation.

■ Retrieve Configuration

You read the parameters saved by using Store Configuration. You must carry out SPM Reset in order to make the read parameters effective.

■ Exit

You exit from the software.

6.5 EDIT MENU

■ Copy (Ctrl+C)

You can paste data displayed in the Display Window to another application using Copy & Paste.

When you select Copy, the contents of the Display Window are copied. When you start another application and select Paste, the data in the Display Window will be transferred as an image.

✍ The copied image fills the 512×512 screen in the Display Window.

■ Copy Data

When you select Copy Data, the data (image or graph) displayed in the Display Window and also the measurement data displayed in the SPM Data Information window are copied.

Use this item when moving data from the scan mode to the process mode.

✍ You cannot use this item to move data to an application outside the WinSPM system.

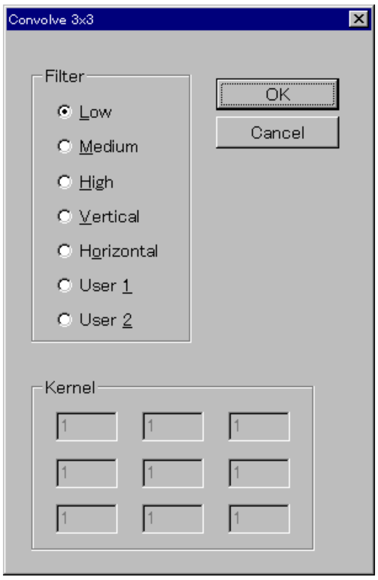
■ Paste Data

This item is effective if SPM data is transferred on to the clipboard by using Copy Data. When you select Paste Data, the data that was transferred onto the active Display Window and also the measurement data will be transferred.

6.6 PROCESS MENU (IMAGE PROCESSING FUNCTION)

6.6.1 Filter

These are two filtering methods: Convolve 3×3 and Convolve 5×5. Convolve 3×3 and Convolve 5×5 use a matrix of three columns and three rows, and five columns and five rows, respectively. In the Convolve 3×3, filtering is applied to the range of 1 pixel surrounding the applied point (center of matrix). In the Convolve 5×5, filtering is applied to the range of 3 pixels surrounding the applied point (center of matrix).

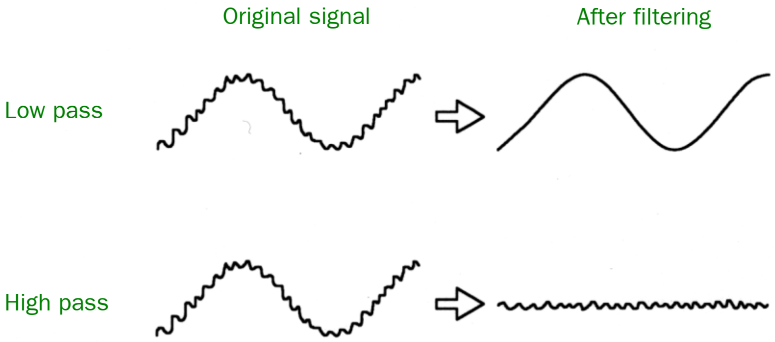


The current image is smoothed by filtering.
The following filter functions are provided.

Filter	Description
Low	Low-pass filter
Median	Median-pass filter
High	High-pass filter
Horizontal	Horizontal smoothing
Vertical	Vertical smoothing
user1, user2	User defined filter

Noise having a certain frequency component is eliminated by the filtering function.

【Example】For one line signal in an image:



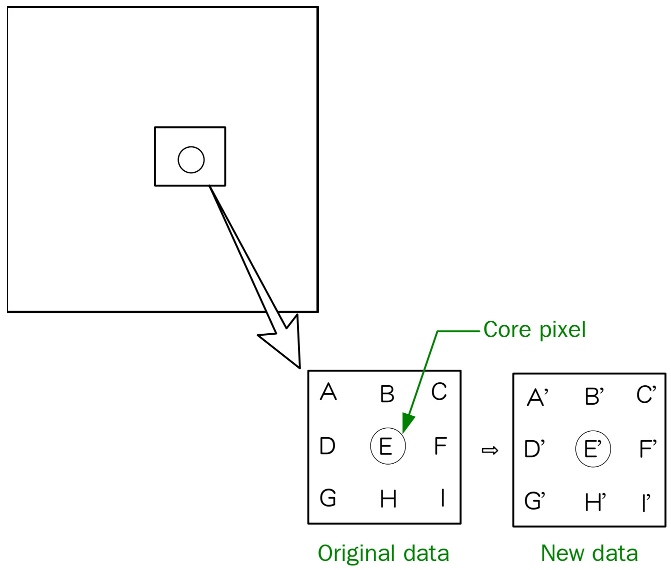
Filtering is performed as shown above.

The matrix element for each filter is as follows.

Filter	convolve 3×3	convolve 5×5
Low	$\begin{vmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{vmatrix}$	$\begin{vmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{vmatrix}$
Median	$\begin{vmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{vmatrix}$	$\begin{vmatrix} 1 & 2 & 4 & 2 & 1 \\ 2 & 4 & 8 & 4 & 2 \\ 4 & 8 & 16 & 8 & 4 \\ 2 & 4 & 8 & 4 & 2 \\ 1 & 2 & 4 & 2 & 1 \end{vmatrix}$
High	$\begin{vmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{vmatrix}$	$\begin{vmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 25 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{vmatrix}$
Horizontal	$\begin{vmatrix} 0 & 0 & 0 \\ 1 & 1 & 1 \\ 0 & 0 & 0 \end{vmatrix}$	$\begin{vmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{vmatrix}$
Vertical	$\begin{vmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \end{vmatrix}$	$\begin{vmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{vmatrix}$

Actual filtering is carried out by a weighted average with the filtering operator for the core pixel. For example, if the 3×3 median filter is applied to core pixel E, the following calculation is carried out for the new image data E'.

$$E' = \begin{vmatrix} A & B & C \\ D & E & F \\ G & H & I \end{vmatrix} \times \begin{vmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{vmatrix} \equiv \frac{A+2B+C+2D+4E+2F+G+2H+I}{1+2+1+2+4+2+1+2+1}$$



When User 1 or User 2 is selected in the Filter frame, the matrix element definition frame Kernel becomes effective, and you can enter matrix elements by using the keyboard.

The method of entering is as follows.

1. Enter an integer between –128 and +128 (the total sum of the matrix elements must not exceed 128) using the keyboard.

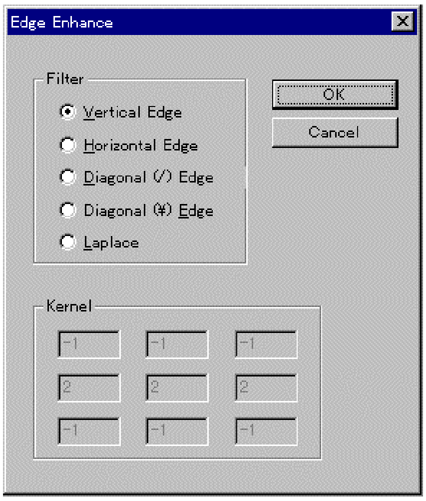
   Press the TAB key. Then the highlighted matrix element is defined and the next element will be highlighted.

   ✍ The matrix elements defined in User 1 or User 2 can be saved using the Store Configuration function.

2. Click on the OK button.

   Filtering is executed.

6.6.2 Edge Enhance



The current image is edge-enhanced.
The following edge enhancement functions are provided.

Filter	Description
Vertical Edge	Enhancement in the vertical direction
Horizontal Edge	Enhancement in the horizontal direction
Diagonal [／] Edge	Enhancement in the diagonal (／) direction
Diagonal [＼] Edge	Enhancement in the diagonal (＼) direction
Laplace	Enhancement of perimeter out-line by Laplace transformation

The following filtering operation is applied in the same manner as the Convolve 3×3 function.

Filter	Matrix element
Vertical Edge	$\begin{vmatrix} -1 & 2 & -1 \\ -1 & 2 & -1 \\ -1 & 2 & -1 \end{vmatrix}$
Horizontal Edge	$\begin{vmatrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{vmatrix}$
Diagonal [／] Edge	$\begin{vmatrix} -1 & -1 & 2 \\ -1 & 2 & -1 \\ 2 & -1 & -1 \end{vmatrix}$
Diagonal [＼] Edge	$\begin{vmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{vmatrix}$

$$\text{Laplace} \quad \begin{vmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{vmatrix}$$

Filtering operation is applied in the same manner as the Convolve 3×3 function.
Clicking on the OK button executes the designated edge-enhancement function.

6.6.3 Differentiate

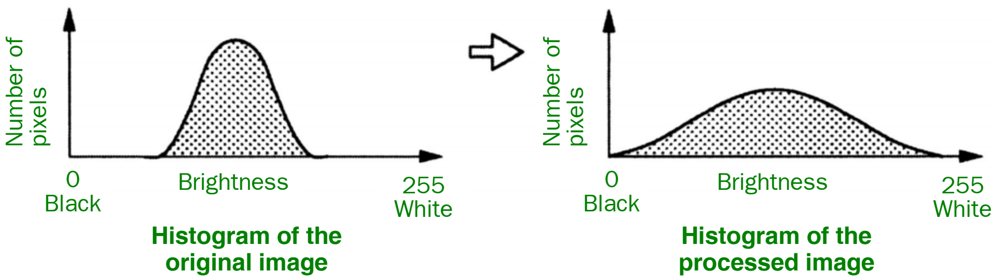
The current image is differentiated at a certain angle.
The following filtering operation is applied in the same manner as the Convolve 3×3 function.

$$\begin{vmatrix} 0 & \sin\theta & 0 \\ 0 & -\sin\theta - \cos\theta & \cos\theta \\ 0 & 0 & 0 \end{vmatrix}$$

Here is the angle at which the differentiation is to be carried out. Enter an angle in degree, (as an integer between –90° and +90° using the keyboard. Clicking on the OK button executes the differentiation function.

6.6.4 Normalise

The contrast range for the current image is broadened.
The Normalise function changes the image contrast so that the darkest part of the image becomes 0, and the brightest part of the image becomes 255. In other words, the brightness range of an acquired image is expanded to the full brightness range of the display (0 to 255). This function does not influence measurement data.

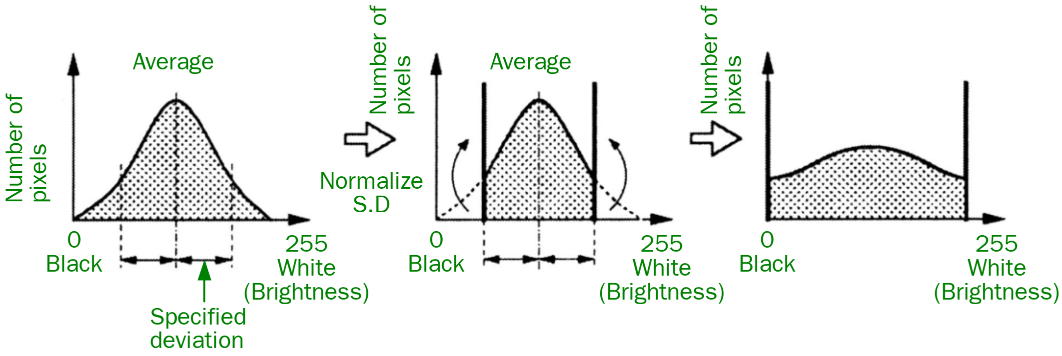


6.6.5 Normalise S.D.

One of the contrast-enhancement methods carried out by expanding the brightness range.

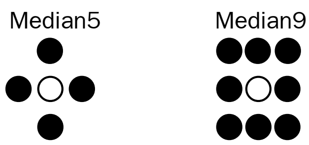
1. Click on Process in the main menu; then select Normalise S.D. in the pull-down menu.
   A histogram of brightness will be displayed on the displayed window, and the Enter s.d.'s range to keep data window will be displayed.
2. Specify the range of deviation.
   The Normalise S.D. function is executed.

When a deviation value is specified, the brightness range within the specified deviation value is expanded to the full brightness range of the display (0 to 255). The brightness range outside of the specified deviation value is displayed in black (0) or white (255).
✍ This function does not influence measurement data.

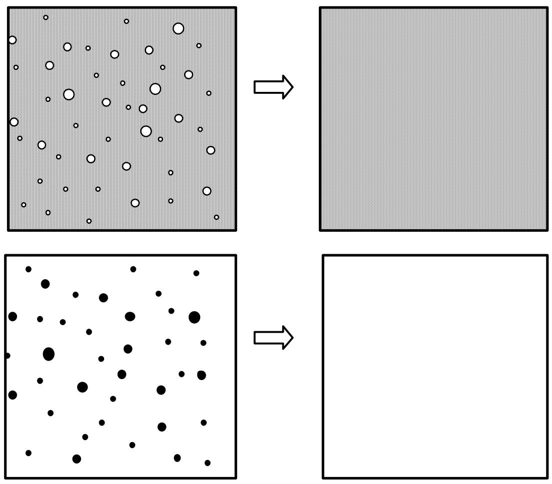


6.6.6 Median

Electric spot noise (spike noise) on an image is eliminated.
In this function, the data of the center pixel and the surrounding 4 or 8 pixels are selected, and the value of the center pixel is replaced with the middle value of the selected 5 or 9 pixels. This function is called Median filter.



The Median filter can eliminate spike-shaped electric noise in an image.



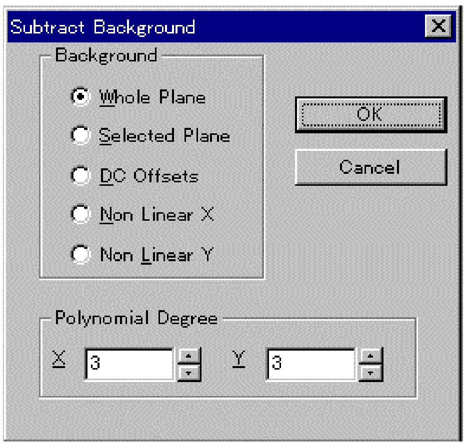
Original image **Processed image**

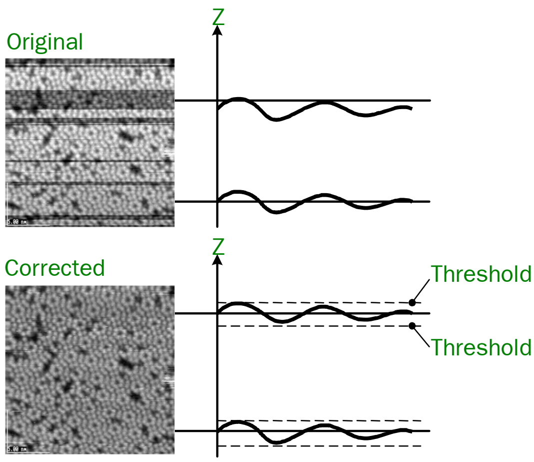
◆ Click on Process in the main menu; then select Median 5 or Median 9 in the pull-down menu.
The function is immediately executed.

6.6.7 Subtract Background...

If the brightness (background) of the image changes in a certain direction, make correction for this change.

- Whole Plane
  Corrects the tilt of the entire image as a single plane.
  Clicking OK starts correction.
- Select Plane
  Corrects the tilt of a square area specified by the mouse, as a single plane.
  Clicking OK starts correction.
- DC Offset
  Computes the offset of the brightness of the overall screen, and corrects it.
  Clicking OK starts correction.
- Non Linear X
  This function corrects the image using a polynomial approximation if the image is curved in the X direction. Specify the degree of the polynomial equation using Polynomial Degree. You can specify a degree between 3 and 9.
  Clicking OK starts correction.
- Non Linear Y
  This function corrects the image using a polynomial approximation if the image is curved in the Y direction. Specify the degree of the polynomial equation using Polynomial Degree. You can specify a degree between 3 and 9.
  Clicking OK starts correction.
- Line Averaging
  This function corrects the following kinds of images by fitting the average value obtained for each line in the X direction as the average value of the height over the entire screen.
  Clicking OK displays a Threshold bar chart, so specify the height range over which the average is to be computed, while referring to the preview. Clicking OK in the bar chart starts correction.
  ✍ In almost all cases, there is no need to set Threshold.





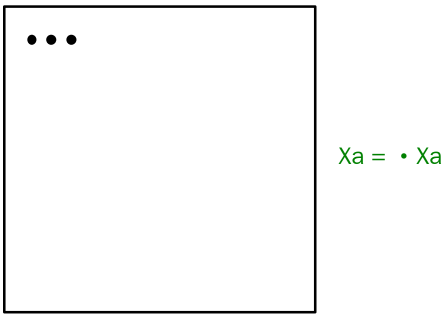
6.6.8 Single Math

A mathematical operation is performed for each pixel of the current image.
The following eight mathematical operations are provided.

Operation	Description	Effective value
Invert	Brightness-inverted image display	—
Multiply	Product of pixel data and a constant	The same image if 1.0
Divide	Pixel data divided by a constant	The same image if 1.0
Bitwise AND	Logical multiplication of pixel data and a constant in each bit	Integer 0 to 65535
Bitwise OR	Logical sum of pixel data and a constant in each bit	Integer 0 to 65535
Bitwise XOR	Exclusive OR of pixel data and a constant in each bit	Integer 0 to 65535
Add	Sum of pixel data and a constant	Integer 0 to 65535
Subtract	Difference of pixel data and a constant	Integer 0 to 65535

Here, pixel data does not mean the display brightness data (0 to 255) but the acquired 16 bit raw data (0 to 65535). Although an integer from 0 to 65535 can be entered for Bitwise AND, OR, XOR, Add and Subtract, the result is converted to the range 0 to 255 for display.
If the resultant of the mathematical operation is negative, it is replaced with 0. If the resultant of the mathematical operation exceeds 255, it is replaced with 255.

A mathematical operation is performed for each pixel, as follows.



【Example】

Invert

Original image	Calculated value
0 (0000 0000)	→ 255 (1111 1111)
128 (1000 0000)	→ 127 (0111 1111)

Multiply

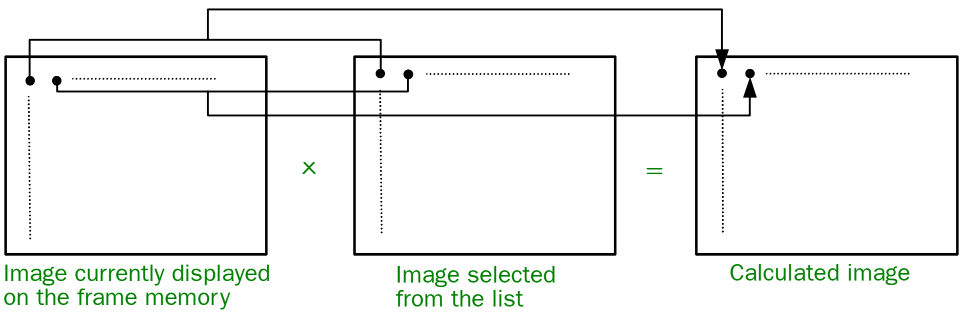
Original image	Constant	Calculated value
20	3.0	60
128	3.0	255

6.6.9 Double Math

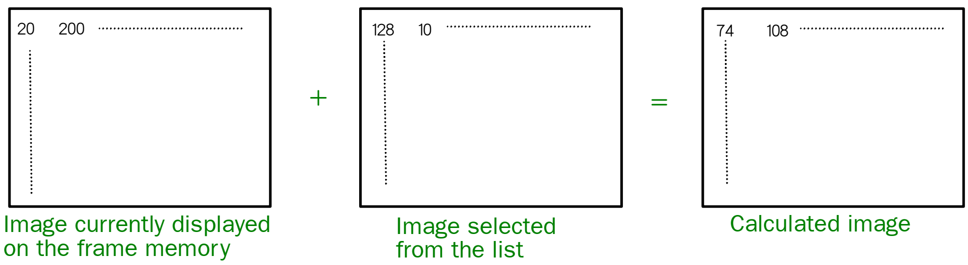
A mathematical operation is performed for each pixel of the current image and any desired image in the computer memory.
The following ten mathematical operations are provided.

Operation	Description
Add	Average of the data; (a+b)/2
Subtract	Difference of the data; (a–b+255)/2, that is, [a+(255–b)]/2
Difference	Difference of absolute value of the data; |a|–|b|
Multiply	Product of the data; (a∗b)/255
Divide	Quotient of current image data divided by selected image data (a/b) Note: If “b” is zero, resultant set to “a”.
Bitwise AND	Logical multiplication of the two data in each bit (a AND b)
Bitwise OR	Logical sum of the two data in each bit (a OR b)
Bitwise XOR	Exclusive OR of the two data in each bit (a XOR b)
Minimum	The smaller of the two data
Maximum	The larger of the two data

✍ Here, a shows the current image data and b shows the selected image data.



Example】 When Add is selected,



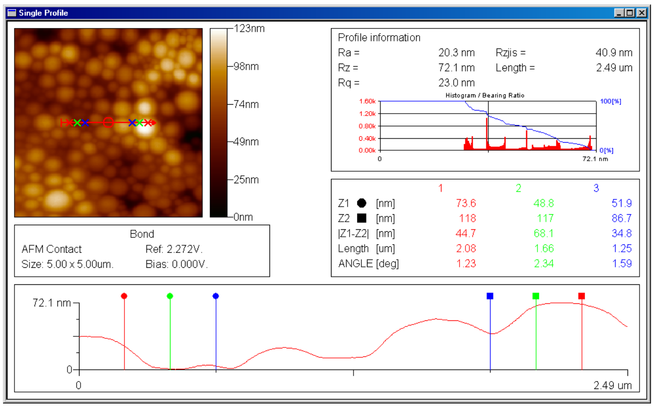
6.7 ANALYSE MENU (IMAGE PROCESSING FUNCTION)

6.7.1 Profile

In the current image, a straight line is drawn between two specified points, and the height data along this straight line is line-plotted and displayed.
The results of analysis are displayed in a dedicated window that is separate from the Display Window.

■ Single Profile

This function analyzes and measures the line profile in the analysis image.
Select Profile – Single from the Analyse menu.



● Designating Analysis Position

- Preview image

  The preview of the analysis image is displayed together with height data. Designate the analysis position by moving the line indicated by the arrow.

- Designating the analysis position

  If you align the mouse cursor with both ends of the line, the cursor will change to a cross-cursor. You can then change the analysis position by dragging the cursor with the button on the mouse held down.

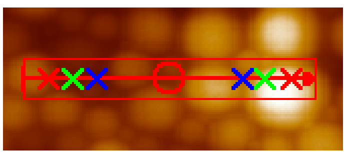
  You can also change the cursor to a cross also by aligning the mouse cursor to the center of the line. The entire line can be moved by dragging the cursor with the left button on the mouse held down in this state.

  While the cursor is changing to a cross, the coordinate on the image is displayed in the pop-up window.

- Broad line and simple line

  You can change the cursor to a cross by aligning the mouse cursor to both ends of the line. The submenu can be displayed by clicking the right button on the mouse in this state.

  Selecting Broad line changes the display of the line as shown below.



At this time, the average of the cross sectional shape of the area enclosed with a square is used as the result of cross sectional analysis. This area can be freely changed by changing the width of the square with the mouse cursor.
Select Simple Line from the submenu to return control to the normal cross sectional shape analysis (analysis aimed at the shape on the line only).

- Addition and deletion of marker

  You can display the submenu by clicking the right button on the mouse with the mouse cursor aligned with the marker (x) displayed on the line (at this time, the mouse cursor does not change).
  If you select Delete Marker, the marker aligned with the cursor will be deleted.
  If you select Add Marker, a new marker will be added. However, only up to maximum three sets of markers can added.
  ✍ Note that the submenu for marker operation may not be displayed except at the time of simple line.
- Changing the Profile Display Color

  Aligning the mouse cursor with both ends of the line changes cursor to a cross. The submenu is displayed by clicking the right button on the mouse in this state.
  The profile display color can be changed by selecting Change Color.

● Data Information

Information about the image to analyze (title, measurement mode, measurement parameter) is displayed.

● Line Plot

Height information on a designated line is displayed as line plot.

- Vertical and horizontal axes of graph

  The vertical axis represents height along the line, and the horizontal axis represents length along the line. The vertical axis shows the difference between the maximum and minimum line plots, and the horizontal axis shows the length of the line plot. The grid at the axial center shows a value 1/2 of the maximum value.
- Line-width Analysis of a line plot

  You can perform line-width analysis of a displayed line by adding a marker to the line plot.
  The three colored lines shown in the graph indicate the analysis position in the line plot. You can move the analysis position by dragging each line with the left button on the mouse held down. The analysis position is indicated by the x mark even if it coincides with the arrow on the preview image above.
  The results of analysis are displayed in the area at the bottom of the Cross Sectional Information.

● Saving Analysis Results

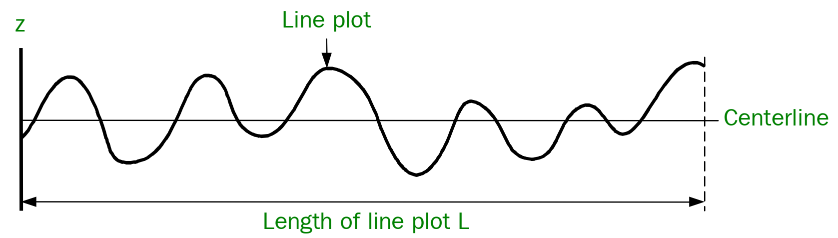
Clicking the right button on the mouse in a field where the analysis result is displayed on the screen displays a submenu.
If you select Save Data, the Save As dialog appears and the analysis result (all analysis results displayed) can be saved in file in the text format.

● Cross-sectional information

The results of various analyses on the line plot are displayed. The kinds of analyses and the analysis methods are shown below.

- Definition

  A line plot is defined as follows.



The height z along an arbitrary length l in the line plot is defined as

$$z = f(l)$$

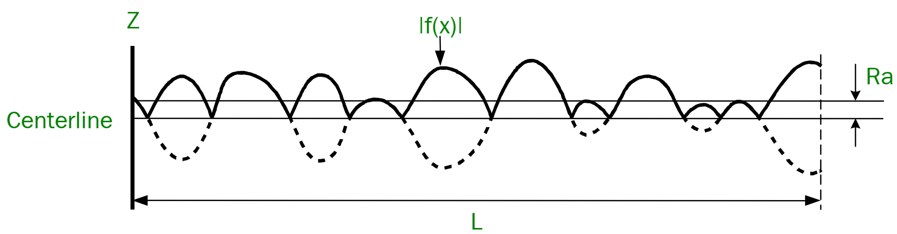
The height Z_0 at the centerline is defined as follows.

$$Z_0 = \frac{1}{L}\int_0^L f(l)dl$$

- Average roughness (Ra)

  Uses the equation for computing the arithmetic average roughness Ra stipulated by JIS B0601.

  Ra is stipulated as the "value expressed by the following equation when the center-line is taken as the X-axis and a line plot is expressed as f (x)".



$$R_a = \frac{1}{L}\int_0^L |f(x)|dl$$

- Root mean square roughness (Rq)

  Stipulated as the "root mean square of the deviation from the centerline".

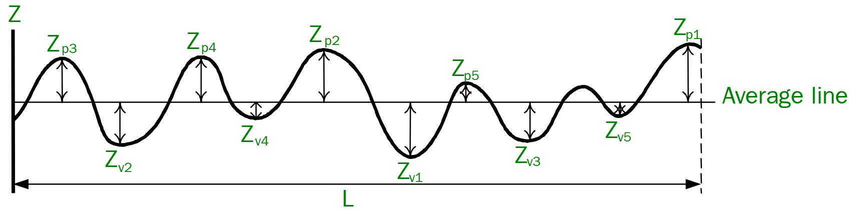
$$Rq = \sqrt{\frac{1}{L}\int_0^L (f(l) - Z_0)^2\, dl}$$

- 10-point average roughness (Rzjis)

  Uses the equation for computing the 10-point average roughness Rz stipulated in JIS B0601:1998.

  (The 10-point average roughness itself is not stipulated in JIS B0601:2001.)

The 10-point average roughness is stipulated as the “sum of the average value of the absolute values of the deviation from the centerline between the largest deviation and the fifth deviation, and the average value of the absolute values of the deviation between the smallest deviation and the fifth deviation.



$$Rzjis = \frac{\left|Z_{p1} + Z_{p2} + Z_{p3} + Z_{p4} + Z_{p5}\right| + \left|Z_{v1} + Z_{v2} + Z_{v3} + Z_{v4} + Z_{v5}\right|}{5}$$

- Maximum difference between high and low (Rz)

Stipulated as the “difference between the maximum value Z_{max} and the minimum value Z_{min} of the height z, on the analysis screen”.

$$Rz = Z_{max} - Z_{min}$$

This value is also shown on the vertical axis of the line plot.

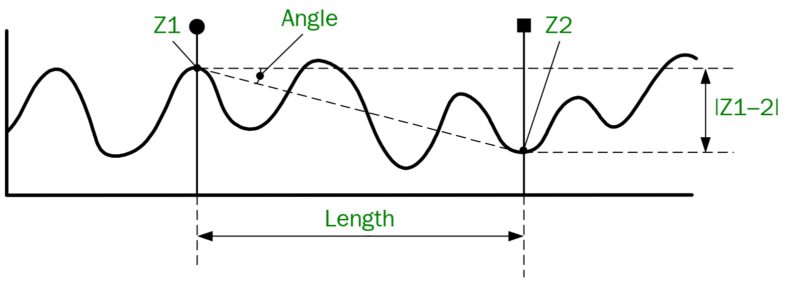
- Length of the line plot (Length)

Indicates the length L of the line plot. This value is also shown on the horizontal axis of the line plot.

● Results of performing measurement on the line plot

The results of performing measurement on the line plot are displayed.

In measurement analysis, the ● and ■ markers displayed in the cross-sectional graph form a set, enabling you to perform a total of three measurement analyses. Each set is identified according to the display color.



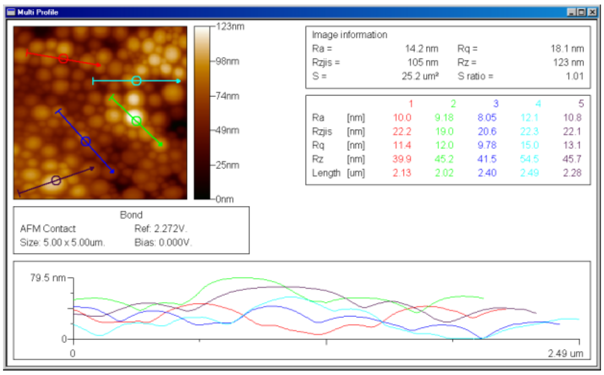
Z1:	Height at ● marker position
Z2:	Height at ■ marker position
|Z1-Z2|:	Absolute value of difference between high and low at the ● marker position and the ■ marker position
Length:	Distance in the horizontal direction between the ● marker position and the ■ marker position

Angle: Elevation angle (tilt) of the ■ marker position when seen from the ● marker position

✍ The displayed values are the values computed in the analysis plane, so the angle will differ from that shown in the line plot.

■ Multi Profile

This function performs line profile analysis to the five largest profiles in the analysis image.
Select Profile – Multi from the Analyse menu.



● Analysis position specification

Basic operations are the same as Single Profile.

- Addition and deletion of line profile

  Multi Profile can analyze up to maximum five line profiles. The submenu can be displayed by clicking the right button on the mouse from the preview image. Line profile can be added by selecting Add Profile.

  Align the mouse cursor with the end of the line showing the line profile you want to delete and click the right button on the mouse. A submenu appears. Select Delete Line to delete the line profile.

● Image data

Same as for Single Profile.

● Line plot

The height data on the added line is displayed as a line plot.

- Line plot display

  The added line plots are all displayed on the same graph. Each plot is identified according to the display color.

- Vertical and horizontal axes of graph

  The vertical axis is the height on the line, and the horizontal axis is the length on the line. The vertical axis displays the maximum high-low difference in the displayed line plot, and the horizontal axis displays the length of the line plot that has the longest plot length in the line plot. The grid at the axis center indicates 1/2 of the maximum value.

● Saving the results of analyses

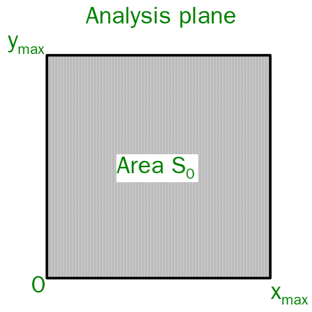
When you click the right mouse button on the region where the results of analyses are displayed, the submenu will appear.
If Save Data is selected from the submenu, Save as dialog box will appear, and the all analysis results displayed on the screen can be saved on the disk file in the text form.

● Image data

The kinds of analyses and the analysis methods are shown below.

• Definition

Define the analysis plane as follows.



The height z at arbitrary coordinates (x, y) in the analysis plane is defined as follows.

$$z = f(x, y)$$

The average value Z_0 of the height z in the analysis plane is defined as follows.

$$Z_0 = \frac{1}{S_0}\int_0^{x_{\max}}\int_0^{y_{\max}} f(x, y)dxdy$$

The area S_0, which is based on the assumption that the analysis plane is flat (ideal), is defined as follows.

$$S_0 = x_{\max} \times y_{\max}$$

• Average roughness (Ra)

The equation used for computing the average roughness Ra stipulated in JIS B0601 has been expanded to apply to a 3-dimensional plane. It is stipulated as the "arithmetic average of the absolute value of the deviation from the average height Z_0 of the analysis plane".

$$Ra = \frac{1}{S_0}\int_0^{x_{\max}}\int_0^{y_{\max}} \left| f(x, y) - Z_0 \right| dxdy$$

• Root mean square roughness (Rq):

This is stipulated as the "root mean of the deviation from the average height Z_0 of the analysis plane".

$$Rq = \sqrt{\frac{1}{S_0}\int_0^{x_{\max}}\int_0^{y_{\max}} \left(f(x, y) - Z_0\right)^2 dxdy}$$

• 10-point average roughness (Rzjis)

The equation used for computing the 10-point average roughness Rz stipulated in JIS B0601:1998 has been expanded to apply to a 3-dimensional plane. (The 10-point average roughness itself is not stipulated in JIS B0601:2001.)
It is stipulated as the "sum of the average value of the absolute values of the deviation from the average height Z_0 in the analysis plane between the largest deviation and the fifth deviation, and the average value of the absolute values of the deviation between the smallest deviation and the fifth deviation.

$$Rzjis = \frac{\left|Z_{p1} + Z_{p2} + Z_{p3} + Z_{p4} + Z_{p5}\right| + \left|Z_{v1} + Z_{v2} + Z_{v3} + Z_{v4} + Z_{v5}\right|}{5}$$

Z_{p1},Z_{p2},Z_{p3},Z_{p4},Z_{p5}: Deviation values between the largest deviation and the fifth deviation in the analysis plane
The corresponding positions are displayed using red characters on the preview screen.

Z_{v1},Z_{v2},Z_{v3},Z_{v4},Z_{v5}: Deviation values between the smallest deviation and the fifth deviation in the analysis
The corresponding positions are displayed using blue characters on the previous screen.

• Maximum difference between high and low (Rz)
Stipulated as the "difference between the maximum value Z_{max} and the minimum value Z_{min} of the height z, on the analysis screen".

$$Rz = Z_{\max} - Z_{\min}$$

• S: Surface area
The net surface area of the analysis plane is computed as the sum of the vector product of a finely divided surface.

• S ratio: Surface area ratio
The ratio of the net surface area to the surface area S_0, which is based on the assumption that the analysis plane is flat (ideal), is computed.

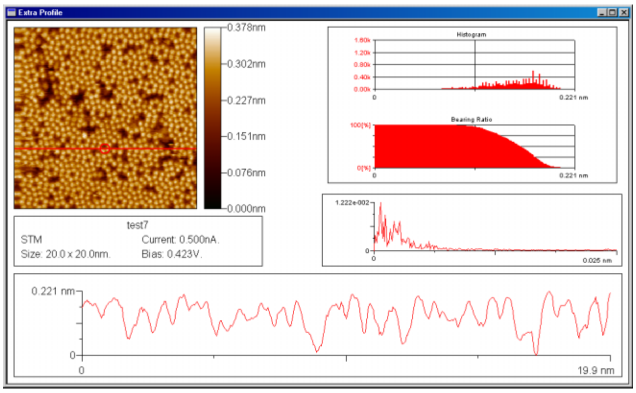
$$S_{ratio} = \frac{S}{S_0}$$

● Analysis Results in Line Plot (Table at right center of screen)

Results of analyses in each line plot are displayed.
The type and method of analysis are the same as Single profile.

■ Extra Profile

Performs frequency analysis of cross section in the horizontal or vertical direction and histogram・cumulative percentage for an analysis screen.
Select Cross sections and Extra from the Analyze menu.



● Designating Analysis Position

Basic operations are the same as Single Profile.

• Designating analysis position

Set the position in the horizontal or vertical direction by dragging the center of the line. The length of the line cannot be changed.

• Vertical line and horizontal line

Select the cross section either in the horizontal or vertical direction from the extra profile.
Aligning the mouse cursor with the center of line and clicking the right button on the mouse displays a submenu. Selecting Vertical line displays a line in the vertical direction and selecting Horizontal line displays a line in the horizontal direction.

● Data Information and Line Plot

Same as Single Profile.

● Histogram and Cumulative Ratio (Bearing Ratio)

The histogram of height (Z) component and cumulative ratio (bearing ratio) in the cross sectional shape on line are displayed.

● FFT Analysis Result (Graph at right center of screen)

The FFT analytical result (power spectrum) in the cross sectional shape on line is displayed.

● Save Analytical Result

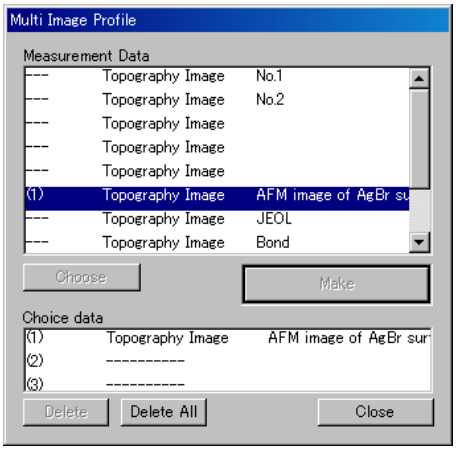
The submenu can be displayed by clicking the right button on the mouse in an area where the analytical result on the screen is displayed.
Selecting Save Data displays the Save As dialog and the analysis result (all analysis results displayed) can be saved in file in the text format.

■ Multi Image Profile

Performs cross-sectional analysis for the same line on multiple images.
For instance when you observe three types of images such as topography, elasticity and viscosity of a sample for viscoelasticity measurement at one time, you can use this function for analyzing the cross section of the same line on the different types of images.

● Selection of analysis data

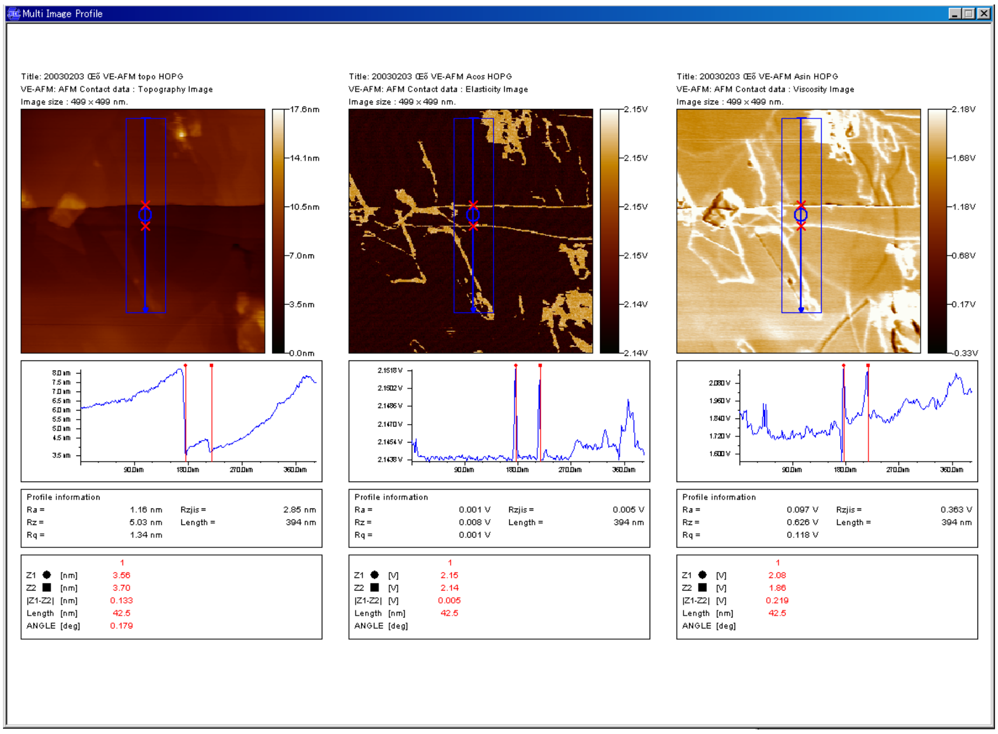
Displaying the first of a set of images that you want to analyze in the Display Window, select Cross sections – Multi Image from the Analyze menu.
The Multi Image Profile dialog box appears.



- Measurement Data
  The list of SPM data stored in memory is shown. Select a set of data you want to analyze from the list. The selected data is displayed in the Display Window.
- Choose button
  Click on Choose to select the data from the list of Measurement Data. The selected data is displayed in the Choice data area.
- Choice data
  The list of data selected from the Measurement Data area is shown here. You can select up to three measurement data items to analyze. When you start the analysis process, the data displayed in the Display Window automatically appears at the top of the Choice data area.
- Delete button
  Deletes the single SPM data selected in the list of Choice data.
- Delete All button
  Deletes all data currently selected in the list of Choice data.
- Make button
  Performs cross sectional analysis, using the SPM data selected in the list of Choice data. The display of the result changes depending on the number of the selected data.
  ✍ This button functions only when more than two data are selected.
- Close button
  Closes the Multi Image Profile dialog box and stops analysis processing.

● Display and operation of the analysis screen

The displayed information of the multi-image profiles varies depending on the number of the selected data. However, the analysis results for certain data are generally shown in the vertical direction as seen below.



The display arrangement may differ but the function, operation and displayed information are the same as those for a Single Profile. You can select any position in the SPM data for cross sectional analysis and a new positional change will be applied to any analysis operation of the SPM data.

✍ However, the histogram of cross section information and the cumulative ratio graph are not displayed.

6.7.2 Measure

Calculates and displays various measurement values for the acquired image. The measurement functions are integrated in the cross-sectional analysis functions in Sect. 6.7.1.

- **Area**

Number of pixels, area, averaged specimen height and root-mean-square value of specimen height within a designated region are measured.

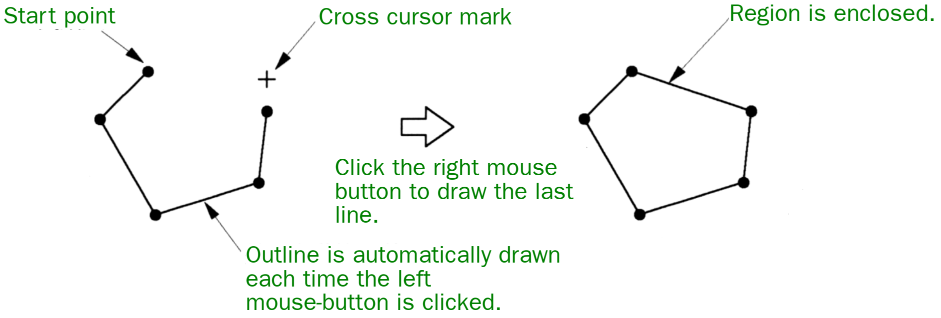
1. Click on Analyse in the main menu and select Measure in the pull-down menu. Then select Measure Area in the pull-down submenu.

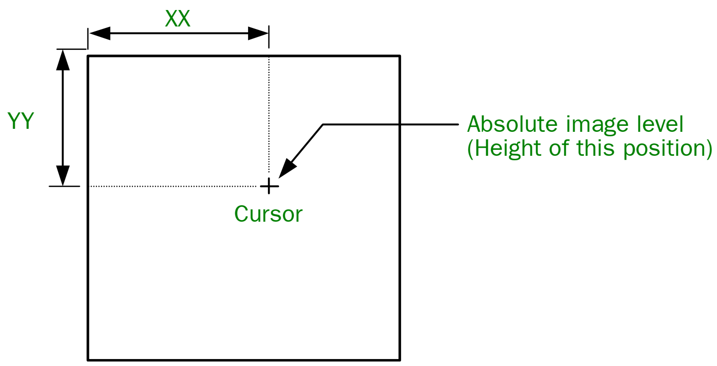
A cross cursor "+" appears on the image.

2. Move the cursor to the starting point of the desired region to be measured with the mouse; click the left mouse-button. The cursor will be fixed at the point.

Move the cursor to the next corner of the region and click the left mouse-button; then a line will be drawn between the points. Continue the same operation until the desired region is completely enclosed.

The last line is drawn by clicking the right mouse-button.

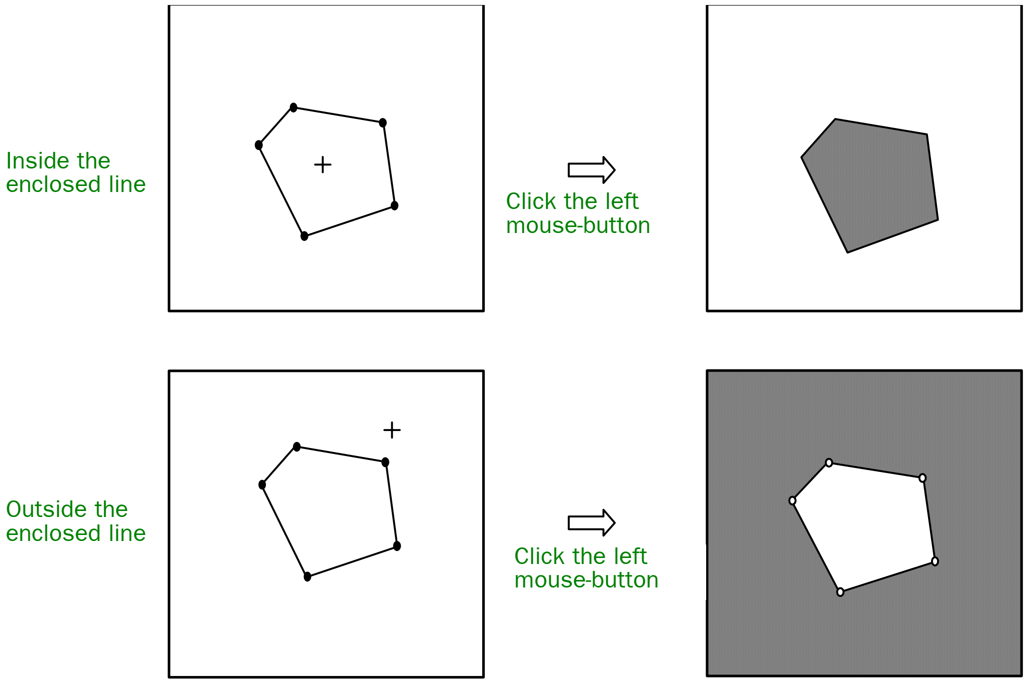




✍ The cursor coordinates (origin is the top-left corner) are indicated in Cursor position (XX, YY).

✍ The absolute image level is indicated in image height XX nm.

3. Specify the region to be measured by placing the cursor inside or outside of the enclosed line and click the left mouse-button. The specified region is displayed in black.



The number of pixels, area, averaged specimen height and root-mean-square value of specimen height within the designated region are indicated in the window.

● Line

Measures the cross sectional shape between two points. The measured surface profile can be handled as a sort of spectrum data.

1. Select Line from the Measure pull-down menu

The mouse cursor changes a cross.

2. Specify the starting point of cross sectional profile measurement.

Click the left button on the mouse.

3. Specify the ending point of cross sectional profile measurement.

Click the left button on the mouse.

A graph showing the cross sectional profile between two points specified from Display window is displayed.

4. Save data

Enter a title in the Image Profile window and click OK, and the cross section profile will be saved as data. Clicking Cancel does not save the data.

- **Point**

The distance and a relative image-height between two designated points on an image are measured.

1. Select Point in the pulldown sub-menu.
   A cross cursor "+" appears on the image.
2. Move the cursor to the starting point of the measurement with the mouse; click the left mouse-button.
   The cursor will be fixed at the point.
3. Move the cross cursor +. When the cursor is moved, the following information is indicated in the window:
   - Present coordinates of the cursor
   - Image height at the present cursor position
   - Relative image height between the present cursor and previous cursor positions
   - Distance between the present cursor and previous cursor positions
   - The highest and lowest image level on the straight line between the present cursor and previous cursor positions
4. Press the left mouse button.
   The + mark moves to the position of the cross cursor, and this position becomes the new measurement starting point.
5. Repeat steps 3 and 4.
6. Press the right mouse button to terminate this measurement.

- **Roughness**

This function displays the results of roughness analysis of the overall height of the currently displayed image (the height of the surface irregularities of the specimen). Select roughness from the Measure pull-down menu. The mean and RMS values of the height, and also the computed average roughness are displayed in the window.

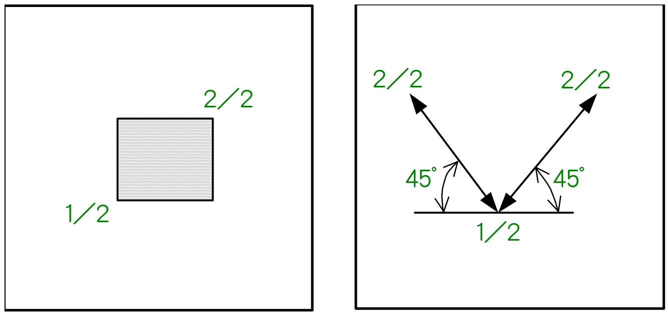
- **Surface Area**

This function displays the surface area of the currently displayed image. Select Surface Area from the Measure pull-down menu. The surface area is displayed in the window.

6.7.3 Zoom

The designated region of the current image is enlarged. With Rectangle you can designate an optional rectangular region, and with Square you can designate a square region.

1. Click on Analyse in the main menu and select Zoom in the pull-down menu. Then select Rectangle or Square in the pull-down sub-menu. A cross cursor "+" appears on the image.
2. Designate two diagonal points of an area to be magnified. The designated region is enlarged at the moment the second point is designated.
   If you select Square, the cursor can move only in a 45° direction.



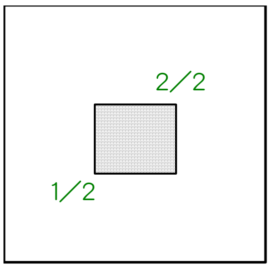
The relation between the specified image size and the enlarged image size is as follow.

Specified area		Enlarged area
Smaller than 128×128	→	128×128
Smaller than 256×256	→	256×256
256×256 or larger	→	512×512

6.7.4 Trim

The image outside of a designated region on the current image is erased. With Rectangle you can designate an optional rectangular region, and with Square you can designate a square region.

1. Click on Analyse in the main menu and select Trim in the pull-down menu. Then select Rectangle or Square in the pulldown sub-menu.
   A cross cursor "+" appears on the image.
2. Designate two diagonal points of a region to be trimmed.
   When you select Square, the cursor can move only in a 45° direction.

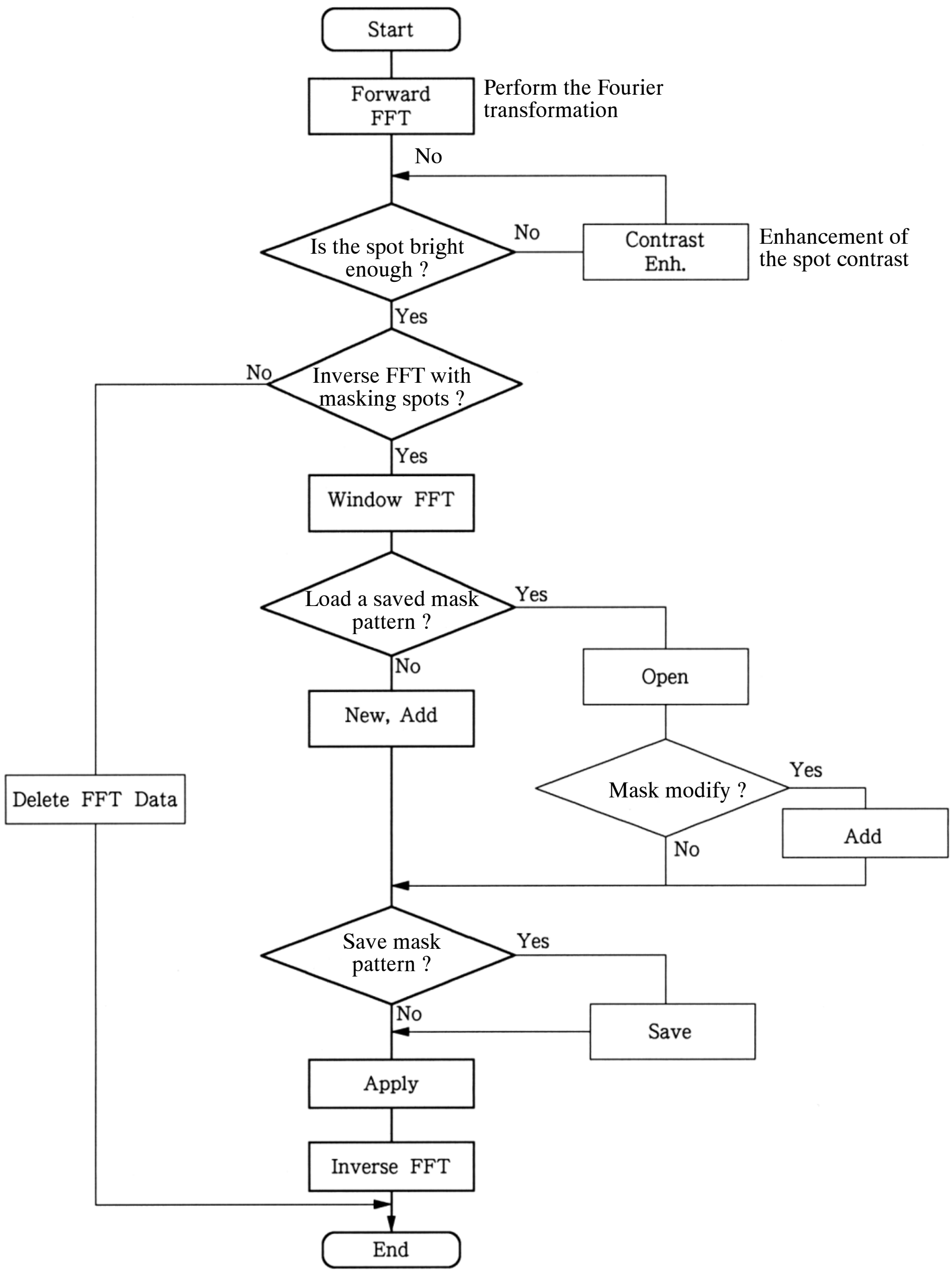


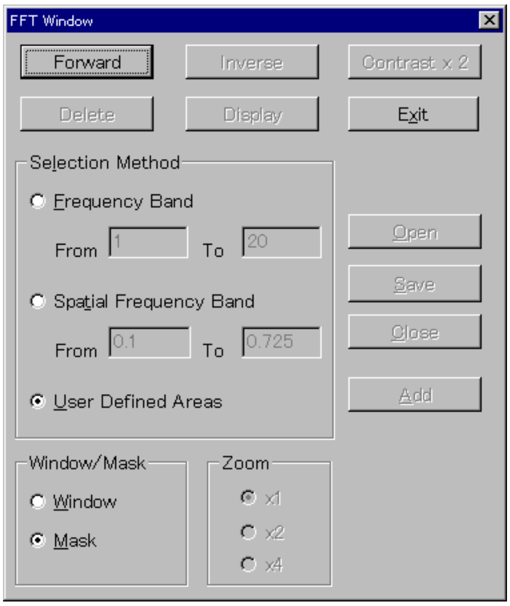
3. The image outside of the specified region is erased at the moment the second point is designated.
   The data in the erased region are set to 0 (black).

6.7.5 FFT (Fast Fourier Transformation)

The two-dimensional FFT is applied to a real image to obtain a spot image (a diffraction pattern of the real image). Also, the inverse transformation is applied to a spot image to obtain the real image. This function is useful to abstract and display a periodic structure of the obtained image.

Click on Analyse in the main menu and select FFT in the pull-down menu. The FFT window will be displayed. The procedure for the FFT function processing is shown below.





■ Forward

This function Fourier-transforms the current image, and displays the transformed spot (diffraction image).

◆ Select Forward from the FFT window.

Fourier transformation starts, and the spot (diffraction image) resulting from transformation is displayed.

✍ If the spot is dark, you can increase the contrast using Contrast×2.

■ Inverse

This function performs reverse Fourier transformation on a Fourier-transformed spot (diffraction image), and displays a real image.

◆ Display the Fourier-transformed spot (diffraction image) in the Display Window, and select Inverse in the FFT window.

Reverse Fourier transformation starts, and a real image is displayed.

✍ If you wish to recall a spot (diffraction image) that was previously Fourier-transformed and memorized in the computer, use Display to display the spot image. If you select Select to display an image, the computer will recognize the image as a spot image, preventing it from being reverse-Fourier-transformed.

■ Contrast ×2

This function accentuates the contrast (brightness) of the spot image that was Fourier-transformed using Forward.

◆ Display a spot image, and select Contrast ×2 of the FFT window.

The contrast (brightness) is intensified by a factor of two.

✍ The contrast enhancement is performed only on the displayed image and has nothing to do with the original data itself.

✍ The Contrast ×2 operation can be repeated as many times as needed until a good enough contrast is obtained. The contrast is doubled each time.

■ Delete

Fourier-transformed data is deleted from the computer memory.

◆ Select Delete from the FFT Window.

■ Display

A Fourier-transformed spot image is displayed on the Display Window.

◆ Click on the Display button in the FFT Window.

A Fourier-transformed spot image will be displayed.

✍ If no Fourier-transformed data is in the computer memory, an error message will appear.

■ Zoom

When a Fourier-transformed spot image is so small that the setting of the FFT Window is very difficult, the ×2 or ×4 zooming function and the Add function are used to enlarge the image.

■ Add

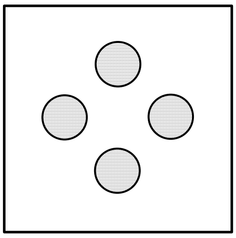
A masking window is set to specify the spots to be used for inverse FFT.

✍ The words Masking Window are used to distinguish it from the Display Window.

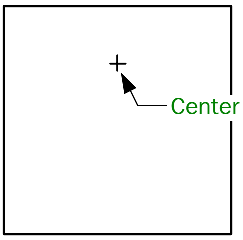
1. Display a Fourier-transformed spot image on the Display Window. Click on the Add button in the FFT Window. Then, a + cursor will appear on the spot image.
2. Setting Masking Window
   a. Select Mask in the Window/Mask frame.
   b. Move the cursor to the center of the masking window to be set, and press the left mouse button.
   c. Specify the radius of the masking window by moving the cursor and clicking the left mouse button.
      The area specified as a masking window is displayed by a circle.
3. Deleting the Masking Window
   a. Select Window in the Window/Mask frame.
   b. Move the cursor to the center of the circle, and click the left mouse button.
   c. Specify the radius of the circle to be deleted by moving the cursor, and click the left mouse button.
      The specified circle area will be deleted.

● Setting the Masking Window

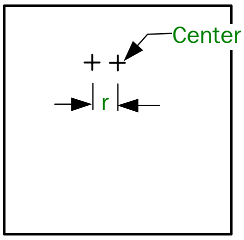
Example 1】



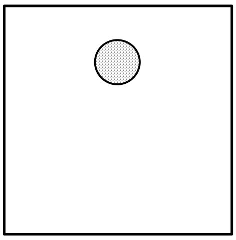
When creating four masking windows. Spots within these circles are used for inverse FFT.



Select “Mask” in the “Window/Mask” frame ; position the cursor at the center of the desired masking window; then click the left mouse-button.

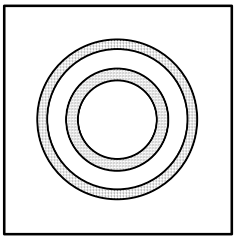


Move the ‘cursor to set the radius r; then click the left mouse button.

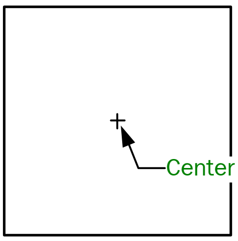


A masking window with a radius r is created. Repeat this procedure as many times as necessary.

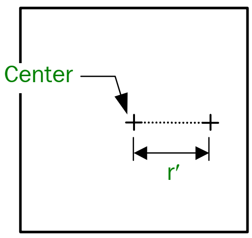
Example 2】



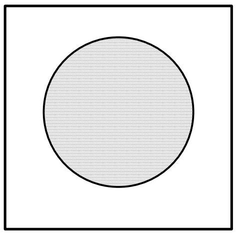
When creating coaxial rings. Spots within these rings are used for the inverse FFT.



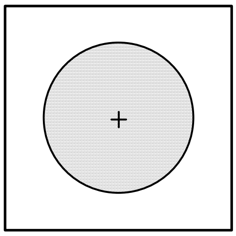
Select “Mask” in the “Window/Mask” frame; position the ‘cursor at the center of the desired masking window; then click the left mouse-button.



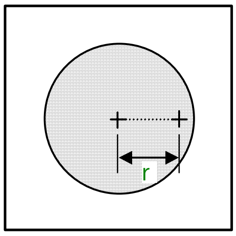
Move the cursor to set the outer radius r’; then click the left mouse button.



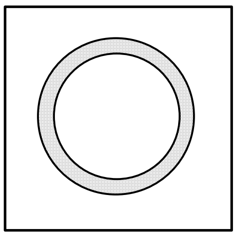
A masking window having radius r’ is displayed.



Select “Window” in the “Window/Mask”frame; position the cursor at the center of the desired masking window; then click the left mouse-button.



Move the cursor to set the inner radius r; then click the left mouse button.



The circle having radius r is erased. A ring-type masking window is specified. Repeat this procedure as many times as necessary.

■ Close

The current masking window is erased, or canceled.

◆ Click on the Close button in the FFT Window.

✍ When this function is performed, the masking window on the Display Window is still displayed, but the masking window applied to the spot image in the computer memory is erased.

✍ In order to display the spot image to which a masking window is not applied, operate Display FFT.

■ Open

A masking window saved on the disk is loaded into the computer memory.

1. Display a spot image (diffraction pattern) and click on the Open button in the FFT Window.
2. Enter the file name to be loaded using the keyboard; and click on the Load button.

   Then the file is loaded and the masking window is displayed on the spot image.

   ✍ If the sizes of the displayed spot image and the loaded masking window are different (for instance, the displayed spot image is 128×128, and the loading masking-window is 512×512), it causes an error.

Save

A created masking window is saved on the disk.

1. Display the masking window to be saved on the Display Window and click on the Save button in the FFT Window.
2. Enter the filename under which to save it using the keyboard; and click on the Save button.

   Then the masking window is saved on disk.

   ✍ A file name must be 8 characters or less. If an extension is omitted, ".MSK" is automatically added.

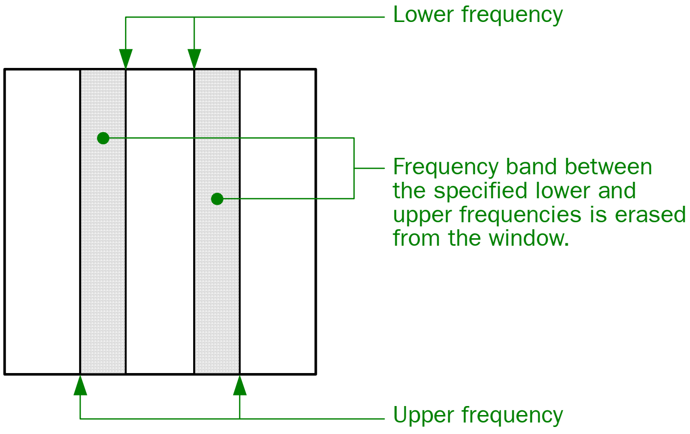
Selection Method

● Frequency band

A vertical strip masking window is defined. The masking window is applied to a specified frequency band.

1. Enter the lower frequency in the From input box and the upper frequency in the To input box. Select Mask or Window in the Window/Mask frame. Then, click on the Add button in the FFT Window.

   [Window]: The frequency band between the specified lower and upper frequencies will be erased from the window.

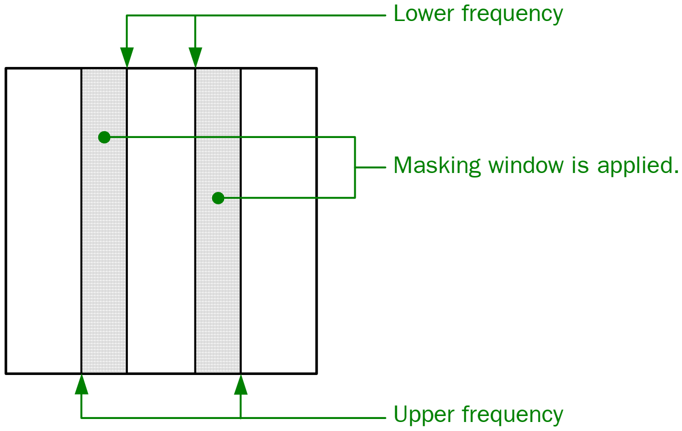


2. To eliminate electric noise of 50 Hz to 60 Hz, input as follows.

   Enter lower frequency 50

   Enter upper frequency 60

   [Mask]: A masking window is applied to the frequency band between the specified lower and upper frequencies.



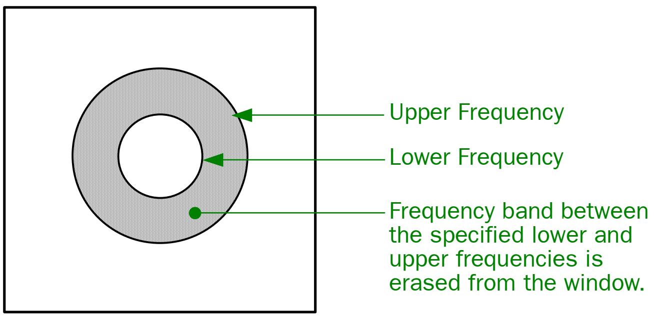
● Spatial Frequency Band

A coaxial ring masking window is easily defined as a spatial frequency band.

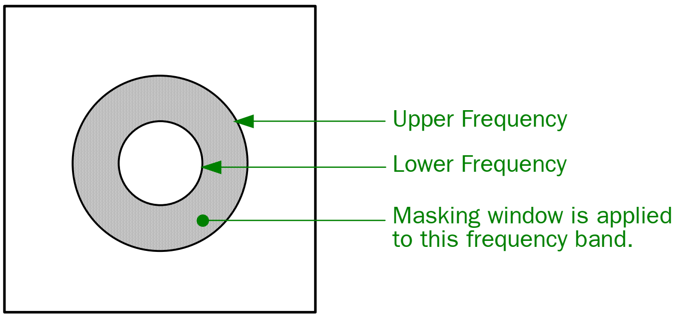
◆ Enter the lower frequency in the From input box and the upper frequency in the To input box. Select Mask or Window in the Window/Mask frame. Then, click on the Add button in the FFT Window.

✍ The unit is 1/nm.

[Window]: The frequency band between the specified lower and upper frequencies will be erased from the window.

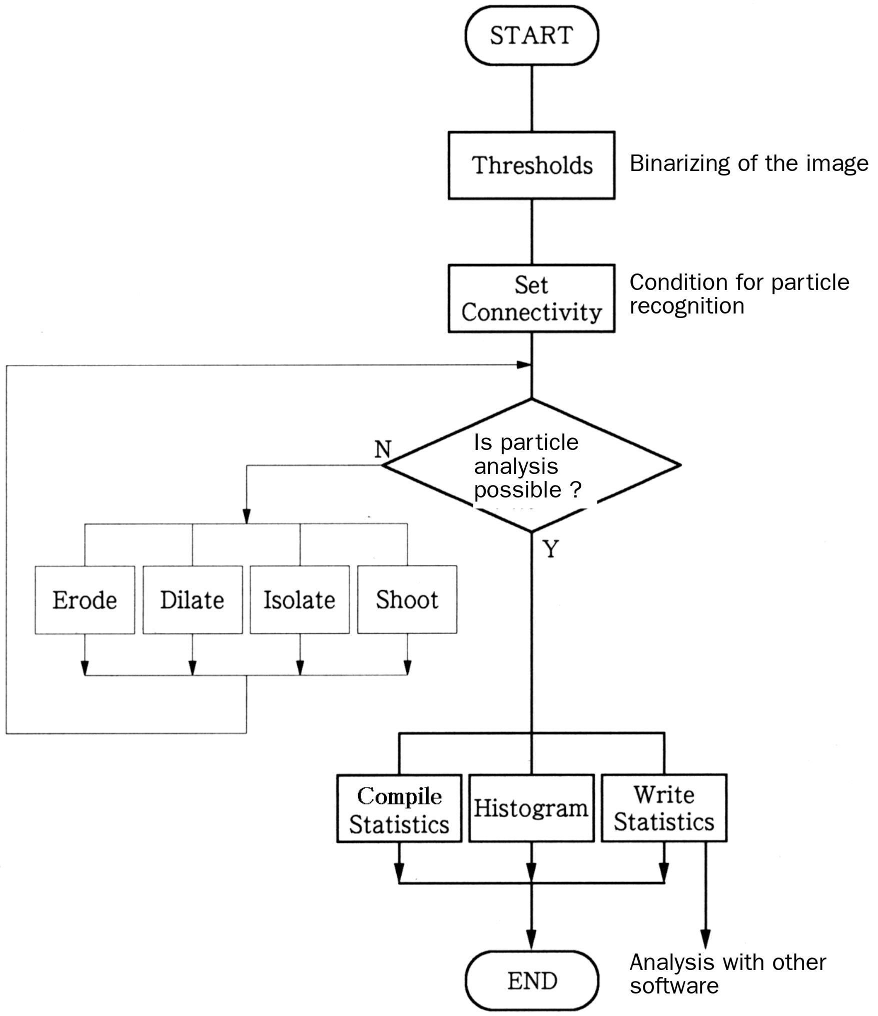


[Mask]: A masking window is applied to the frequency band between the specified lower and upper frequencies.



6.7.6 Particle Analysis

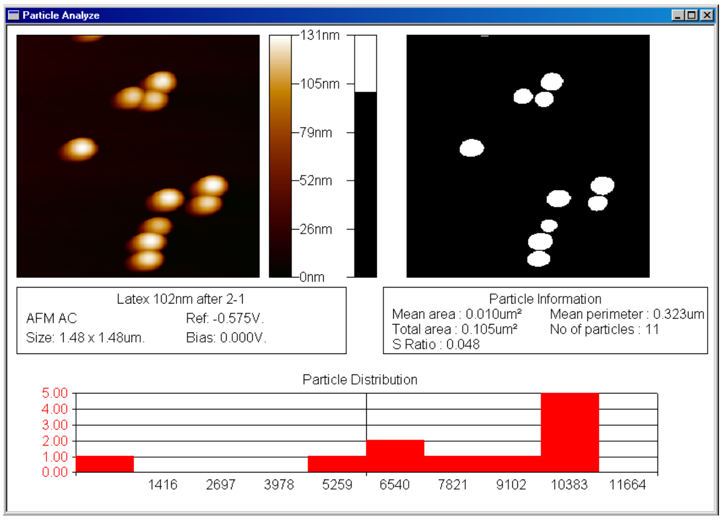
The Particle analysis function includes measurements of the number of particles and the area of each particle in an image. The procedure for the particle analysis is shown below.



■ Particle Analyze Window

The particle analyze window and particle analyze setting window open when particle analysis is conducted.

In the particle analyze window are displayed the image to analyze, binary digitized image, image data and analysis result.



● Image to analyze (image on the left)

The image for particle analysis and its SPM information are displayed.

● Binary digitized image (image on the right)

Image to analyze digitized in a binary value. The threshold level is displayed at the left of the screen. The threshold level to digitize in a binary value is set from the particle analysis setting window.

● Particle information (bottom of binary digitized value image)

Here is displayed the information about particles extracted by binary digitized value processing.

• Mean area	Mean area of groups of particles extracted
• Mean perimeter	Mean perimeter of groups of particles extracted
• Total area	Sum of all areas of groups of particles extracted
• S (area) ratio	Ratio of total area of groups of particles to the total area in the image
• No. of particles	Total number of particles extracted

Information can be displayed by setting a threshold value from the particle analyze setting window and executing analysis.

● Statistic information

The statistic processing result is displayed as histogram by setting the threshold value and executing analysis from the particle analyze setting window.
The statistic specie to display is set from the particle analyze setting window.

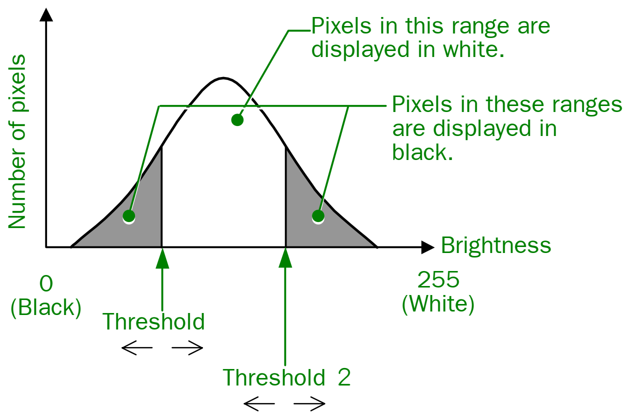
■ Particle Analysis Setting Window

● Setting tab window

Tab window that performs various settings and analysis processing, such as setting of threshold value level for binary value digitizing processing, processing of extracted area and setting of decision system.

- Threshold value setting

Determines the value of threshold when expressing an image by a binary digitized value.
Moving the threshold value slider changes the threshold value for binary value digitizing processing and the binary digitized value of the particle analysis window. Determine the threshold value while checking with the original image.



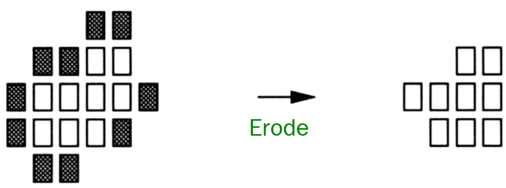
The threshold value can be changed by moving the bar chart. Select OK to determine it.

• Connection decision
  Changes the connecting conditions for deciding as one particle.
  Clicking the radio button changes the setting.

The pixels connected to a point of interest are judged to be the same particle.

• Analyse
  Performs detecting processing and analysis processing to detect particles according to the setting of threshold value level and the setting of connection legend.
  If the threshold value is changed after analysis is conducted, it is necessary to conduct analysis over again, making it necessary to click analysis for a second time.

• Erode
  Excludes one pixel layer from the area around particles.
  This function becomes effective after analyze processing is performed.



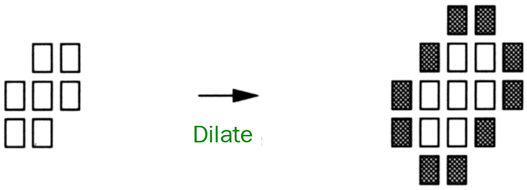
■ show the pixels to be taken away.

• Dilate

Adds one pixel layer to the area around particles.

This function becomes effective after analyze processing is performed.

【Example】



• Isolate

Excludes from the display any particles composed of a specified number of pixels or fewer.

This function becomes effective after analyze processing is performed.

Clicking Isolate displays the “Enter smallest particle size/pixels”. For example, if 10 is entered here, all particles, each of which is composed of 9 pixels or fewer, are excluded.

• Shoot

Deletes a designated particle.

This function becomes effective after analysis processing is performed.

Clicking Shoot changes the mouse cursor into a cross on the binary digitized value image. Moving the cross cursor onto the particle to delete and pressing the left button on the mouse deletes the selected particle.

• Histogram

Selects the type of histogram about the information of all particles to display at statistic analysis in the particle analyze window.

- Area: Displays the statistic result of the area of all particles
- Diameter: Displays the statistic result of the diameter of all particles.
- Area/diameter^2: Displays the statistic result of roundness (area/diameter^2) of all particles.
- Number of bars: Sets the number of bars of a histogram to display (integer value within 3 to 128).

● Statistic tab window

This tab window becomes effective after analyze processing is performed.

In this window are displayed the result of particle analysis, but also specific particles are detected and data are written.

• Statistic result

Statistic result is displayed.

Types of statistic data include area, number of pixels, diameter and roundness.

• Order of listing

Sets the order of listing data when displaying the statistical result.

- Position: Lists numeric values in increasing order in the particle position on the image (XY coordinate).
- Area/ diameter^2: Lists roundness (area/ diameter^2) in increasing order.
- Area: List areas in increasing order.

- Diameter — List diameters in increasing order.

- Select

  Selects the numeric data of particles on the binary digitized value image.

  When Select is clicked, the particle analyze setting window disappears. Select a particle of which numeric value you want to know from the binary digitized value image in the particle analyzes window and click the mouse. The particle analyze setting window appears again and the display on the statistic result moves to the selected particle data.

- Write Statistics

  The statistical results are written to a text file.

  The Compile Statistics data is saved on the disk.

  The relationship between the format and the parameters is as follows.

Delimiter — End of line

Title→Number	X1	Y1	X2	Y2	Area/nm^2	Area/pix	Perimeter
1	245	0	250	3	3.337860E-002	14	4.198683E-001
2	202	3	206	7	3.099442E-002	13	4.698625E-001
				⋮			

6.7.7 Draw Mesh

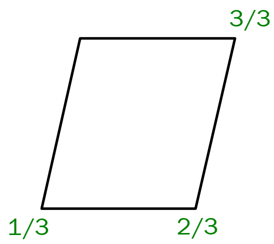
A mesh is overlaid on the displayed image.

1. Click on Analyse in the main menu and select Draw Mesh in the pull-down menu.

A cross cursor “+” appears on the image.

2. Designate 3 corners of a parallelogram.

Designate the starting point (1/3), the 1st vector endpoint (1/3 R 2/3), and the 2nd vector endpoint (2/3 R 3/3).



Unit cell designation method

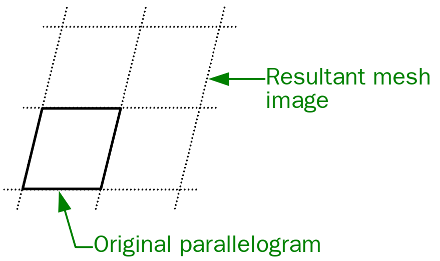
This operation designates the shape of the unit cell of the mesh.

The message “Enter integral factor to scale vectors down by” is displayed on the window.

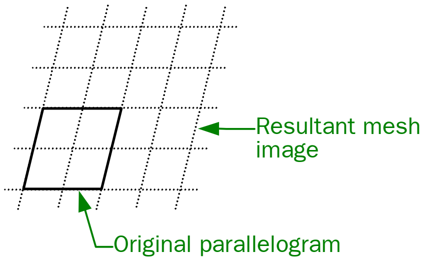
3. Input a numerical value-the denominator of division of the designated parallelogram-to scale down the parallelogram to the actual unit cell of the mesh (each side of the displayed parallelogram is divided by the entered number).

【Example】

If 1 is input, the designated parallelogram becomes the unit of the mesh image. If 2 is input, a parallelogram whose size is half the four sides of the designated parallelogram becomes the unit of the mesh image.



If '1' is entered

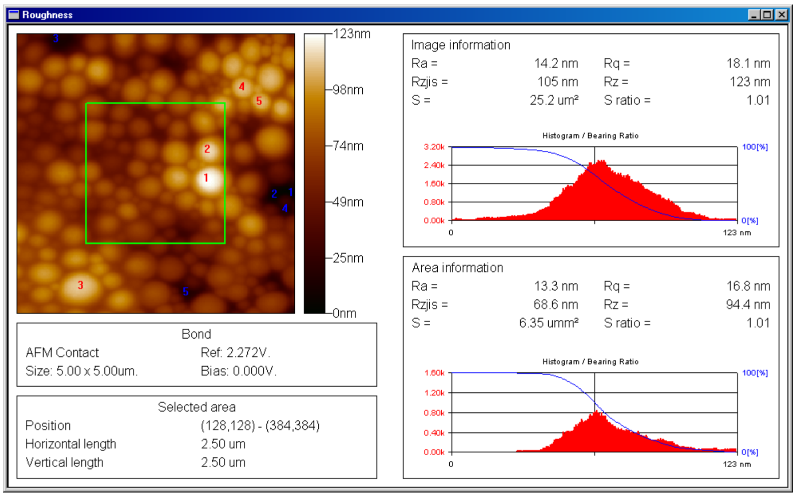


If '2' is entered

4. Click on the OK button; then the mesh is overlaid on the entire image.

6.7.8 Roughness

Analyzes surface roughness. The analysis result is displayed in a dedicated window different from the Display window.



● Designating Analysis Area

- Preview image

  Preview of the analysis screen is displayed along with height information. The analysis area is designated from this screen.

- Designating analysis area

  Clicking the right button on the mouse from the preview screen displays a submenu. Selecting Select area from the submenu displays a green square frame on the screen. The size and position of this frame can be changed with the mouse. Surface roughness analysis is conducted within the area designated by this frame.
  To delete the analysis area, select Delete area from the submenu.

• Rz On/Off

The red and blue letters 1 to 5 displayed on the preview screen are the extraction positions in 10-point average roughness (Rzjis) analysis. Whether this extraction position is to be displayed or not can be set by selecting Rz off or Rz on.

● Data Information

Information about the analysis image (title, measurement mode, measurement parameter) is displayed.

● Select Area

When an analysis area is selected, the position coordinate in the upper left corner of the area, horizontal width and vertical width are displayed.

● Image Information/Selected Area Information

The entire analysis image, result of surface roughness analysis in a selected area, and histogram/cumulative percentage are displayed.

☞ Refer to Sect. 6.7.1, “Profile” for the method of roughness analysis.

6.8 GEOMETRY MENU (IMAGE PROCESSING FUNCTION)

6.8.1 Translate

Shifts the current image parallel to itself on the screen.

1. Click on Geometry in the main menu; then select Translate in the pull-down menu.

   A cross cursor "+" appears on the image, and the message "Select point 1/2" is displayed.

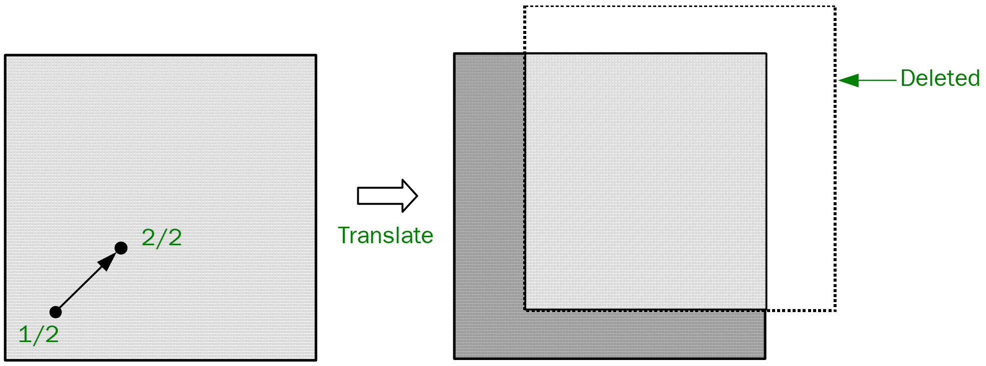
2. Designate the starting point of image shift with the mouse.

   The message "Select point 2/2" is displayed on the window.

3. Designate the ending point of image shift.

   The whole image will shift in parallel from the first point to the second.

   ✍ The part of the original image that lies outside the screen is deleted. Also, the vacant part of the current image is displayed in black (0).



After 'Translate' operation

6.8.2 Rotate

Rotates the current image on the screen.
The following four rotations are provided:

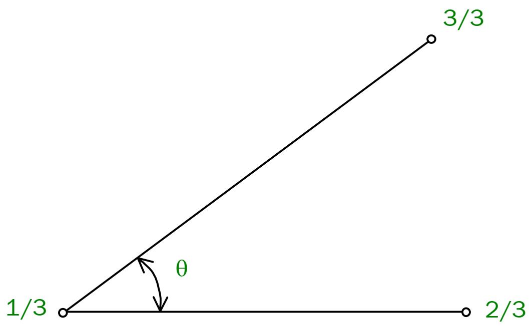
Rotation	Description
90	The image is rotated 90° clockwise around the image center.
180	The image is rotated 180° clockwise around the image center.
270	The image is rotated 270° clockwise around the image center.
theta	The image is rotated to a specified angle in a designated direction around the designated point on the image.

1. Click on Geometry in the main menu; then select Rotate in the pull-down menu.

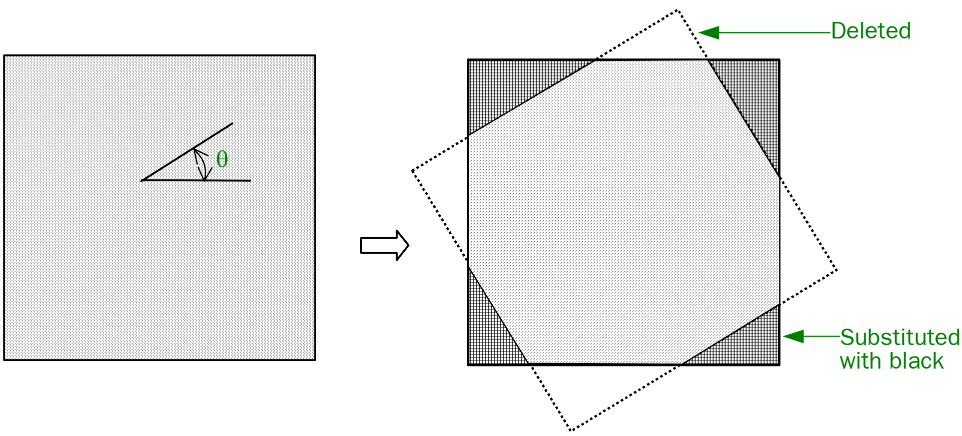
   When Rotate 90, Rotate 180 or Rotate 270 is selected, image rotation is immediately executed.

2. When Rotate theta is selected, a cross cursor “+” appears on the image. Then designate the rotation center (1/3), the rotation starting line (2/3), and the rotation end line (3/3) in accordance with the guidance displayed on the window.

Data of the parts of the original image lying outside the screen is deleted. Also, the vacant parts of the current image are displayed in black (0).



Designation of the rotation angle



Rotation angle **After the “Rotate” operation**

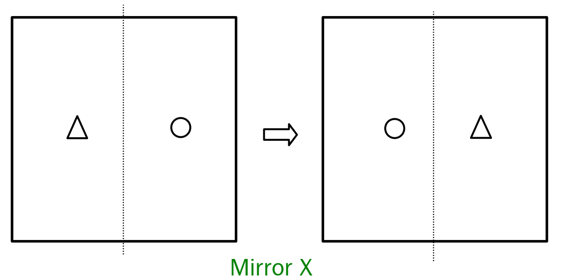
6.8.3 Mirror

A mirror image of the current image is displayed.
The following three mirror functions are provided:

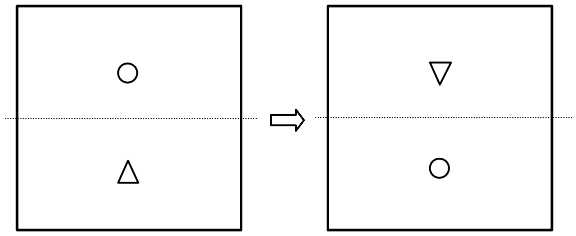
Mirror	Description
Mirror X	Reverse the image from left to right
Mirror Y	Turn the image upside-down
Transpose	Reverse the image from left to right and turn it upside-down

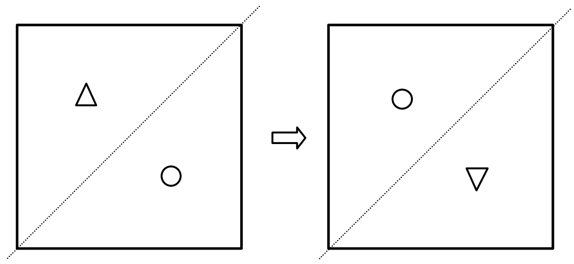
◆ Click on Geometry in the main menu; then select Mirror in the pull-down menu.

Select Mirror X, Mirror Y or Transpose on the pull-down submenu. The designated mirror image will be displayed.



Mirror X





Transpose

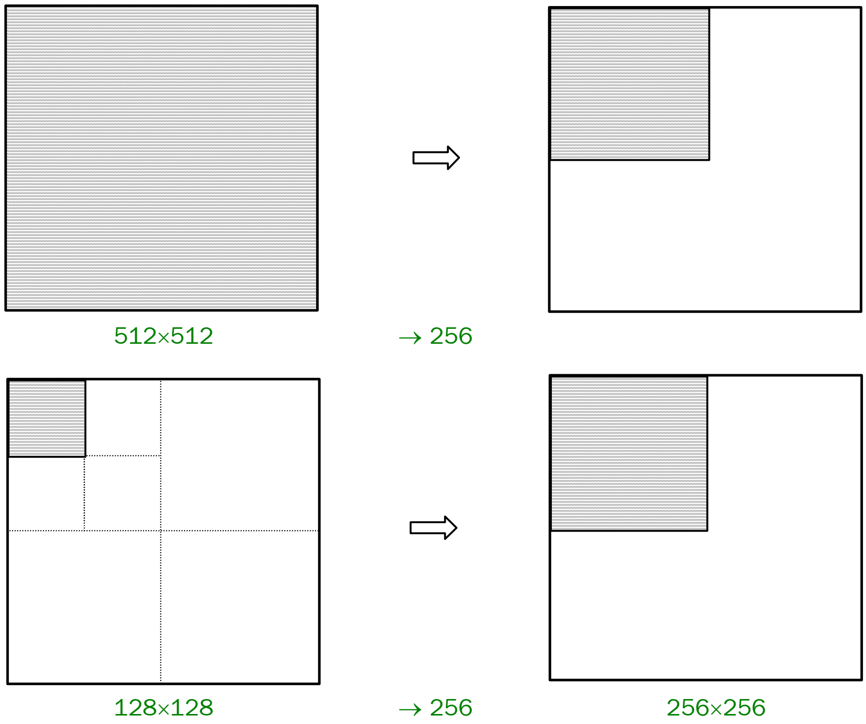
6.8.4 Resize

The size of the current image is changed.
The following three changes are provided:

Resize	Description
128	Change to 128×128 pixels
256	Change to 256×256 pixels
512	Change to 512×512 pixels

◆ Click on Geometry in the main menu; then select Resize in the pull-down menu. Select 128, 256 or 512 on the pull-down submenu. The resized image will be displayed.

✍ Selecting the same size as the current image causes an error.



6.8.5 Pad Points

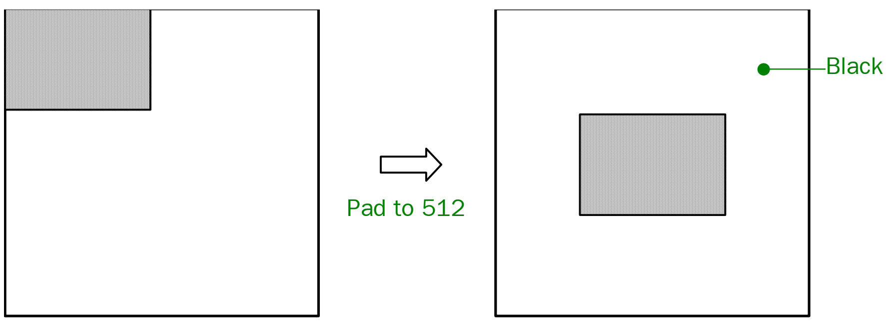
The current image is shifted to the center of a larger frame.
The following three pads are provided:

Current image	Padded image size
128×128	256, 512
256×256	512
512×512	—

◆ Click on Geometry in the main menu; then select Pad Points in the pull-down menu. Select 256 or 512 on the pull-down submenu. Then the current image will be shifted to the center.

The surrounding area of the image is replaced by black (0).

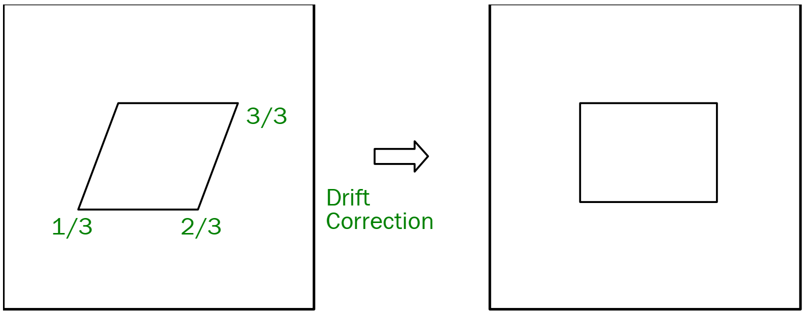
✍ Selecting any frame size other than those listed in the table above would cause an error.



6.8.6 Drift Correction

Corrects the distortion (drift) of the current image.

1. Click on Geometry in the main menu; then select Drift Correction in the pull-down menu.
   A cross cursor "+" appears on the image.
2. Specify an image distortion at 3 corners of a parallelogram—the starting point (1/3), the 1st vector endpoint (2/3), and the 2nd vector endpoint (3/3)—in accordance with the guidance displayed on the window.
   A corrected image is displayed.



Current image **Corrected image**

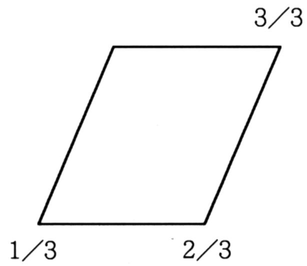
If the parallelogram used for designation is small, the corrected image is also small. The size relation between the designated parallelogram frame and the converted square frame is as follow:

Designated parallelogram	Corrected image
Less than 128×128	128×128 pixels
Less than 256×256	256×256 pixels
256×256 or more	512×512 pixels

6.8.7 Average Unit Cell

The entire image is reconstructed with a designated unit cell.

1. Click on Geometry in the main menu; then select Average Unit Cell in the pull-down menu.
   A cross cursor "+" appears on the image.
2. Designate 3 corners of a parallelogram as a unit cell.
   Designate the starting point (1/3), the 1st vector endpoint (2/3), and the 2nd vector endpoint (3/3) in accordance with the directions displayed on the window. This operation designates the shape of the unit cell of the mesh.
   The message "Enter integral factor to scale vector down by" is displayed on the window.

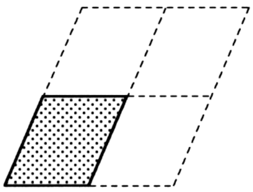


Method for designating a unit cell

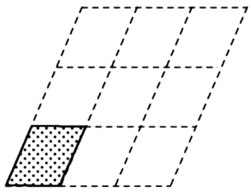
3. Input a numerical value-the denominator of division of the designated parallelogram-to scale down the parallelogram to the actual unit cell of the mesh (each side of the displayed parallelogram is divided by the entered number).

【Example】

If 1 is entered, the size of unit cell is the same as the displayed parallelogram.
If 2 is entered, the actual size of unit cell becomes 1/2 in each direction.



If '1' is entered.



If '2' is entered.

Click on the left mouse button; then the mesh frame with the actual unit cell is overlaid on the original entire image; all unit cell images are averaged and the resultant unit cell image is displayed in the top left corner of the image display screen.
The message "Continue the designation of unit cell?" is displayed.

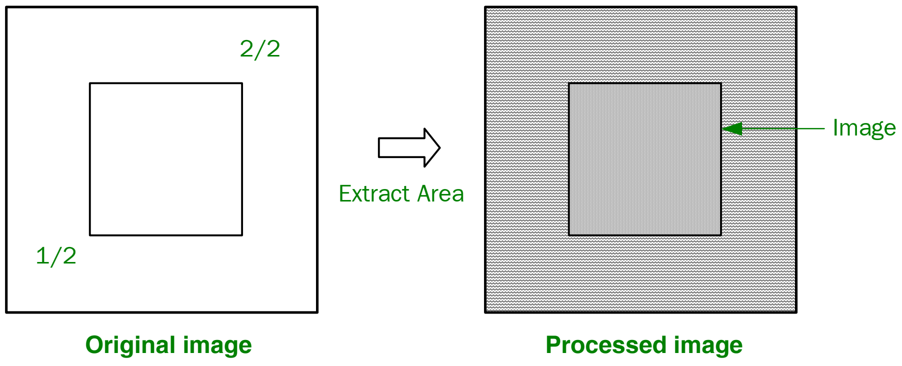
- Selecting Yes returns to the process 2.
- Selecting No makes the extracted unit cell occupy the screen.
- Selecting Cancel cancels processing.

6.8.8 Extract Area

The region outside of the designated area on the current image is substituted with black (0). This black area can be replaced by another image using the Replace Area function.

1. Click on Geometry in the main menu; then select Extract Area in the pull-down menu.
A cross cursor "+" appears on the image.

2. Designate a rectangle by specifying two diagonal points, 1/2 and 2/2.
Then, the area outside of the designated rectangle changes to black (0).



6.8.9 Replace Area

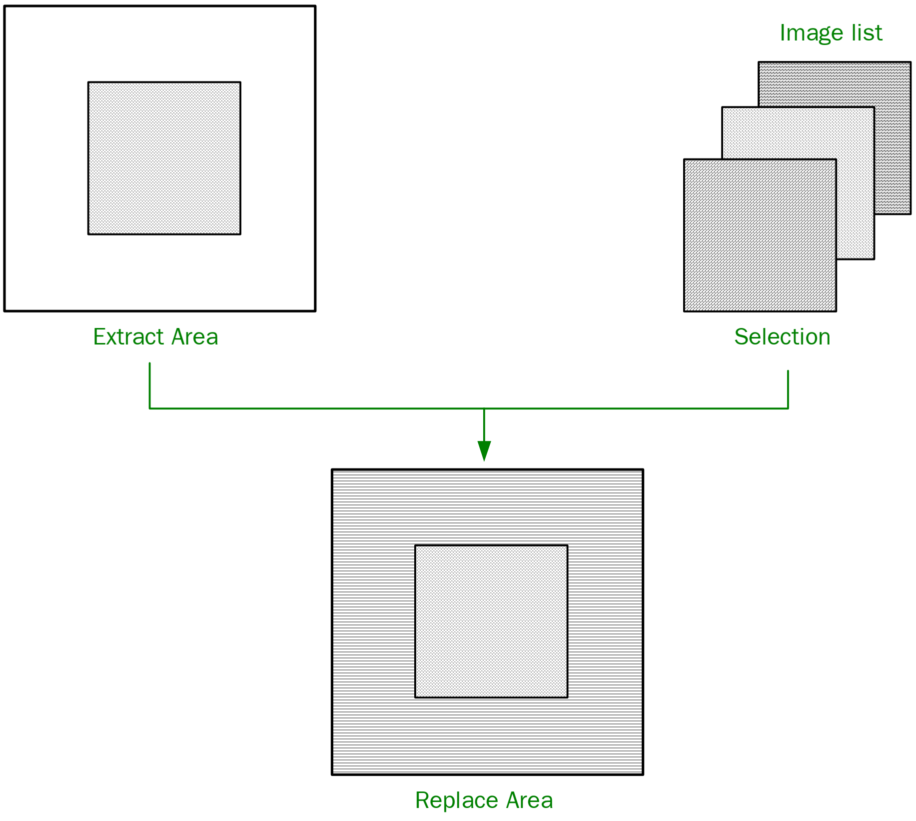
The black area made with the Extract Area operation is replaced by another image.

1. After the Extract Area operation, click on Geometry in the main menu; then select Replace Area in the pull-down menu.

Then a list of images stored in the computer memory is displayed on the window.

2. Select an image to be inserted into the black area.

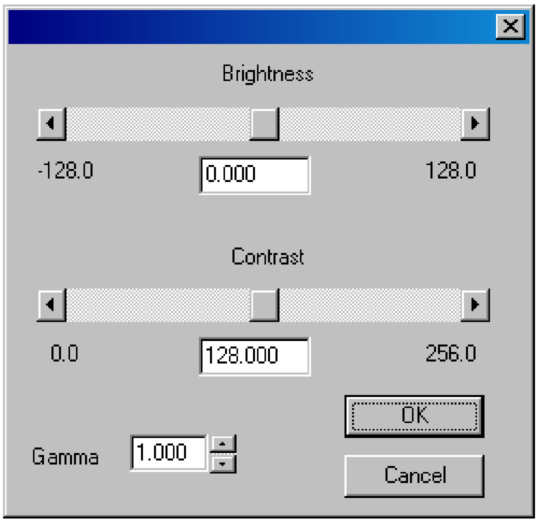
The black area of the current image is replaced by the selected image.



6.9 LUT (HEIGHT INFORMATION)

6.9.1 Brightness/Contrast

Adjusts the contrast and brightness of the current image.



- Brightness

  Adjusts the brightness of the image. Numeric values can be set within the (–128 to 128) range. The smaller the value, the darker the image. The standard value is 0.

- Contrast

  Adjusts the contrast of the image. Numeric values can be set within the (0 to 256) range. The smaller the value, the lower the contrast (gradient difference becomes faint). Increasing the value increases contrast and makes it easy to view the gradient difference, but the area in which the gradient exceeds the limit becomes larger because the higher and lower limits of the gradient are limited. The standard value is 128.

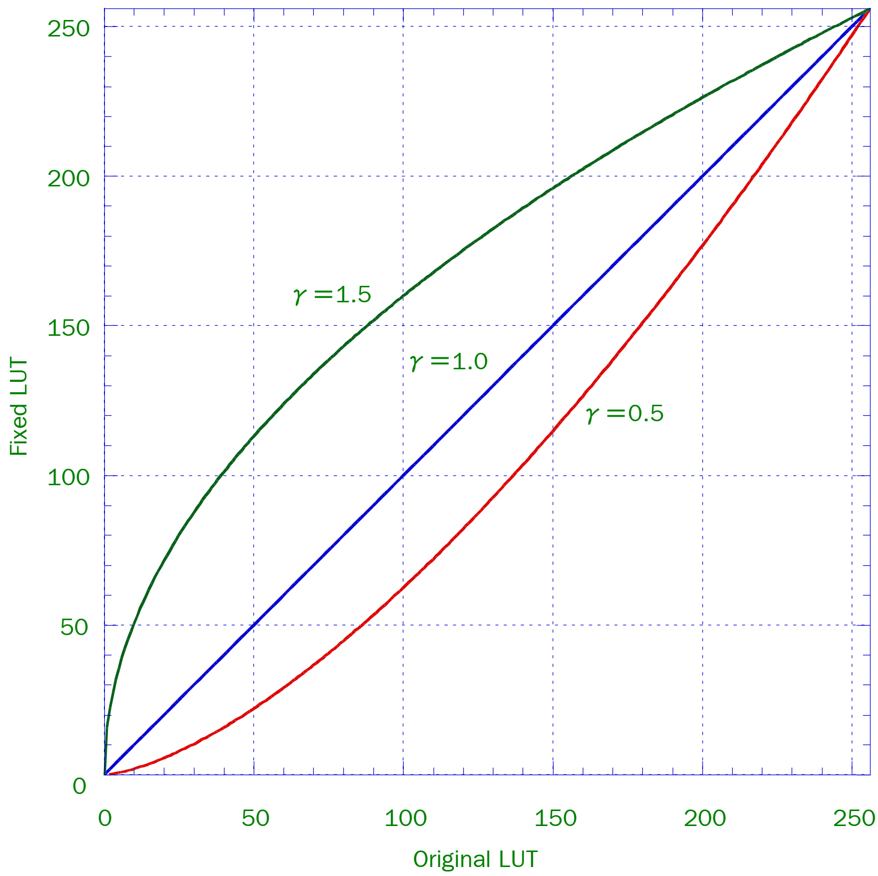
- γ value

  Adjusts the profile of the gradient change curve.
  Here, image correcting calculation, called γ correction, is used.
  The general expression for γ correction is given by the following equation.

$$O = I^{\gamma} \times K$$

O: Output signal
I : Input signal
γ : γ value
K: Correction signal

The numeric value can be set within the (0.1 to 10.0) range. The standard value is 1.0.
Given that brightness contrast is 128, the gradient change curve will be as follows when the γ value is 0.5, 1.0 or 1.5. The gradient change curve is linear when the γ value is 1.0.



1. Select Brightness/Contrast from the LUT pull-down menu. An image is displayed with a size of 400 × 400 pixels.
2. Adjust Brightness, Contrast and γ value by operating the bar chart and click OK.

   Operate the bar chart referring to the LUT bar and histogram on the left of the image.

✍ The change of brightness and contrast using this function can be applied only to a displayed image. The original data in the computer memory is not changed with this function. In order to change the image data in the computer memory, Transform Image Data must be executed.

6.9.2 Set Window

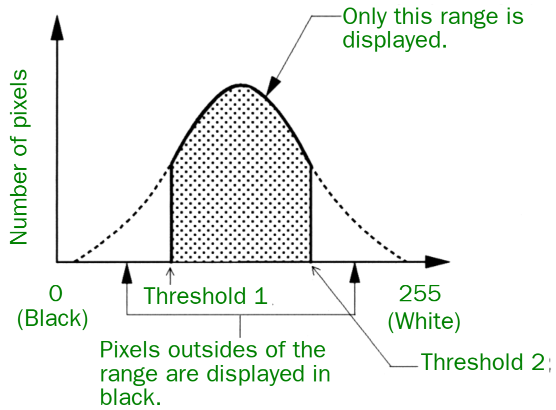
This function displays only points that lie within the set brightness range. Points of high brightness that are outside this range are set to 255 (white), and points of low brightness are set to 0 (black).

1. Select Set Window from the LUT pull-down menu.

   An image is displayed as 400(400 pixels, and Threshold1 and Threshold2 are displayed in the window as bar cursors.
2. Adjust the Threshold1 and Threshold2 values, and click OK.

   The operator will be asked “Do you transform image data? If transformed, other image data will be created”.

Clicking OK creates a new image from which data out of the range has been deleted.
If Cancel is clicked, the changes affect only on the image. The original data stored in the computer memory remains unchanged. To change the data in the computer memory, it is necessary to process Transform Image Data.



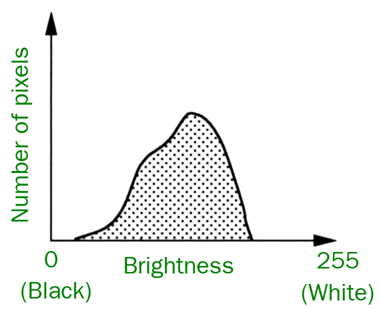
6.9.3 Histogram

A pixel histogram of the current image is displayed and equalized.

■ Display Histogram

◆ Select Display Histogram in the LUT pull-down menu.

The brightness histogram of the current image is displayed.

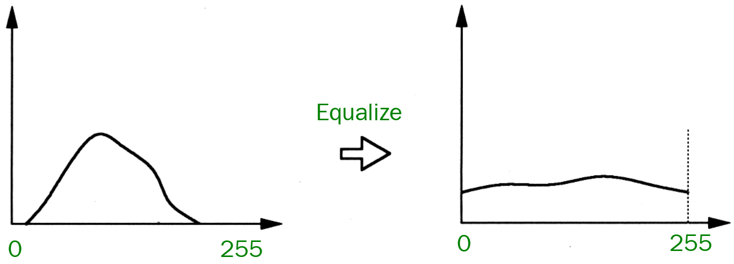


■ Equalize

◆ Select Equalize Histogram in the LUT pull-down menu.

The image contrast is equalized as shown in the figure below. The image contrast is reconstructed so that the brightness histogram of the new image becomes almost flat between 0 (black) and 255 (white).

✍ The Equalize function is applied only to the displayed image. The image data in the computer memory remains unchanged with this function. In order to change the image data in the computer memory, Transform Image Data must be executed.



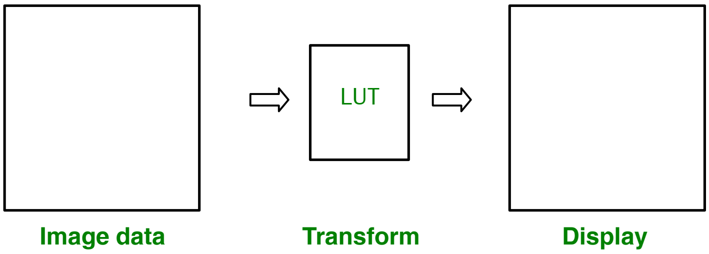
6.9.4 Display Image LUT

The current LUT (Look Up Table) is displayed on the image as a graph.

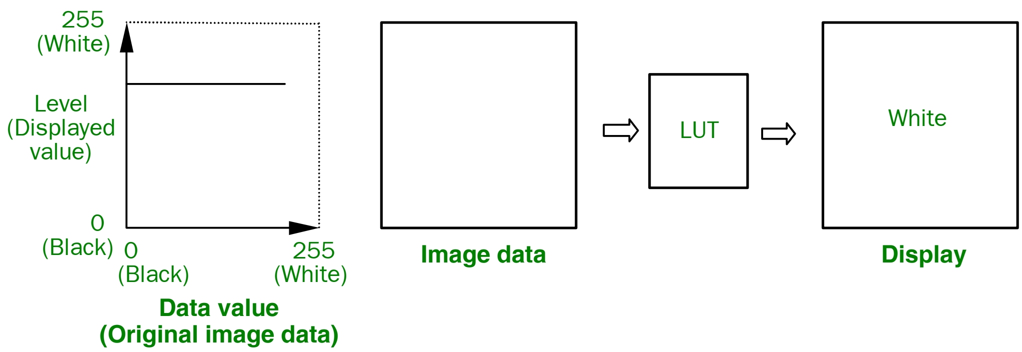
◆ Select Display image LUT from the LUT pull-down menu.

The current LUT is displayed on the image.

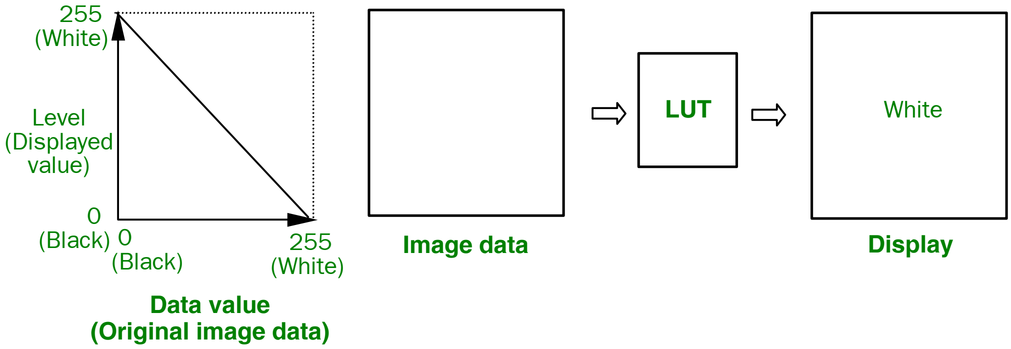
The LUT is a data-transform function for displaying the original data on the image display screen.



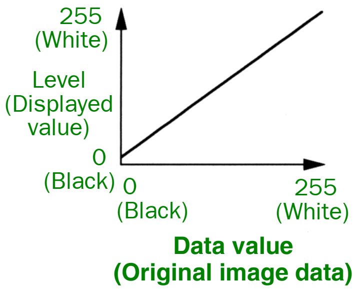
For example, if the LUT is like the one shown below, the displayed image is all white (255).



Or, if the LUT is like the one shown below, an inverse-video image is displayed.

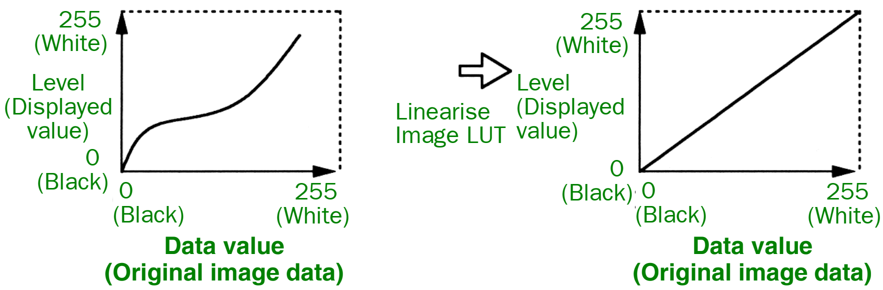


Each image has its own LUT. Usually, the LUT is defined as a default as shown below, but after Brightness/Contrast operation is implemented on an image on display, the LUT is changed.



6.9.5 Linearise Image LUT

The LUT of the current image is changed to a linear function (its default).
When the LUT of the current image is changed to a linear function, the image brightness and contrast are also changed. This function is to force the LUT to a linear function (its default). Therefore, if Linearise Image LUT is operated for the following LUT, the LUT is linearized as shown in the figure below (right).



- Select Linearise Image LUT from the LUT pull-down menu.

  Then the current LUT is linearized. The image is displayed with the linearized LUT.

  ✍ Whether the LUT has been linearized with this function or not can be confirmed with the Display Image LUT function.

6.9.6 LUT Math

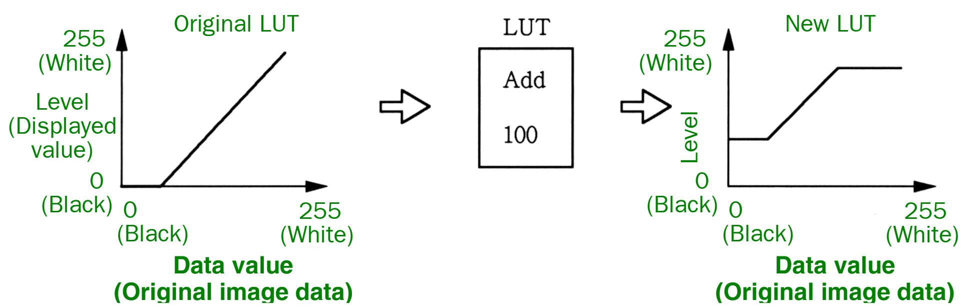
An LUT is mathematically operated on with addition, multiplication or other operation.

The following eight operations are provided:

Operation	Description
Inverse	Level axis of LUT is inverted.
Reverse	Data axis of LUT is reversed.
Add	A constant is added to LUT.
Bitwise And	AND operation with a constant for each bit
Bitwise Or	OR operation with a constant for each bit
Bitwise Xor	XOR operation with a constant for each bit
Multiply	LUT is multiplied by constant.
Divide	LUT is divided by constant.

【Example】

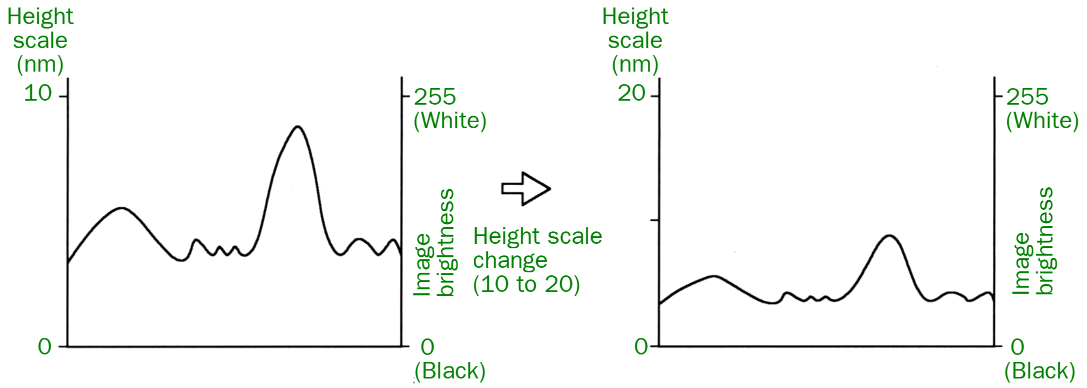
If 100 is added to a current LUT with the Add operation, the image is displayed with the new LUT shown below.
If the result of a numerical operation is outside the range of 0 to 255, the data is set to 0 or 255.



LUT Math

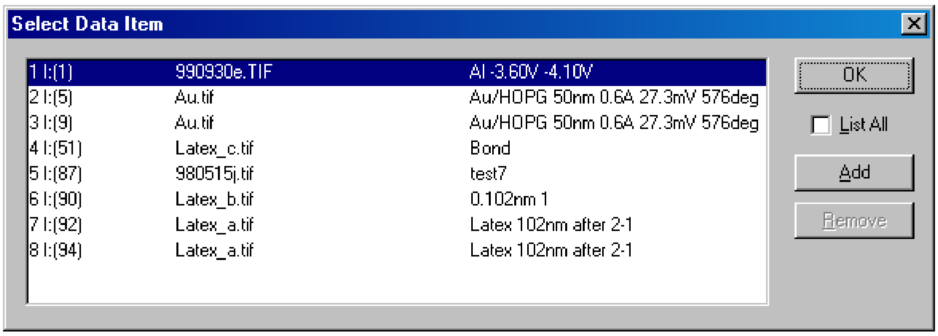
6.9.7 Fix Z scale

Fix Z Scale changes the scale of the image brightness (height of specimen-surface unevenness).
For instance, in the case of a height profile displayed with the Profile function as shown below (left), the scale of height (brightness) is 0 to 10 nm for image brightness of 0 (black) to 255 (white). If the scale is changed to 0 to 20 nm, the displayed height (brightness) profile changes as shown below (right). The contrast of the displayed image is also changed.
This function is used to compare two images whose height scales differ from each other, by converting them to the same height scales.



1. Select Fix Z Scale from the LUT in the pull-down menu.

The data selection window is displayed.



2. Select an image from the Select Data window.

Only the same type of image is displayed in the Select Data window.

To register an image to compare, select a desired image from the list and click Add. Repeat this step and select all the required images (Selected images are displayed blue).

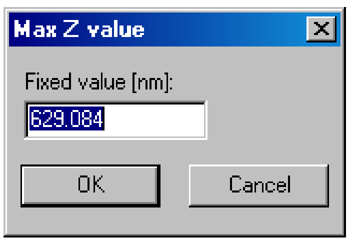
To eliminate an image from the images to compare, select an image to eliminate and click Remove.

3. When finishing to select an image to compare, click OK.

The maximum Z value is displayed.

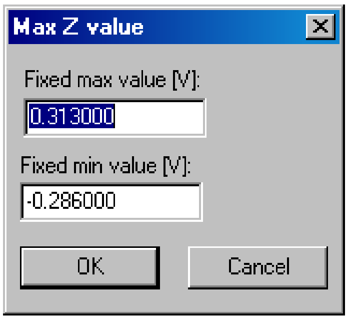
The content of the maximum Z value window differs depending on whether the image is the TOPO image or other.

- In the case of TOPO image



The largest Z-direction scale (Z height) on a selected image is displayed as the update value because the minimum value of the TOPO image is always specified as 0.

• In the case of other than TOPO image



The largest Z-direction scale (Z height) on a selected image is displayed as the maximum update value and the smallest Z-direction scale is displayed as the minimum update value.
The update value can be changed. When the update value displayed is 198.237nm, for example, it can be rounded off to a round number like 200.000nm. Upon determining the update value, click OK.

The height information of all the selected images is unified by the set update value.
The height information of all the selected images is unified by an update value. It can be compared under the same conditions in cross sectional analysis and three-dimensional display.

6.10 DISPLAY MENU (IMAGE PROCESSING FUNCTION)

6.10.1 Display

From among the image data stored in the computer memory, the current image data is displayed in the Display Window.

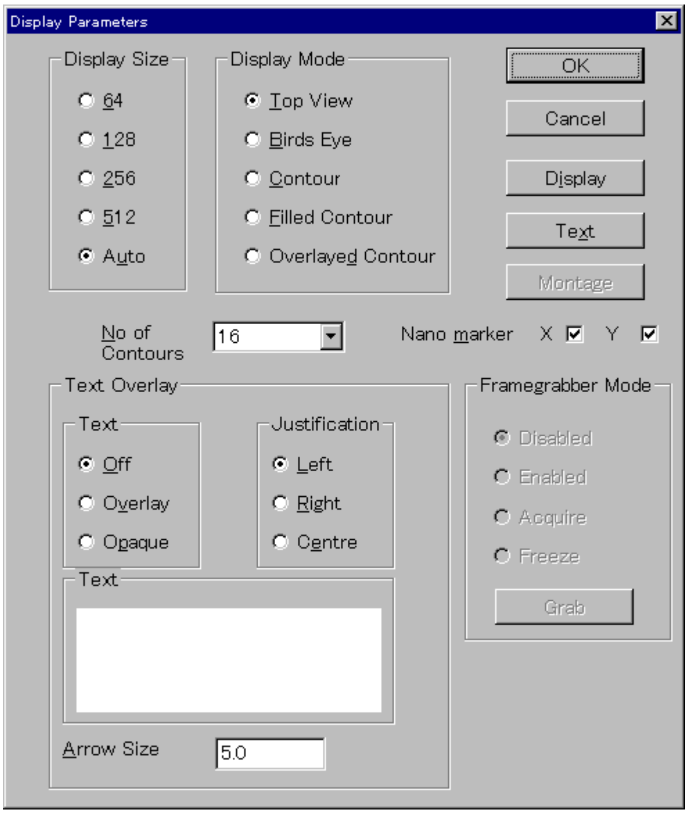
◆ Select Display in the Display pull-down menu.

The current image stored in the computer memory is displayed in the Display Window.

✍ This function is used to display an image again after clearing the display with the Clear FS function.

6.10.2 Display Parameters

Parameters for displaying an image are set in this window.



✍ Parameters set in this window are in effect regardless of the parameters set for scanning as long as they are not changed.
For example, if Display Size is 64, an image is displayed as 64×64 when loaded from a disk, even if the original image was scanned at 512×512.

● **Display Size**

The image display size is specified in this frame by selecting a radio button. The choices 64, 128, 256, 512 and Auto are provided. When a button is selected from among 64, 128, 256 and 512, an image is displayed in the selected pixel size regardless of the original image size. When Auto is selected, an image is displayed in the original image size.

● Display Mode

Selection	Contents
Top View	This mode is the normal display mode. Height (signal level) corresponds to brightness. Conversion of signal level to image brightness is performed by LUT. Usually, a higher signal level (height) is displayed at higher brightness.
Bird's Eye	An image is displayed as a shaded image.
Contour	Contour lines are displayed. Density of contour lines can be set in the "No. of Contours" selection-box in this window.
Filled Contour	Areas between the contour lines are filled with a brightness corresponding to the image level.
Overlaid Contour	Contour lines are overlaid onto the "Top View" image.

● Number of Contours

The number of contour lines for the Contour mode is specified in this selection-box.

● Nano Marker

A scale marker can be displayed to show the size of an image. When the X or Y check box is checked, the marker is shown. The marker length and unit are automatically calculated.

● SPS Measurement Points

SPS Measurement Points on the displayed image can be displayed.

● LUT Bar

The status for displaying images can be displayed.
If the check box is checked, the status for displaying images is that the LUT bar is always displayed at the right of an image, and an image is always displayed as 400×400.

● Text Overlay

Text and an arrow mark can be overlaid on the image in the Display Window.

● Text frame

Selection	Contents
Off	An arrow mark is displayed, but no text is overlaid.
Overlay	Text is overlaid directly on the image.
Opaque	Text is displayed on black background.

● Justification frame

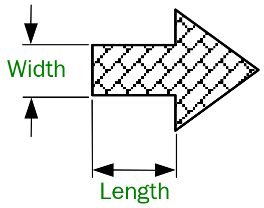
Selection	Contents
Left	Text lines are left-justified.
Right	Text lines are right-justified.
Center	Text lines are centered.

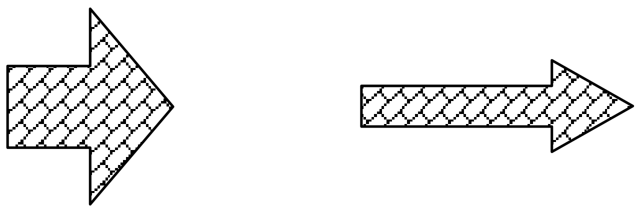
● **Text frame**

Text is entered in this input box using the keyboard. To change to a new line, use the mouse cursor, not the Enter key.

• Arrow Size

The length and width of the arrow mark are specified in this input box.





【Example】length/width = 1.0　　　　length/width = 5.0

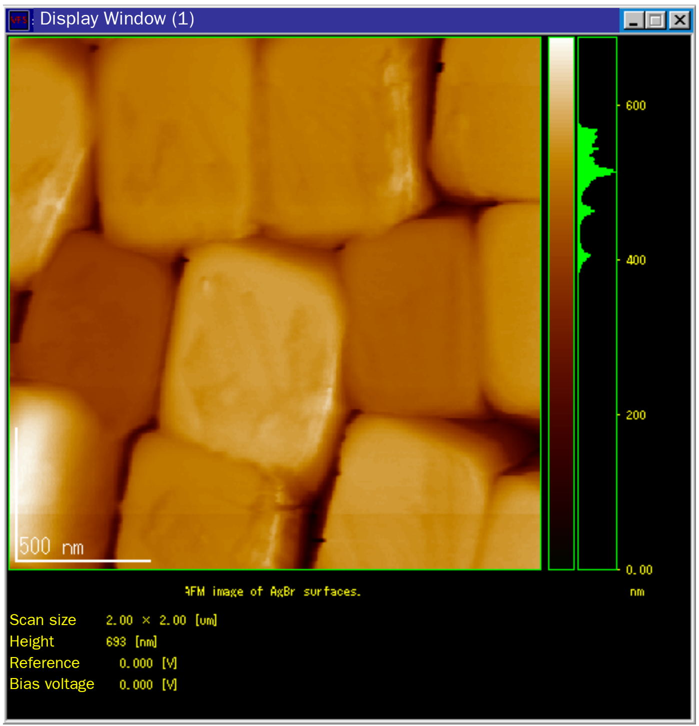
When you click on the Text button, a “+” cursor will appear on the image. Designate the starting and ending points of the arrow mark using the cursor.

● **Font**

Font type, font size, and character decoration can be set for title display character (Title), scale display character (Scale), and overlaid character (Text Overlay).
Selecting the font type from the pull-down menu and clicking Select button display the setting dialog box.

6.10.3 Full Display

If the Full Display function is selected when no check mark is put to the Display LUT bar by Display Parameters, the following image will appear in the Display Window.



If the Full Display function is selected when a check mark is put to the Display LUT bar by Display Parameters, the following image will appear in the Display Window.

6.10.4 3D Display

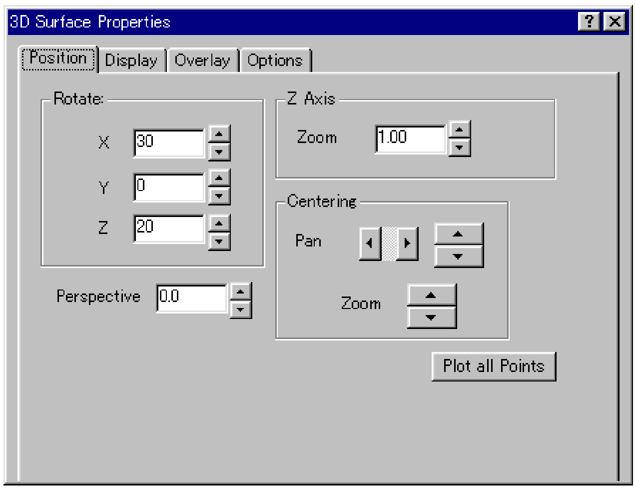
This function displays an SPM image in three dimensions. The 3-dimensional image appears in a separate window (3D Window) from the Display Window.

■ Quality of 3-dimensional display

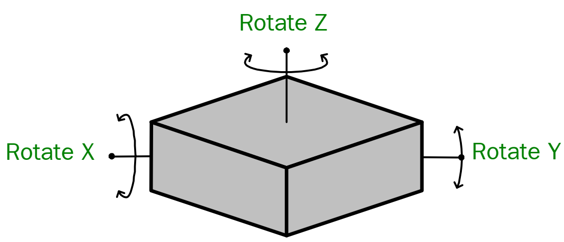
The 3-dimensional image is normally a simplified display. When you click the Plot all Points button, the precision display computation starts, enabling a more accurate 3-dimensional image to be displayed.
The time taken from when you click Plot all Points until a high accuracy 3-dimensional image is displayed differs depending upon the performance of the computer used. Generally, however between 10 and 20 seconds are necessary.
Set each parameter of the 3-dimensional image described below using the simplified display condition, then after determining the parameters carry out accurate display computation.

■ Set parameters for 3-dimensional display

● Position tab (position adjustment)



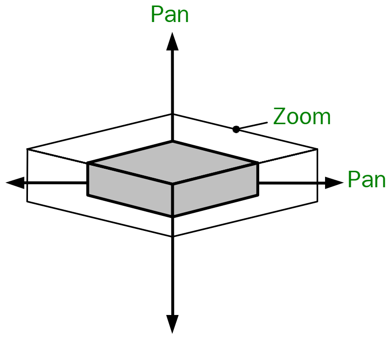
- Rotate
  Specify the rotational angle in each of the X, Y and Z directions. (360°)



- Zoom
  Adjust the magnification (Zoom) in the height direction.

• Centering

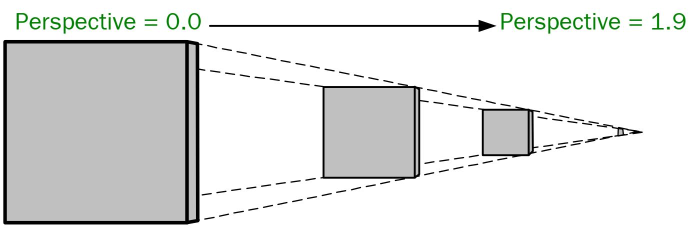
Adjust the display position (Pan) and enlargement ratio (Zoom) on the screen.



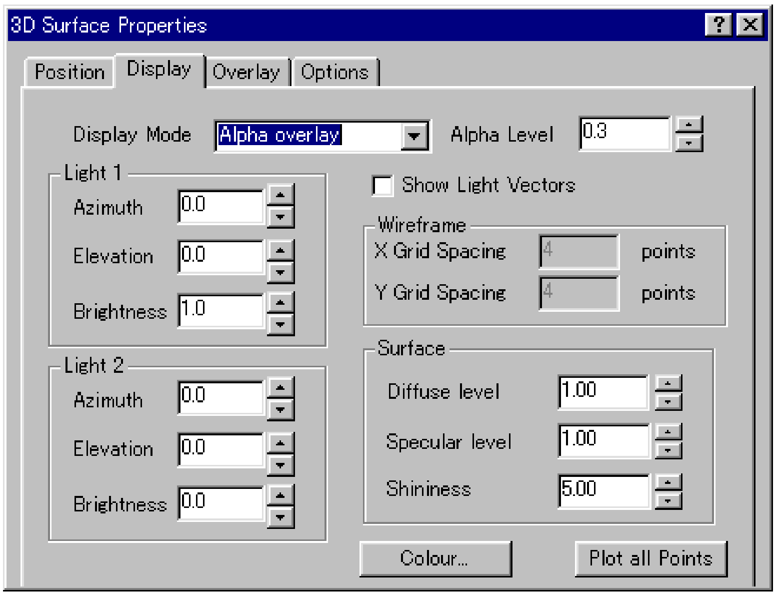
• Perspective

Specify the distance from the observation point of the 3-dimensional image. (0.0 – 1.9)

If you increase this value, the image will appear as a 3-dimensional image that is viewed from a long distance away. As you increase this value, the image moves away from the observation position (display screen) toward the disappearance point (infinite-point).



● Display tab (drawing setting)



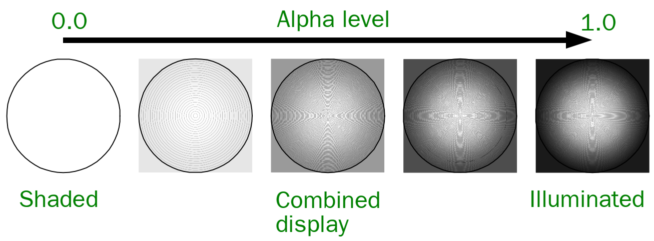
• Display Mode

Specify the method of drawing a 3-dimensional image.

Illuminated	Performs 3-dimensional display computation for the condition in which the surface is illuminated by light, and displays the results.
Shaded	Displays a 3-dimensional solid image. The display colors of the surface are based on those of the original image.
Grid	Displays a 3-dimensional solid image using a wire frame.
Merge	Combines two images into a 3-dimensional image. The height of the two combined images is compared at all points. In all cases, the higher point is used to draw the 3-dimensional image. Combining of the images is done by an Illuminated display.
Alpha overlay	Combines a Shaded display and an Illuminated display. A semi-transparent Illuminated image is displayed superimposed on a Shaded image.

• Alpha Level

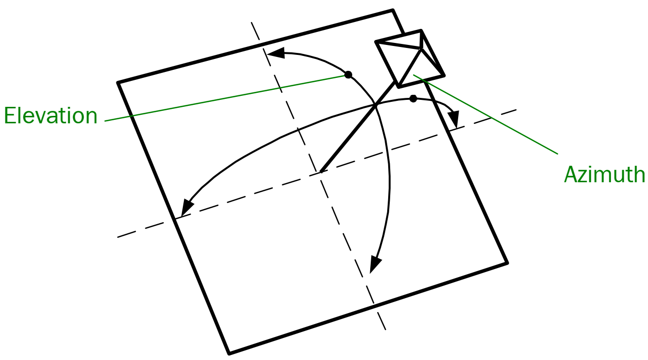
Set the degree of opacity (alpha level) of the Illuminated image displayed over the Shaded image when making an Alpha overlay display.
0.0 is the same as a Shaded display, and 1.0 is the same as an Illuminated display.



• Light1, Light2

Used to adjust the illumination direction of the light source. You can set up to two light sources.

Azimuth	Specifies the angle of rotation in the horizontal direction with respect to the screen (360°).
Elevation	Specifies the angle of rotation in the vertical direction with respect to the screen (–90° to 90°).
Brightness	Specifies the intensity of the light from the light source.



- Wireframe
  Specifies the wire frame interval for a Grid display.

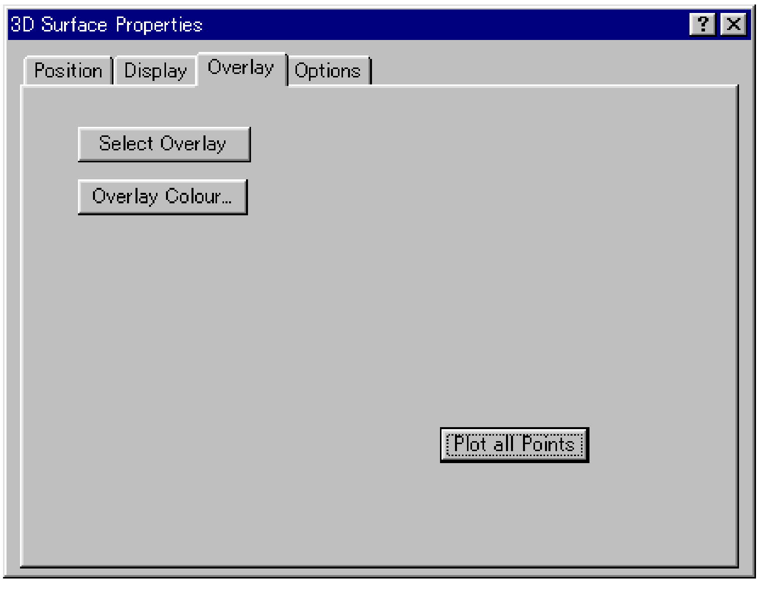
X Grid Spacing	X direction frame interval
Y Grid Spacing	Y direction frame interval

- Surface
  Used to adjust the surface drawing for an Illuminated display.

Diffuse level	Specify the light diffusion at the surface. Increasing this value results in a drawing in which the illumination light is highly dispersed (scattered) at the surface.
Specular level	Specifies the degree of light reflected from the surface. Increasing this value results in a drawing in which the illumination light is highly reflected at the surface.
Shininess	Adjusts the shininess of the surface. Increasing this value causes the brightness to decrease.

- Show Light Vectors
  Checking this illustrates the direction of the illuminated light in the image.
- Colour
  Specifies the drawing color for an Illuminated display.

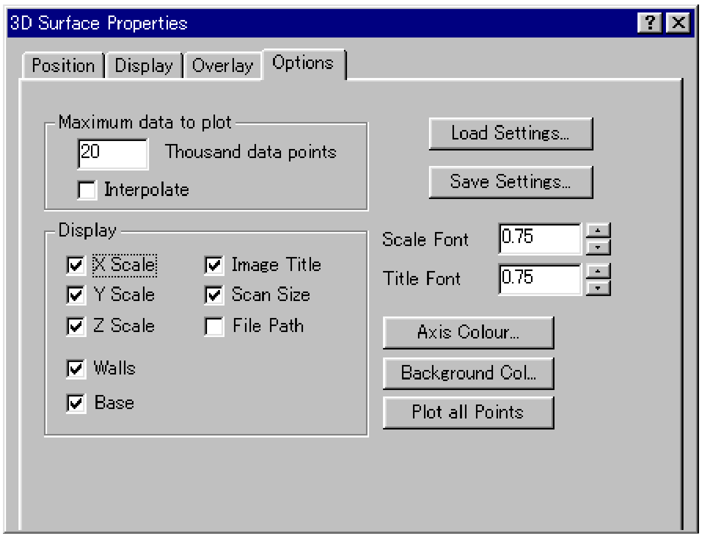
● Overlay tab (combined display setting)



This function sets the combined images for a Merge display.

- Select Overlay
  When you click this item, the Select Data Item window opens, and a list of images currently stored in the memory appears. Here, select the images that you wish to combine.
- Overlay Colour
  Specify the display drawing colors of the images to be combined and displayed.

● Options tab (option setting)



Set the various option functions.

- Maximum data to plot

  Set the computation accuracy for a simplified display. If you increase the value in the text box, the accuracy of the image in the simplified display mode will increase, however it will take more time for the image to be displayed. Normally, set a value of about 10 – 20.

  Also, when you check Interpolate, the image roughness that occurs during 3-dimensional drawing is reduced, however like the above it will take more time for the image to be displayed.
- Display

  Checking this item displays the X, Y and Z direction scales.
- Load Settings

  Checking this item loads the settings for displaying a 3-dimensional image from the file (extension: ∗. 3dp).
- Save Settings

  Checking this item saves the settings for a 3-dimensional image in the file.
- Scale Font

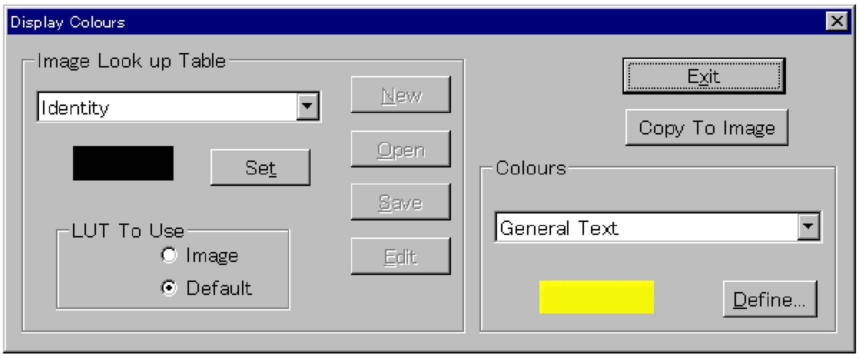
  Sets the font size of the scale display.
- Title Font

  Sets the font size of the title display.
- Axis Colour...

  Sets the display color for a scale display, for example.
- Background Col...

  Sets the background color of the display window.

6.10.5 Display Colours...



The color for displaying an image and colors for displaying other data in the screen are designated.

● Image Look up Table

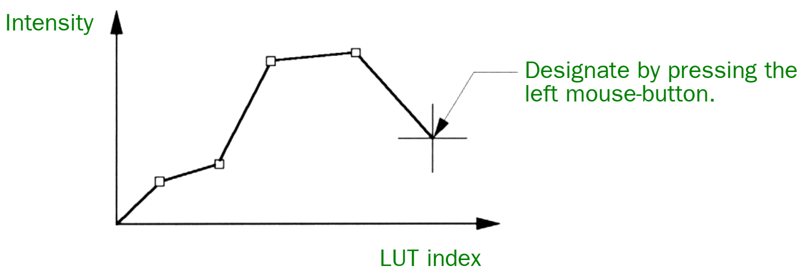
The color for displaying an image is selected in this frame.

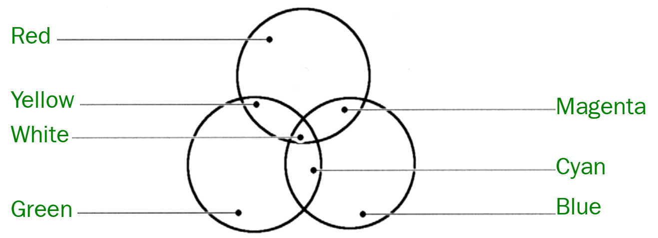
Color table	Description
Identity	Linear gray scale (High: White, Low: Black)
Inverse	Inverse linear scale (High: Black, Low: White)
Logarithmic	Logarithmic gray scale
Pseudo colour	High: Red, Middle: Green, Low: Blue
Blue	Blue mono-color (linear scale)
Yellow	Yellow mono-color (linear scale)
User 1, User 2	User-defined color

New: Image color is defined as displayed in the above box.
Open: A saved color table is loaded from the disk.
Save: The current color table is saved on the disk.
Edit: The current user-defined color table can be changed.

The procedure for making or modifying a color table with “Edit” is as follows:

1. Select User 1 or User 2 and click on the Edit button.
   Red, green and blue color table definition windows will appear.
2. Define the R (red), G (green) and B (blue) tables using the mouse.





- **Colors**

This function is used to set the display colors of the following parts.

Part	Description
Old Image Boundary	Color of a non-current image boundary
Current Image Boundary	Color of the current image boundary
Overlay Text	Color of text superimposed on an image
General Text	Display color of image data
Selected Points	Color of the + mark when specified by the mouse
Axes Color	Color of the graph axes
Plot Color	Color of the graph data display
Reverse Plot Color	Data display color of one of two graphs displayed on the same coordinate axes
Grid Color	Display color of graph grid
CITS Border Color	Color of CITS image border
Framestore Background	Background color of the “Display Window”
Plot 1 to 8	Color displayed in the graph

6.10.6 Clear Memory (FS)

The displayed image is cleared.

◆ Select Clear FS in the Display pull-down menu.

The image displayed on the Display Window is erased.

✍ This function clears only the displayed image or data. Image data in the computer memory are not erased. To do this, use Close in File.

6.10.7 Grab from Memory (FS)

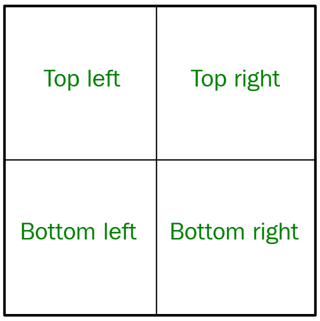
An image displayed on the Display Window is stored in the computer memory with a title name given to it.

1. Click on Display in the main menu; then select Grab from FS in the pull-down menu. Then, a sub-pulldown menu is displayed.

2. Select a part of the image to be stored from the sub-pulldown menu.

The following seven choices are available.

Item	Description
Whole	Whole image in the Display Window
Top left	Top left 1/4 of the Display Window
Top right	Top right 1/4 of the Display Window
Bottom left	Bottom left 1/4 of the Display Window
Bottom right	Bottom right 1/4 of the Display Window
Center	Center 1/4 of the Display Window
Selected	A designated area of the Display Window (refer to the Note below)



✍ When Select is selected, a "+" cursor appears in the image. Then, designate two diagonal points by pressing the left mouse button.

3. The message "Keep colors ?" is displayed on the window. If you want to keep the color data, select Yes.

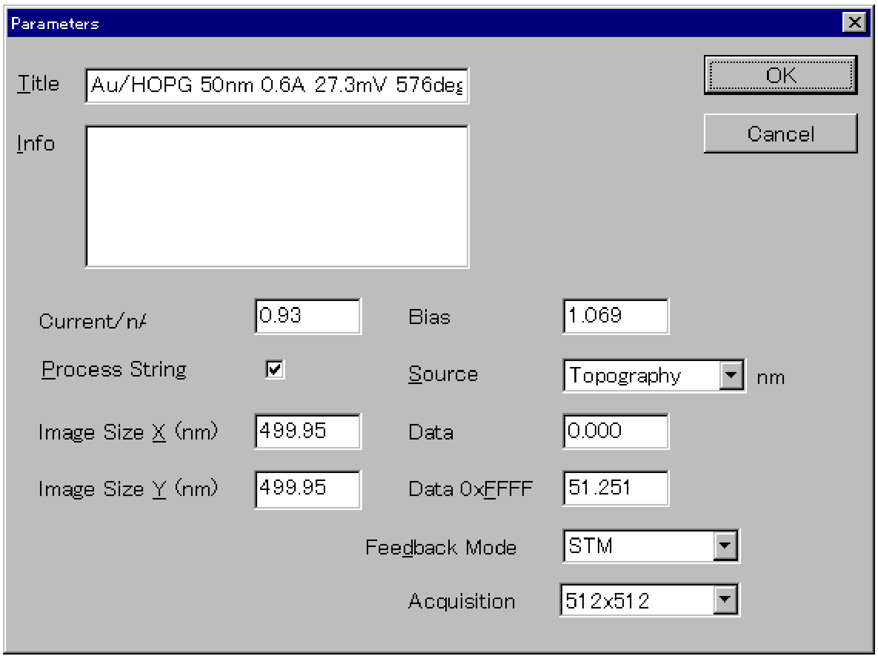
4. The message "Enter image title" is displayed on the window.

5. Input the title using the keyboard.

✍ This title is not the file name saved on the disk, but is listed by the Select function.

6. The designated image is grabbed in the computer memory.

6.10.8 Change Parameters



The contents of the Data Information window are changed. The items that can be changed as follows:

Item	Description
Title	40 characters or less
Info	39 characters×5 lines
Reference/V/Current/nA	Optional
Sample Bias (V)	Optional
Process string	Whether or not the history of ON, OFF, image processing , etc. is displayed
Image Type	Topography, Current image, Log current image, External ADC image, CITS current image, CITS log current image, Force image
Image Size X (nm)	Optional
Image Size Y (nm)	Optional
Data 0*0000	Absolute image level (height) to be displayed in black (0)
Data 0*FFFF	Absolute image level (height) to be displayed in white (255)
Feedback mode	STM, Contact, Slope, FM, FMS
Scan mode	VE-AFM, LM-FFM, KFM, MFM, 1024×1024, 512×512, 256×256, 128×128, Mirror, 2 Inputs (512), 2 Inputs 4 Inputs, Line Scan 512, Line Scan 1024, Montage, Single SPS, SPS Mapping

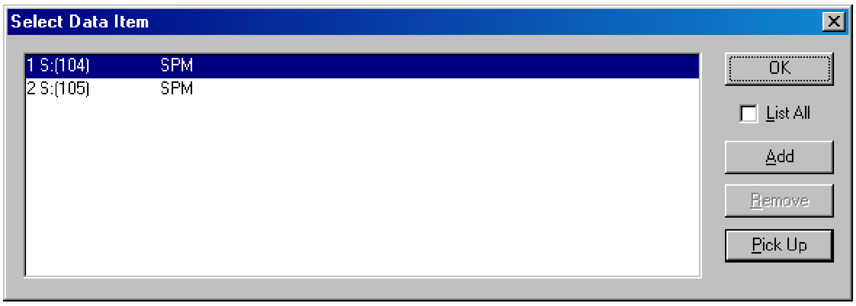
6.10.9 Display SPS Measurement Position

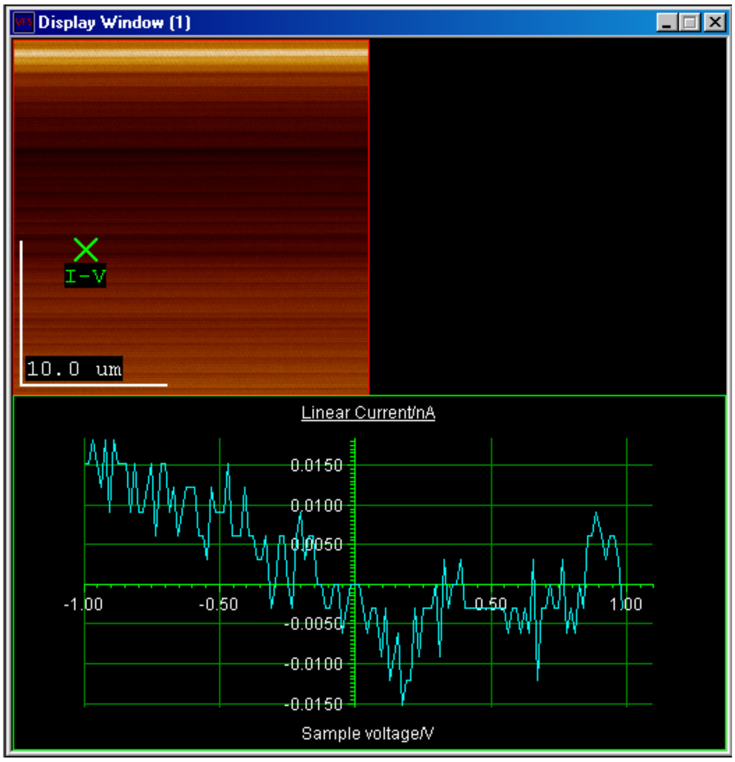
When SPS measurement is performed on an image, its SPS data will be managed along with the image data. Here, SPS data measurement position and spectrum are referenced, SPS data is extracted, etc.

✍ This function becomes effective when the image data containing SPS data is displayed in the Display Window.

1. Select Display SPS measurement position from the Display pull-down menu.

The Select Data Item window is displayed and the selected spectrum measurement position and spectrum are displayed in the Display Window.





2. Select a spectrum to display from the list and click Add.

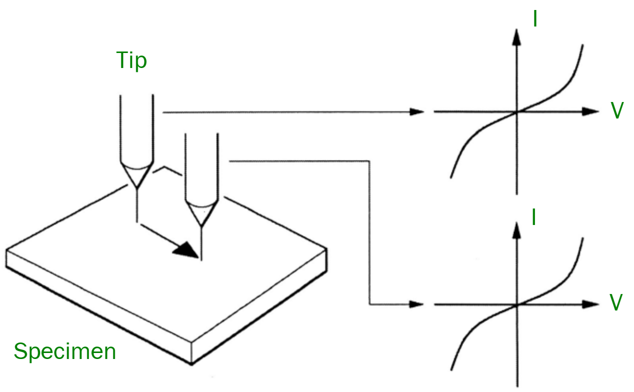
The selected spectrum and SPS measurement position are displayed.

3. Click Pick Up with a spectrum selected.

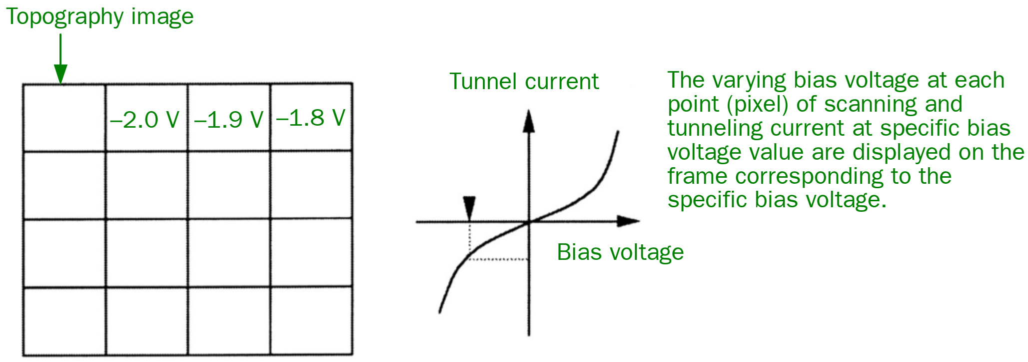
The selected SPS data is pick upped from the image data and can be handled as independent data.

6.11 MAPPING MENU (IMAGE PROCESSING FUNCTION)

The SPS mapping function performs SPS measurements at each point (128×128) in the measurement area while scanning this area. It is possible to perform mapping measurements for various SPS measurements such as I-V, S-V, I-S, force curve and friction force curve.
We here explain the procedure of mapping for I-V measurements, as an example of the SPS mapping function. The procedure of other mapping measurements is the same as that of the mapping for I-V measurements, so when you carry out the other mapping measurements, apply the following explanation to the measurements to be performed.
The SPS mapping measurement for I-V measurements are called the CITS (Current Imaging Tunneling Spectroscopy) function measures I-V characteristics at each point of scanning. That is, I-V data is obtained at each pixel.

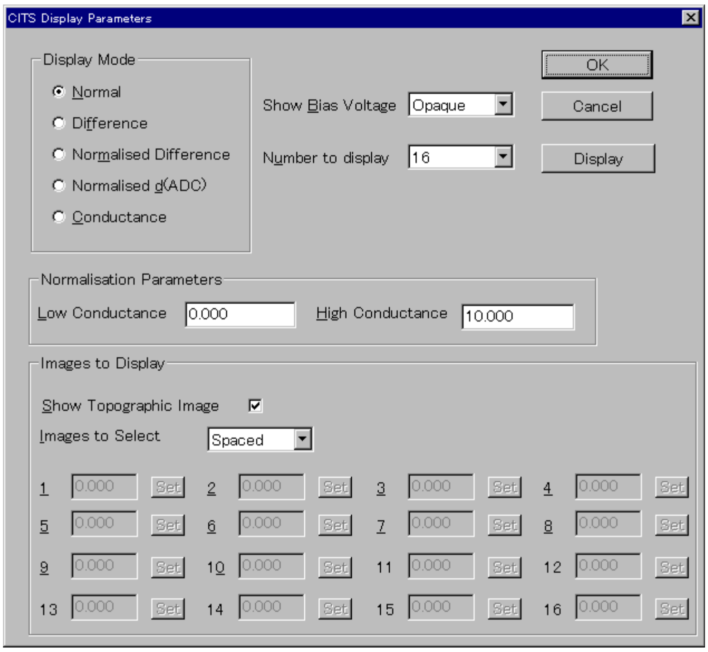


The top left image on the screen is a topographic image obtained under the parameters specified in the SPM Parameters window. The next (right-hand side) image and all others show tunneling current images obtained at various bias voltages without changing the tip height at which the topography image was obtained.



Since I-V data and a topographic image are measured at the same time, there is a perfect position correspondence between the topographic image and tunneling current. It is possible to select, using the mouse, an arbitrary point on the specimen while watching its topographic image and accurately display the I-V characteristics of the selected point.

6.11.1 Display Parameters



The display parameters for CITS images are specified in this window. CITS images are displayed in a size of 128×128 pixels.
The parameters to be set are as follows.

● Display Mode

Display modes are selected with these radio buttons.

- Normal
  Current images are displayed directly.
- Difference
  Images of the current difference between neighboring frames are displayed.
- Normalized Difference
  Images of the normalized current difference between neighboring frames are displayed.
- Normalized d (ADC)
  Images of the normalized current difference between neighboring frames based on the original AD values are displayed.
- Conductance
  Derivative (dI/dV) images are displayed.

● Show Bias Voltage

This function enables the bias voltage used to acquire an electric current image to be either displayed or not displayed.
You can select one from the following two modes:
Overlay of displayed text (The area around text is not erased.) and Opaque (area around text is erased) Off (not displayed)

● Number to display:

You can select the number of images to be displayed (up to 16 images).

● Normalization Parameters

Low conductance: Value that appears black on the display. This parameter is used only in the Conductance display mode.
High Conductance: Value that appears white on the display. This parameter is used only in the Conductance display mode.

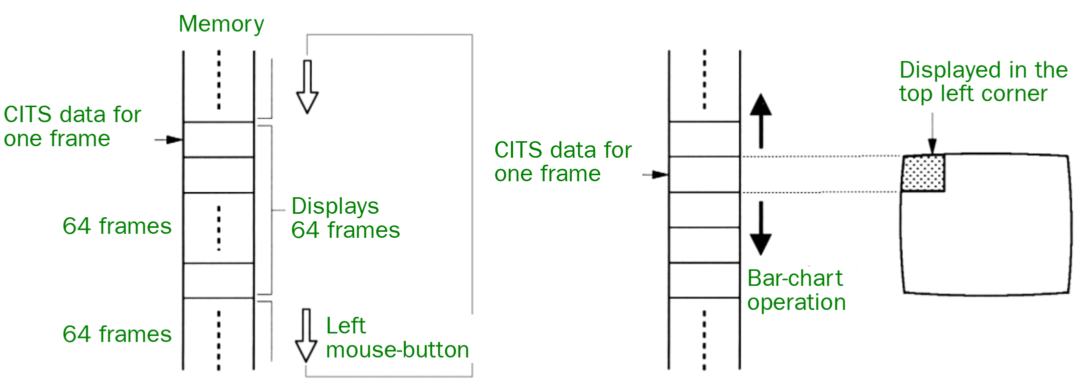
● Images to Display

- Show Topographic Image
  When this check-box is checked, a topography image is displayed in the top left frame of the Display Window.
- Images to Select
  The current image series to be displayed is selected in this selection box.
  None: Nothing is displayed.
  Spaced: Images are displayed in equal voltage intervals.
  First: Designated number of images starting with the first voltage value are displayed. Number is designated in "Number to display."
  Last: Designated number of images starting with the last voltage value are displayed. Number is designated in Number to display.
  Mixed: Images for designated voltages are displayed.

6.11.2 Special Displays

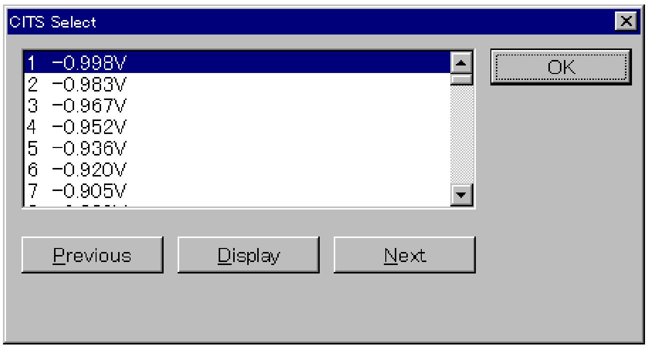
Since one CITS consists of a lot of data, special display modes are provided to display CITS images.

Display Mode	Description
Paged display	Sixteen frames, beginning with the first one, are displayed.
64×64 display	Sixty-four frames are displayed at a time with a size of 64×64 pixels for each frame. If the number of images is 16 or less, these images are displayed at a size of 128×128 pixels. When the "+" cursor is moved to any of the sixty-four image frames, the information of the image is displayed on the "Data Information" window.
Rapid display	All the CITS images are sequentially displayed in real time as a moving picture on the top left 128×128-pixel frame with scroll bar operation.



Paged display (64 × 64 display)   Rapid display

6.11.3 SPS Mapping Select

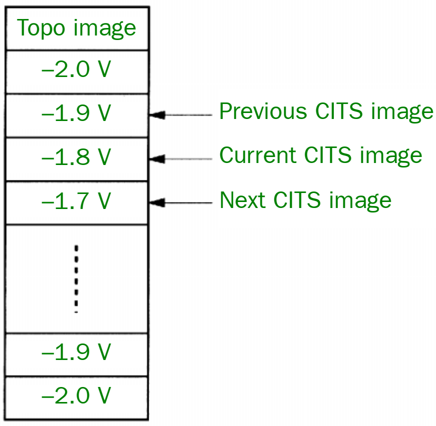


The active SPS mapping image is designated, and always the current SPS mapping image is displayed in the frame next to it.

✍ "Current SPS mapping image" means the image that is currently designated in the computer program.

For example, when the tunneling current image with a –1.8 V bias voltage is the current CITS image and each command is executed, the following CITS images will be displayed.

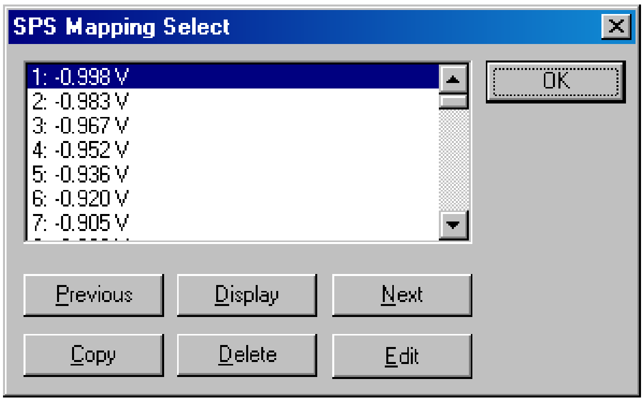
Display:	The CITS image with a –1.8 V bias voltage is displayed in colored frame.
Previous:	The CITS image with a –1.9 V bias voltage is displayed and this image becomes the current image.
Next:	The CITS image with a –1.7 V bias voltage is displayed and this image becomes the current image.



CITS image

6.11.4 Edit SPS Mapping Data Set

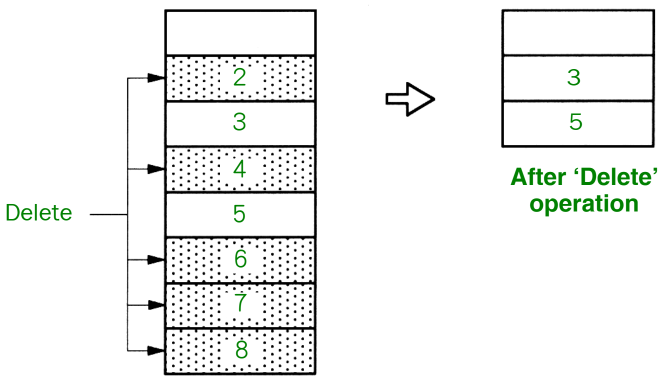
- **Edit**



Used to copy or delete the designated SPS mapping image, or add a comment or title on a designated bias voltage image in the CITS bias voltages.

Select Edit in the Edit SPS mapping Data Set pulldown menu.
The SPS Mapping Select window will appear. The following operations can be performed.

- Previous
  The mapping image prior to the current image is displayed.
- Display
  The current mapping image is displayed again.
- Next
  The mapping image after the current one is displayed.
- Copy
  An arbitrary mapping image extracted as an independent image from among the SPS mapping images is stored in the computer memory.
  For example, the extracted mapping image is treated as an independent image. Therefore, image processing can be performed for this image in the same manner as for an ordinary mapping image.
- Delete
  Arbitrary mapping images are deleted from the SPS mapping data.



Original CITS data

• Edit

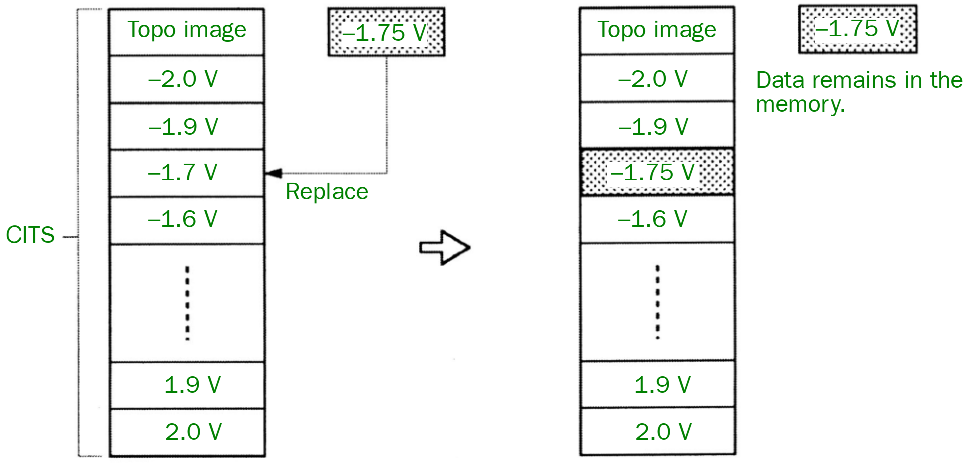
A title is input for the SPS mapping image displayed as the current image.

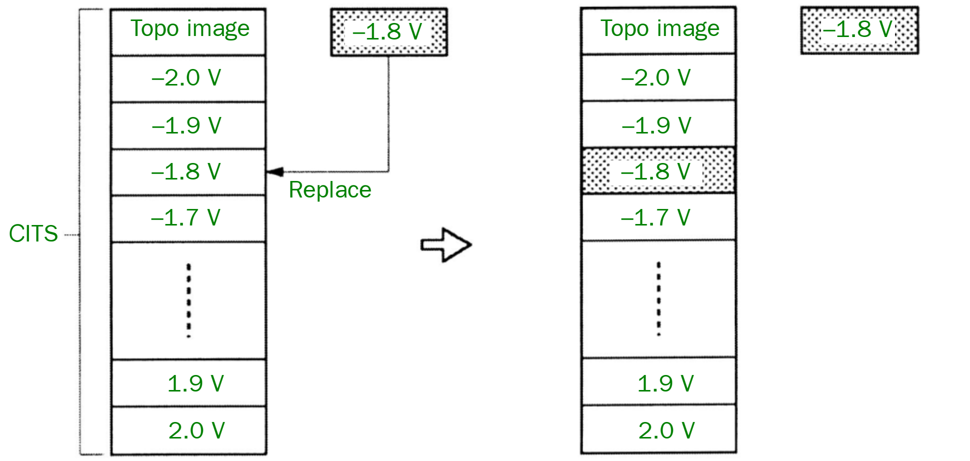
● Replace image

A current image that was stored in the computer memory with the Copy operation is replaced by the original SPS mapping image data.

If there is no tunneling current image that was stored in the computer memory with the Copy operation, selecting this function would cause an error.

【Example】



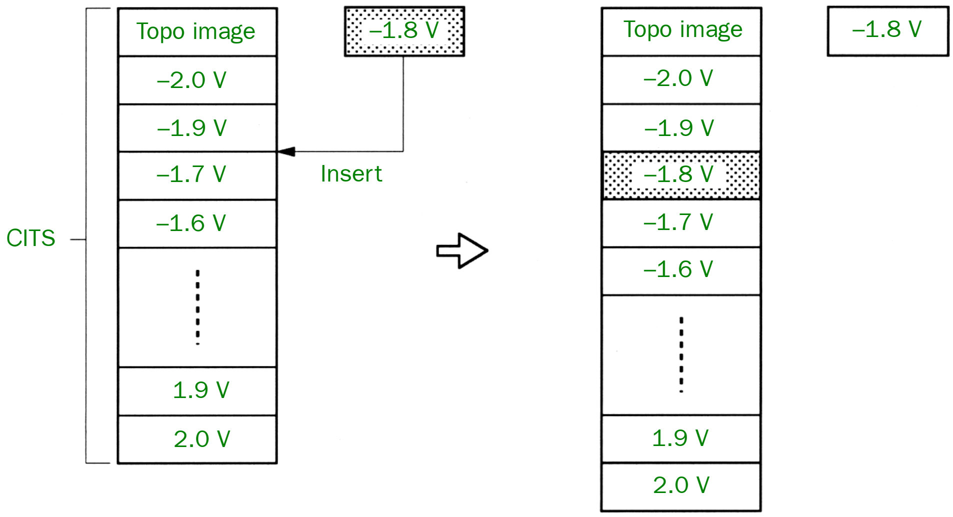


■ Insert image

A current image that was stored in the computer memory with the Copy operation is inserted again into the original SPS mapping image data.

✍ If there is no tunneling current image that was stored in the computer memory with the Copy operation, selecting this function would cause an error.

【Example】



■ Overlay an Image on Topography

A current SPS mapping image is overlaid on a topography image.

■ Split all images

All images comprising of the SPS mapping images are separated, and each split image is stored in the computer memory as an independent current image data.

The message "Keep original SPS mapping data?" is displayed. If Yes is selected, the original SPS mapping data is kept in the computer memory. If No is selected, the original SPS mapping data is erased and only separated mapping images are kept.

6.11.5 Average Images

The designated SPS mapping images are averaged on a group basis that comprises plural images.

1. Select Average Images from the Mapping pull-down menu.

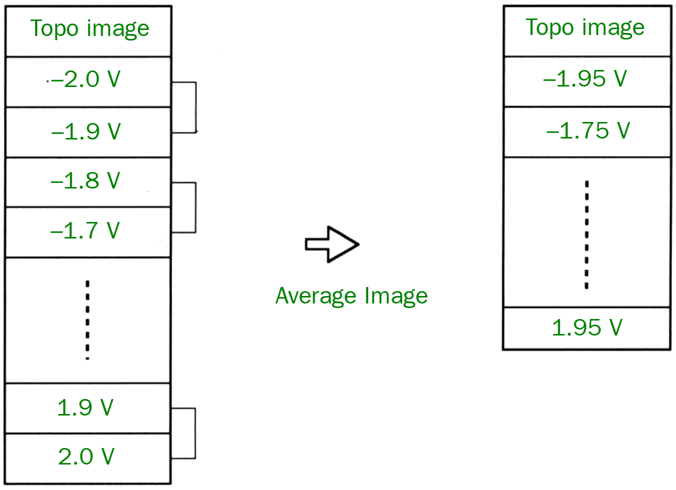
A pop-up window Number of images (2 to 64) to average over will appear.

2. Select a number from 2, 4, 8, 16 and 32.

The designated images are averaged, and the averaged images will be displayed.

【Example】

When 2 is selected:



6.11.6 Duplicate Data Set

The whole SPS mapping data are duplicated in the computer memory.

1. Select Duplicate Data Set from the Mapping pull-down menu.

2. Then the whole data will be duplicated in the computer memory.

6.11.7 Extract Spectra...

The SPS data is derived from the SPS mapping data and is data-processed. The processed data is displayed as a graph.

- **CRT display**

Display on CRT	Description
Normal spectra	Normal SPS data
dI/dV	Derivative of the SPS data
dLnI/dLnV	Normalized result of the derivative of the SPS data
d2I/d2V	Second derivative of the SPS data
d2LnI/d2LnV	Normalized result of the second derivative of the SPS data

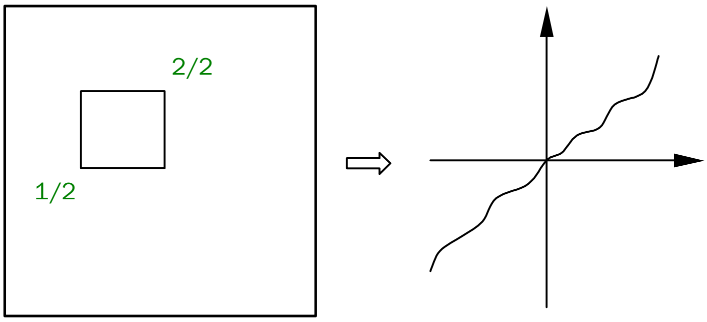
● Selection Type

This function is in effect when the Particle function is applied to a binarized image. When Object is selected, the I-V curves at the points within the designated particles are averaged and displayed.

● Select

The region in which SPS data to be averaged is designated on a TOPO image.

【Designation of one area】



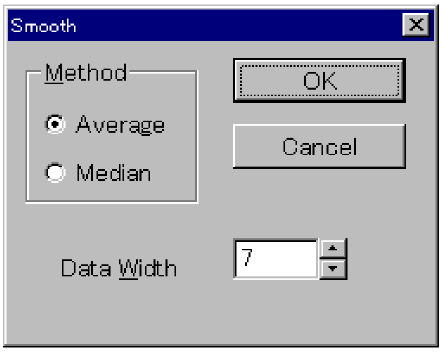
Topographic image
Designate two diagonal points.

I-V curves within the area are averaged and displayed.

6.12 PROCESS MENU (DATA PROCESSING FUNCTION)

This function processes graph data such as I-V data. The menu automatically switches over according to whether the data is image data or graph data.

6.12.1 Smooth



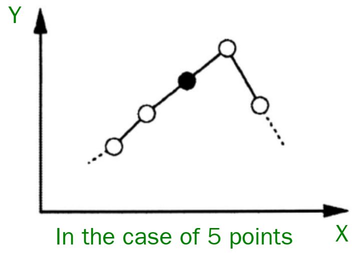
Performs smoothing of graph data.

■ Method

Sets the smoothing method.

● Average

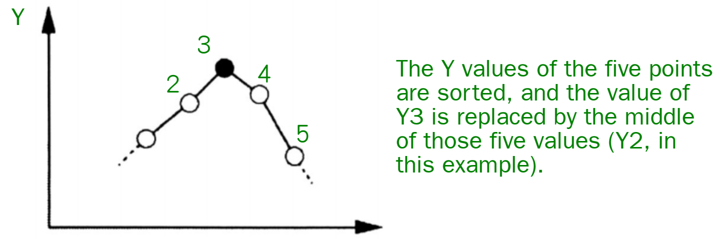
This item performs data smoothing. It computes the mean value of the data for exactly the specified number of points consisting of the point of interest and the adjacent points, and redisplays this mean value as the new value.



✍ The data for both ends of the graph is not processed.

● Median

A noise spike is eliminated. The designated number of data points are compared with neighboring data, and the middle value of these data is taken as the new data value.



A case of five-point median smoothing

✍ The data at the two edges of the graph cannot be processed.

● **Data Width**

The number of data points to be averaged or compared is specified in this input box.

6.12.2 Math X, Math Y

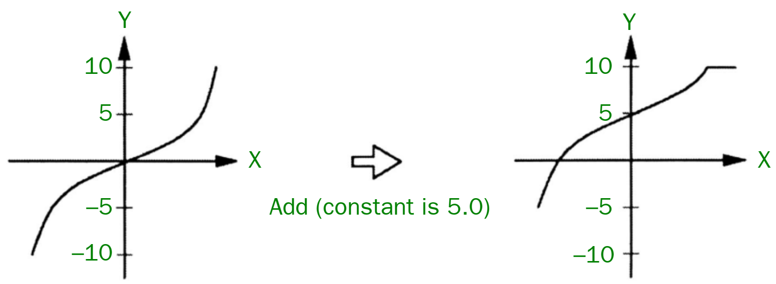
A mathematical operation with a constant is carried out on the X axis (Math X) or the Y axis (Math Y) data.
The following seven mathematical operations are provided.

Operation	Description
Add	Addition of a constant
Multiply	Multiplication with a constant
Divide	Division by a constant
Natural Log	Natural logarithm
Inverse	Invert the sign of value
Absolute Value	Absolute value
Sort	Sorting the data

1. Select Math X or Math Y from the Process pull-down menu. Select the desired operation in the sub-pulldown menu.
2. If Add, Multiply or Divide is selected, the Enter constant window will appear. Enter a constant in the window.

   The designated mathematical operation is performed for the graph data, and displayed.

   ✍ If a mathematical operation overflows, it is set to the maximum or minimum value in the graph data.



Original graph **Processed graph**

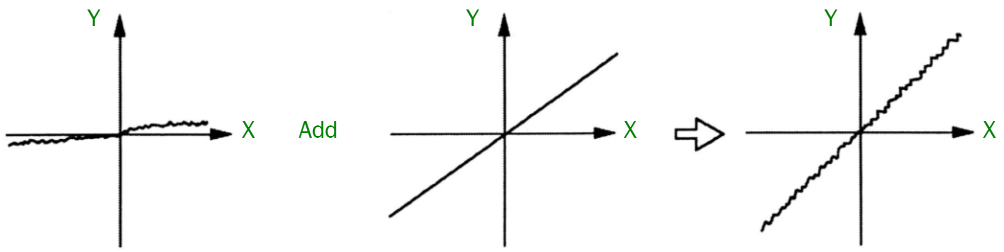
6.12.3 2 Spec Math

A mathematical operation is carried out between the Y axis data of the current graph (displayed graph) and Y axis data of another graph (stored in the computer memory).
The following mathematical operations are provided.

Operation	Description
Add	A + B
Subtract	A – B
Average	(A+B)/2
Difference	|A – B|
Multiply	A × B
Divide	A/B

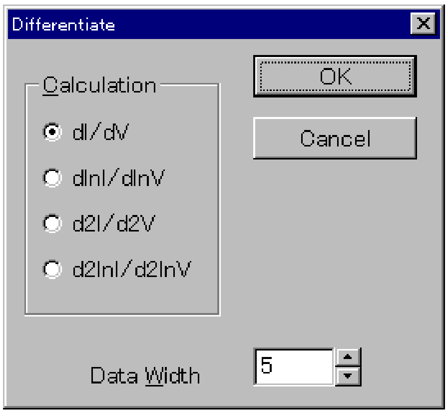
A: Data of the current graph
B: Data of the selected graph

1. Select 2 Spec Math from the Process pull-down menu. Select the desired operation in the sub-pulldown menu. The list of graph data recorded in the computer memory will be displayed. Select a graph to be operated on.
2. The designated mathematical operation is performed between the two graph's data, and the results are displayed.



Current (displayed) graph **Selected graph** **Processed graph**

6.12.4 Differentiate



The displayed graph data is differentiated.

- **Calculation**

A differentiation method is selected in this frame. The available differentiations are as follow:

Operation	Description
dI/dV	1st derivative by the Savitzky-Golay method
dlnI/dlnV	Normalised result of the dI/dV
d2I/d2V	2nd derivative by the Savitzky-Golay method
d2lnI/d2lnV	Normalised result of the d2lnI/d(lnV)2 is normalized by V/I.

- **Data Width**

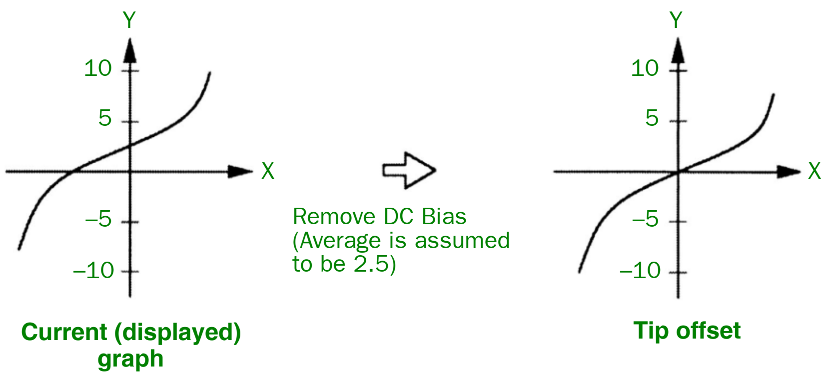
The number of data to be used for the Savitzky-Golay method is specified in this input-box.

6.12.5 Remove DC Bias

All the Y values are averaged, and the result is subtracted from each Y value.

◆ Select Remove DC Bias from the Process pull-down menu.

The operation is performed, and the processed result is displayed.



6.13 ANALYSE MENU (DATA PROCESSING FUNCTION)

6.13.1 Fit Polynomial

A graph is approximated by an nth-degree polynomial.

1. Select Fit Polynomial from the Analyse pull-down menu.

The Enter Polynomial degrees pop-up window will appear.

2. Enter the degree using the keyboard.

If the number ‘n’ is entered, the following polynomial is used for approximation.

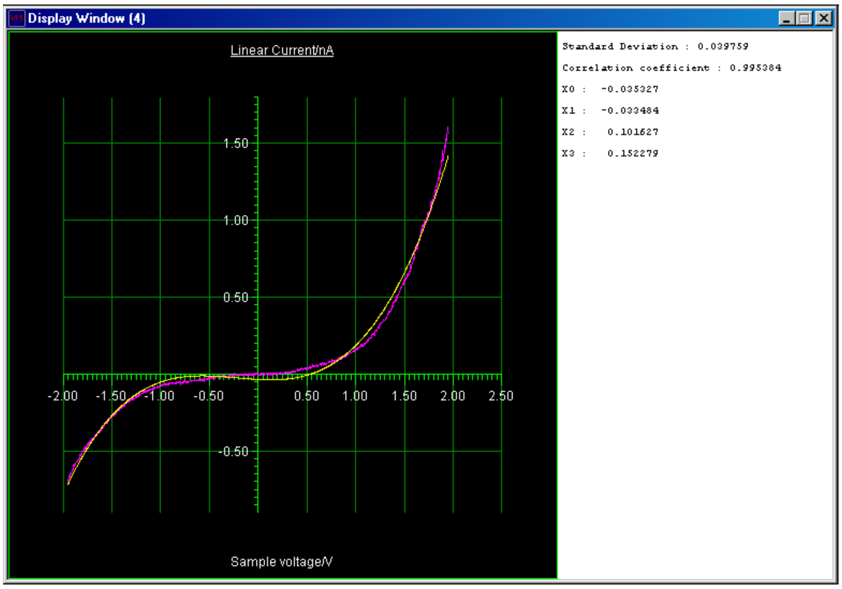
$$A_nX^n + A_{n-1}X^{n-1} + \ldots + A_1X^1 + A_0 = 0$$

In the case of cubic polynomial approximation,

$$A_3X^3 + A_2X^2 + A_1X + A_0 = 0$$

is applied.

After completion of the approximation, the resultant curve is overlaid on the original graph, and the resultant polynomial formula, the standard deviation and the correlation coefficient are displayed on the right of the graph.



The Enter Polynomial degrees pop-up window will appear again.
If you change values of the polynomial formula, the calculation of polynomial degrees can be carried out.
Clicking Cancel finishes the operation.

6.13.2 Zoom

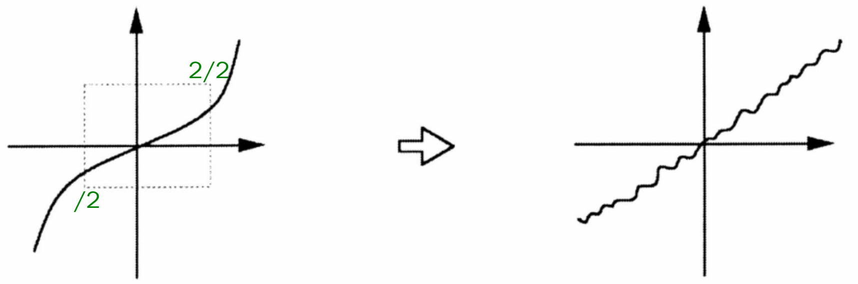
A part of a graph is enlarged.

1. Click on Analyse in the main menu; then select Zoom in the pull-down menu.

A “+” cursor will appear on the graph.

2. Designate two diagonal points of the area to be enlarged with the “+” cursor.

Then the designated area will be enlarged to the full frame size.



Designate the area with two diagonal points

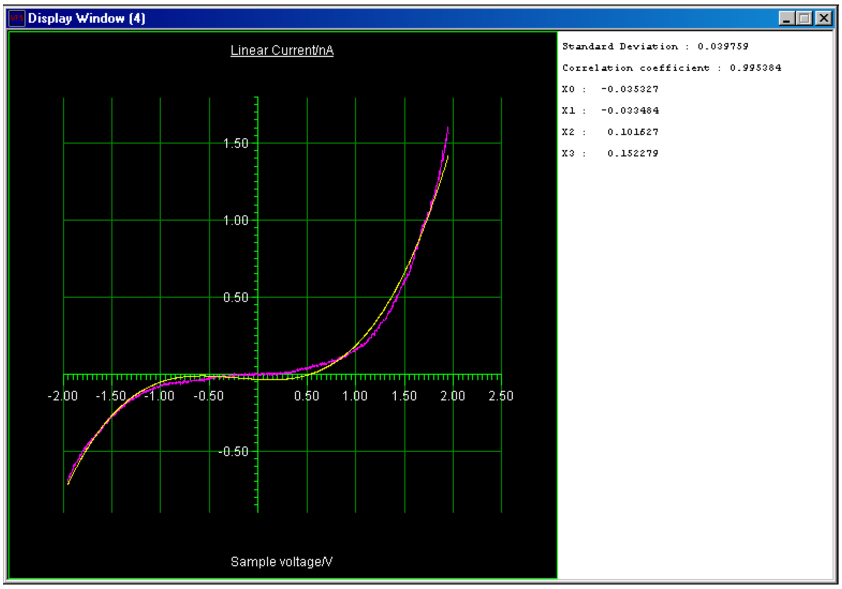
Enlarged graph

6.13.3 Measure

The coordinates of the present cross-cursor position, and the relative distance between the present cross-cursor coordinates and the previous cross-cursor coordinates, are indicated.

1. Select Measure from the Analyse pull-down menu.

The following screen will appear.



2. Drag the red and blue markers on the graph.

Moving the mouse cursor onto the graph changes the cursor to the shape of palm.
The marker can be moved by dragging the marker display position with the left button on the mouse held down.
The values (X value, Y value) of the marker position displayed at the left of the graph and the relative values of two markers (X distance, Y distance) change.
✍ The marker moves along the graph.

3. Click the right button on the mouse.

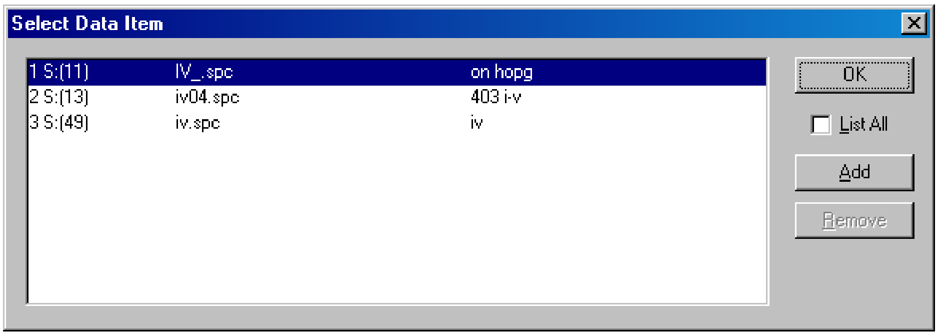
Exits the processing. The marker position can be changed before the right button on the mouse is clicked, but it cannot be changed once the processing is terminated.

6.13.4 Group Plot

A selected graph is overlaid on the current (displayed) graph.

1. Select Group Plot from the Analyse pull-down menu.

The graph display screen and the Select Data Item window are displayed.



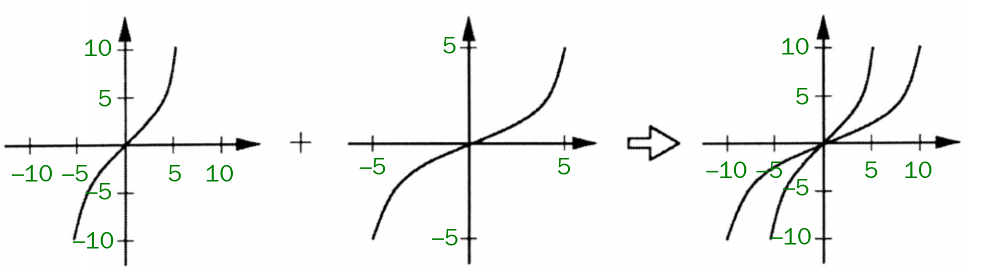
✍ Only SPS data of the same type as the current data is displayed in the Select Data Item window. To display all the data existing in the memory, check List All.

2. Select a graph to overlay.

Select a graph from the list and click Add to display a graph.

3. Continue processing

Multiple graphs are overlaid by repeating graph selection. The vertical axis and horizontal axis of the graph are automatically updated.
If there is any graph you want to remove from the display, select the data you want to remove from the list and click Remove.



Current graph **Graph to be overlaid** **Overlaid graph**
(The scale of the original graph is applied to the overlaid graph.)

Clicking the OK in the graph selection window finishes the operation.

6.13.5 Show FFT

FFT processing is applied to the data of a displayed graph.
The related function is Remove DC Bias.

◆ Select Show FFT from the Analyse pull-down menu. The names of the FFT windows will be displayed in the pulldown sub-menu. The following FFT windows are provided:

FFT window	Description
No window	FFT without window
Cosine window	W (n) = 0.5–0.5cos (10nπ/N)
Parzen window	W (n) = 1–{n–0.5 (N–1)}2/0.5 (N+1)
Cosine arch	W (n) = 1–n–0.5 (N–1)/0.5 (N+1)
Hamming	W (n) = 0.54+(1–0.54) cos (2πn/N)

Select a desired FFT window. FFT is performed and the result is displayed.

✍ The DC bias component is automatically eliminated before the FFT execution.

6.14 DISPLAY MENU (DATA PROCESSING FUNCTION)

Of the menu items, the functions Display Colour, Clear FS, Grab From FS and Change Param... are the same as the corresponding image processing functions.

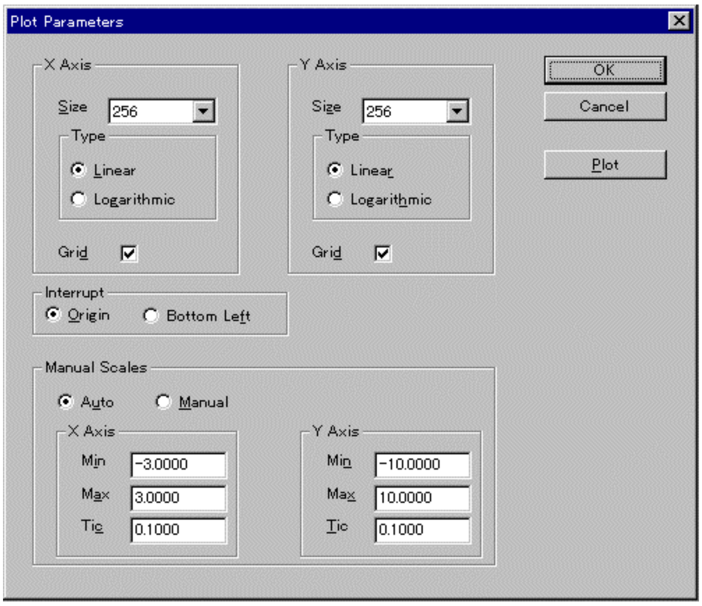
6.14.1 Plot

Re-displays a graph.

◆ Select Plot from the Display pull-down menu.

The graph that was displayed last is re-displayed.

6.14.2 Plot Parameters



● X axis/Y axis

Sets parameters for displaying the X axis and Y axis of the graph.

- Size

  Designate a size on the vertical axis screen. Sizes that can be designated are 256 and 512.
- Type (Plot type)

  Sets whether the linear axis or the logarithmic axis is to be used.
- Grid

  Designates whether a grid line is to be drawn or not.

● Intercept

Designates the intersection between the horizontal axis and vertical axis.
Designating Origin brings the intersection to the center of the graph.
Designating Bottom left brings the intersection to the lower left of the graph.

● Font

The type style, type size and character attribute of font can be set for the title display character (Title), XY-axis title character (X, Y Title) and axis display character (Axes). Select a setting character type from the pull-down menu and click the Set Font button to display a setting dialog.

● Manual Scales

Sets the X-axis and Y-axis scales. They are normally set at AUTO when in used.

- Auto
  Sets whether the axis is to be drawn automatically or manually.
  Displayed according to the data value when checked.
- Min
  Designate the minimum value of the scale to display.
- Max
  Designate the maximum value of the scale to display.
- Tic
  Designate the spacing of the scale to display.

● Plot

Click the Plot button after setting the parameters to re-display the graph.

6.15 SELECT MENU

You can display a list of data in the memory. The list is displayed, and the "✓" mark is attached to the beginning of the current data.

■ Previous Image

Displays the image that is immediately above the current data displayed in the Select list. If the data immediately above the current data is graph data, the image above it will be displayed.

■ Next Image

Displays the image that is immediately below the current data displayed in the Select list. If the data immediately below the current data is graph data, the image immediately below it will be displayed.

■ Previous Data

Displays the data immediately above the current data displayed in the Select list.

Normally, without clicking on this menu item, you can display the data immediately above the current data by pressing the Page Up key on the keyboard. Images, graphs and other data will be displayed without distinction.

■ Next Data

Displays the data immediately below the current data displayed in the Select list.

Normally, without clicking on this menu item, you can display the data immediately below the current data by pressing the Page Down key on the keyboard.

✍ Images, graphs and other data will be displayed without distinction.

6.16 WINDOW MENU

Performs operation for the Display window.

■ Creates New Window

Opens a new Display window. If there are multiple Display windows, the Display window that is marked with a '✓' at the beginning of the Window list is active.

■ Close Window

Closes an active Display window.

Note, however, that you cannot close all of the Display windows. One Display window must always be open.

✍ The Display window is only for display. The data in the memory will remain undeleted even if you close the Display window.

■ Minimize windows

Arranges all applicable windows that are minimized on the software screen.

■ Cascade

Arranges open windows on the software screen in cascade (by slightly changing the position of each window with respect to the adjacent one).

6.17 SPM SCAN MENU

In the process mode you can select only Cantilever Calibration and Scanner Calibration.

■ Cantilever Calibration

Selecting Cantilever Calibration from the SPM Scan menu opens the Cantilever Calibration window, in which you can specify the cantilever calibration values for calculating interatomic force and friction force that are obtained from bending and torsion of the cantilever respectively.

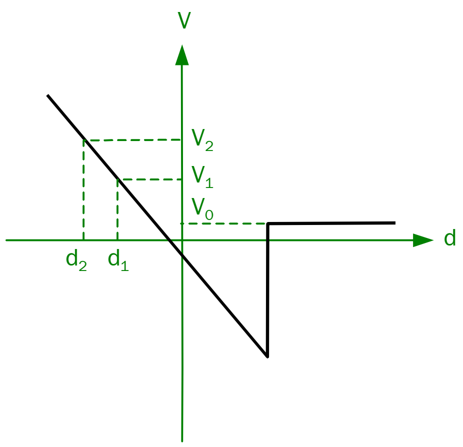
● Force Calibration

Perform cantilever calibration for calculating interatomic force from the bending of the cantilever.

The interatomic force is calculated based on the following equation.

$$F = ka(V - V_0)[nN]$$

- **Apply**
  When the Apply check box is checked, the force image or force curve is displayed with an interatomic-force value calculated from the applied voltage.
- **Spring Constant k [N/m]**
  Enter the spring constant of the cantilever in this input box.
- **Sensitivity a [nm/V]**
  This is the factor related to the sensitivity of the optical lever method.
- **Reference V_0 [V]**
  Enter the Force signal value that is obtained when the force applied to the cantilever is zero in the Reference V0 [V] input box. This value depends upon the instrument or cantilever used. Click on the Apply check box to remove the check mark; acquire a force curve; then calculate it. When the following force curve is obtained, calculate each parameter as follows.



$$a = \frac{|d_2| - |d_1|}{V_2 - V_1}$$

Friction Force Calibration

Perform cantilever calibration for calculating friction force from the torsion of the cantilever.

The friction force is calculated based on the following equation.

$$F = \frac{ka(V - V_0)}{2d \times 10^6}[nN]$$

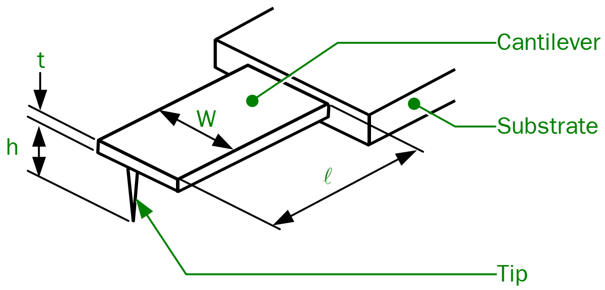
• Apply

When the “Apply” check box is checked, the friction force image is displayed with a friction-force value calculated from the applied voltage.

• Spring Constant k [N/rad]

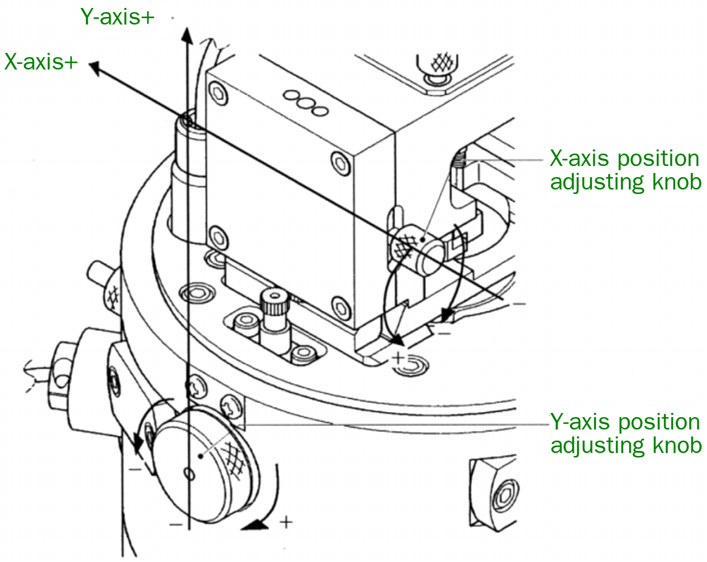
Enter the spring constant of the cantilever in the torsional direction in the “Spring Constant k [N/rad]” input box. The spring constant is calculated from the following equation.

$$k = \frac{wt^3G}{3l(h + t/2)}$$

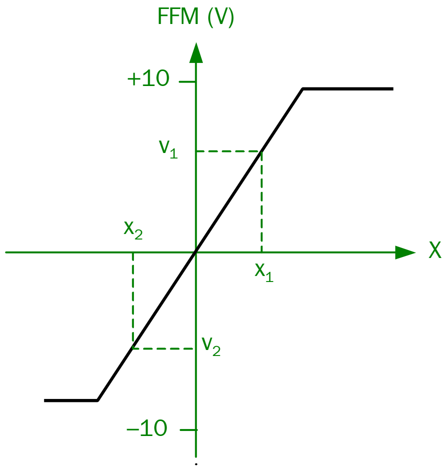


• Sensitivity a [nm/V]

This value depends upon the instrument used. Change the photodiode position (in the X-axis), and then calibrate the sensitivity using the FFM value shown on the AFM AMP indicator.



The X-axis-position adjusting knob shifts 0.5 mm per revolution, and the Y-axis-position adjusting knob shifts 0.25 mm per revolution.
When the following result is obtained, calculate the calibration value from this graph.



$$a = \frac{x_1 - x_2}{V_1 - V_2}$$

✍ The moving distance of the photodiode by turning the adjusting knob per revolution is as follows:

X-axis (mm)	Y-axis (mm)
0.5	0.25

- **Distance d [mm/V]**

  Enter the distance of 40.0 between the cantilever and the photodiode in this input box.

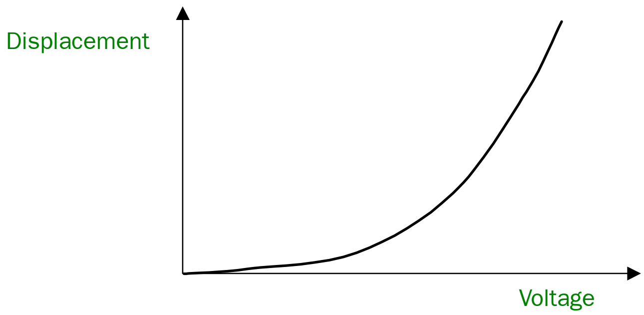
  ✍ The distance is different depending on the model of the instrument:

- **Reference V_0 [V]**

  Enter the Friction Force signal value that is obtained when the force applied to the cantilever is zero in the Reference V0 [V] input box.

■ Scanner Calibration

A tube-shaped piezoelectric scanner is used in the ultra-high vacuum SPM. This type of piezoelectric element has a nonlinear dependence of displacement on voltage in scanning as shown below.



In the SPM controller, the distortion-compensation unit is installed so that nonlinear displacement can be removed.

Selecting Scanner Calibration from the SPM Scan menu opens the Scanner Calibration window.

Specify parameters for compensation and values for displacement range compensation in scanning. These corrections have been done in the factory before shipment.

- **Scanner**

  The Scanner Calibration window allows you to save up to six sets of parameters specified for a scanner calibration so that you can use multiple scanners. Choose the desired set of parameters by clicking on the desired number in the pull-down number list.

  ✍ When you change the present set of parameters, parameters such as voltage for scanner driving will be changed. Be sure not to choose a wrong set of parameters.

- **Description**

  You can name six sets of parameters to distinguish them. When you change a set of parameters, the information in the bottom right of an application window will be changed, and the name given to the set of parameters will be displayed. The name “STD Scanner” is given to the standard scanner in default.

- **Enable Compensation**

  When this check box is checked, the distortion compensation to the XY scanner will function. However, even if this is not checked, the calibration of the scanning range will work.

- **Change Compensation Parameters**

  Only the person who has the authority of administrator can change the parameters for compensation. A floppy disk is provided which recorded the calibration data for every scanner at the time of instrument shipment. You can read the calibration data from the floppy disk by clicking on the Read Settings button.

6.18 HELP MENU

This software comes with on-line help, which can be used as a reference when you do not know how to use a function or do not understand its meaning.

■ Contents

Displays on-line help, and provides a more detailed explanation of the underlined on-line help items. Clicking on an underlined item displays the corresponding explanation.

If you set the help window to a size that is easy to view, the window will be the same size when you next start the system. Also, if you set the help window to Option – Help display – Display at front, the window will always appear at the front. This is useful when you wish to perform an operation while referring to help.

■ Search for Help on

You can search for the contents of on-line help by item. You can also easily perform a search by clicking on keywords.

■ How to Use Help

Displays the method of using on-line help. Some functions are not supported in an actual help operation.

■ About

Displays the version number of the software.

7

APPENDIX

7.1 WINSPM SOFTWARE REINSTALLATION METHOD 7-1
7.1.1 Before Re-installing the WinSPM Software 7-1
7.1.2 Re-installing Windows 7-2
7.1.3 Installing the A/D Board Device Driver in the PC 7-2
7.1.4 Reinstalling the WinSPM Software 7-7
7.2 SETTING UP The WinSPM PROGRAM 7-9
7.2.1 Selecting the instrument 7-9
7.2.2 Saving and Loading the Scanner-Sensitivity Settings 7-11
7.2.3 Saving and Loading the Motor-Drive Position Calibration Values 7-13
7.3 CANTILEVER 7-15
7.4 FILE FORMAT 7-19
7.4.1 Standard TIFF File Structure 7-19
7.4.2 WinSPM image file 7-21
7.4.2a Overall structure of WinSPM image file 7-21
7.4.2b WinSPM image file [1] (SPM Image) 7-22
7.4.2c WinSPM image file [2] (Compressed TIFF) 7-40
7.4.2d WinSPM image file [3] (FFT image file) 7-46
7.4.2e WinSPM image file [4] (CITS image file) 7-47
7.4.3 Spectrum data file 7-50
7.4.4 Image file with spectrum data 7-51
7.4.5 Report file 7-52

7.1 WINSPM SOFTWARE REINSTALLATION METHOD

Below is the method of re-installing the WinSPM software.

7.1.1 Before Re-installing the WinSPM Software

● Reconfirmation of trouble

Before re-installing the software, check the cause of the trouble once again, and if possible, eliminate it.

If the hard disk of the computer is nearly full, make a backup copy of the recorded measurement data, then erase the data from the hard disk to free some space. Particularly, be sure to set aside sufficient space on the hard disk where the WinSPM system is installed.

If devices that are not part of the WinSPM are installed in the computer, remove all of them. Also, if software other than the WinSPM software is installed in the computer, uninstall all of it.

- Component parts of the WinSPM system (computer system)
  - Computer proper
  - Display monitor
  - Keyboard/mouse
  - A/D board
  - WinSPM system software

● Checking the calibrated values of the scanner sensitivity and the motor drive position

Before re-installing the WinSPM software, confirm that the calibrated values of the scanner sensitivity and the motor drive position have been recorded.

☞ Refer to Sect. 7.2.2 and 7.2.3.

After re-installing the software, it is necessary to record those values in the reinstalled WinSPM software once again.

● Items needed when reinstalling the software

Before re-installing the SPM software, obtain the following items.

- Windows installation CD-ROM and its manual that came with the computer
- Computer manuals and device driver installation disk
- WinSPM software installation CD-ROM
- CD-ROM (OmniCD) that came with the A/D board

✍ Some personal computers come with a recovery CD instead of a Windows installation CD-ROM.

7.1.2 Re-installing Windows

If it is necessary to reinstall Windows, remove all of the devices including the A/D board. Then, follow the instructions given in the manual that came with the computer.

After reinstalling the software, confirm that Windows starts normally and also that the computer operates normally. Set up the screen as shown below.

Wallpaper:	None
Number of display colors:	High Color (32 bits)
Screen size:	1280 × 1024
Font	Small font

7.1.3 Installing the A/D Board Device Driver in the PC

When you have reinstalled Windows, install the Data Translation DT3016 A/D board in the PC according to the instructions below.

● Installation of the device driver

✍ Be sure to install the DT3016 A/D converter device driver prior to installing the DT3016 A/D board in the PC.

1. Insert the OmniCD that comes with the DT3016 A/D converter into the PC CD drive.

The installer starts automatically and the DT-Open Layers window appears.

✍ The version of OmniCD may be different depending on the time of shipment.

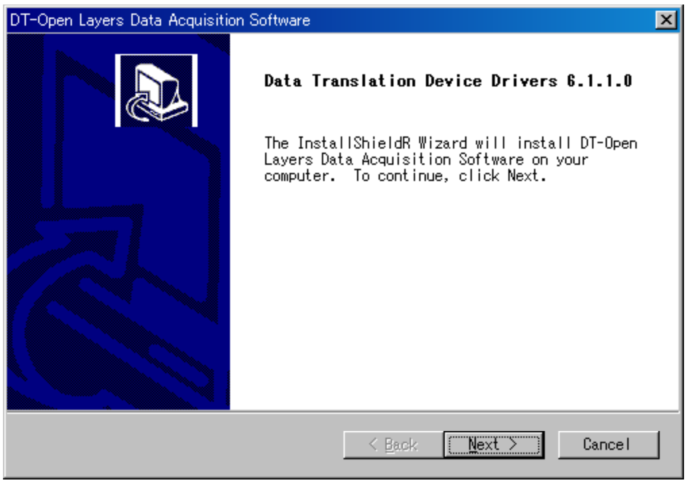
2. Click on INSTALL PRODUCTS.

The software installation window opens.

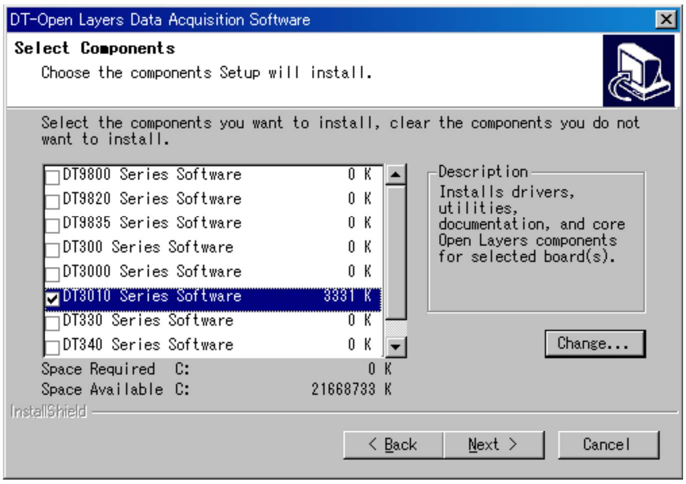
3. Click on DEVICE DRIVERS in this window to start installing the DT3016 A/D converter device driver.

4. The device driver installer displays the window below. Click on the Next > button.

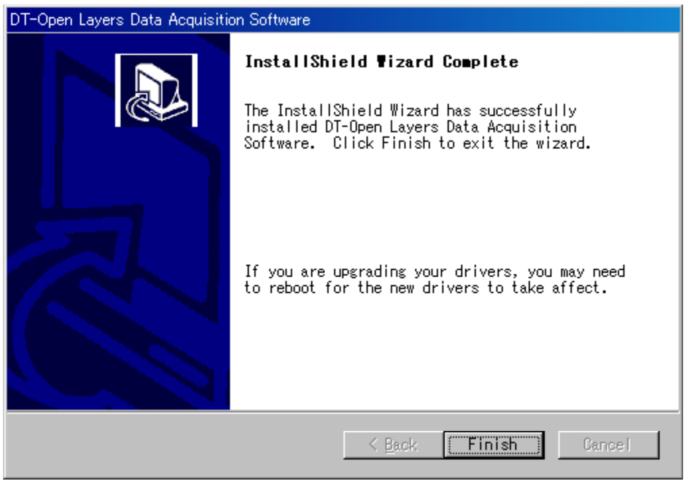
✍ The package version may be different depending on the time of shipment.



5. Follow the instructions issued by the installer. (Use the default settings throughout this process.) A window like the one below appears soon. It enables you to select the kind of driver you wish to install. Here, select DT3010 Series Software from the driver list shown in the figure below and click on the Next > button.



Continue the installation, following the instructions from the installer. The device driver installation will complete and the final window below will appear.

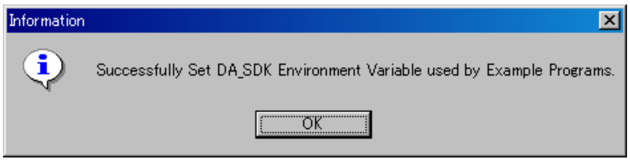


6. Click on the Finish button to end this installation. The DT-Open Layers Core components window, which appeared in step 3, returns. Then, install the DATA ACQUISITION SDK (Software Development Kit).

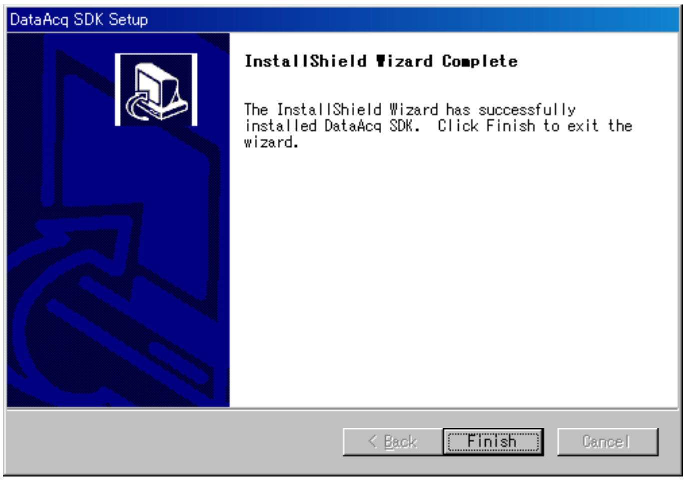
● Installation of the DATA ACQUISITION SDK

1. Click on DATA ACQUISITION SDK in the DT-Open Layers Core components window to start installing the SDK files that control the A/D and D/A boards using the WinSPM software. The DT-Open Layers Data Acquisition Software Development Kit window appears.

2. The SDK file installer starts. Follow the instructions from the installer to install the SDK file. (Use the default settings throughout during this process as in the installation of the device driver.)
3. When the installation has completed normally, the closing message shown below appears. Click on the OK button.



4. The DataAcq SDK Setup window appears. Click on the Finish button.



5. Click on MAIN MENU in the DT-Open Layers Software Development Kit window to return to the OmniCD main (DT-Open Layers) window.
6. Click on EXIT to end installing the A/D Board device driver.

- **Shutting down Windows and installing the DT3016 A/D converter board**

1. Shut down Windows and turn off the PC power.
2. Install the DT3016 board on the desired PCI bus and restart the PC.
   When Windows restarts, Plug and Play operates, recognizing the DT3016 board and setting the driver automatically.
3. After the device driver has been set automatically, restart the PC, following the instructions from Windows.

This completes the installation of the DT3016 board in the PC.

7.1.4 Reinstalling the WinSPM Software

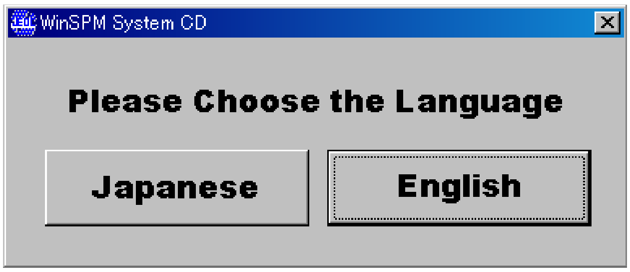
Re-install the WinSPM software as follows:

● Reinstalling the WinSPM software (WinSPM system)

Reinstall the WinSPM software using the appropriate installer.

1. Insert the WinSPM software CD into the CD drive of the PC.

   The setup program automatically starts and displays the following dialog.

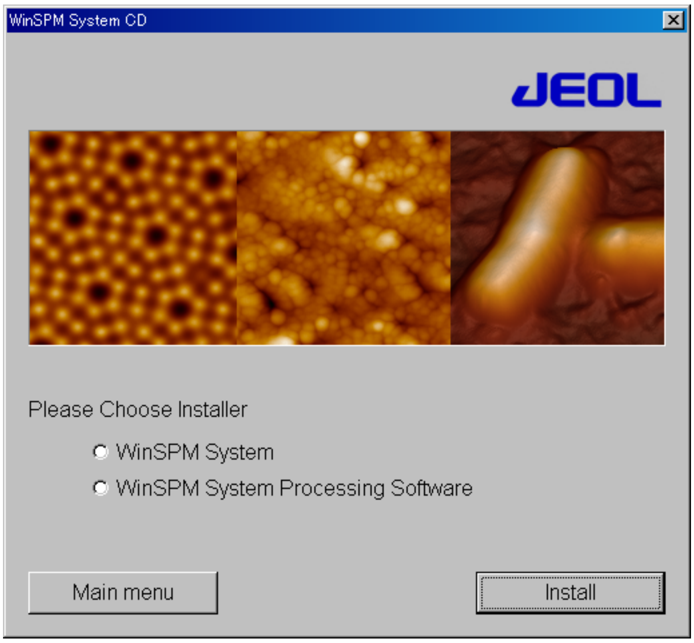


2. Click on English.

   The WinSPM System CD setup window opens.

3. Click on Install WinSPM System.

The WinSPM System CD installer selection window opens.

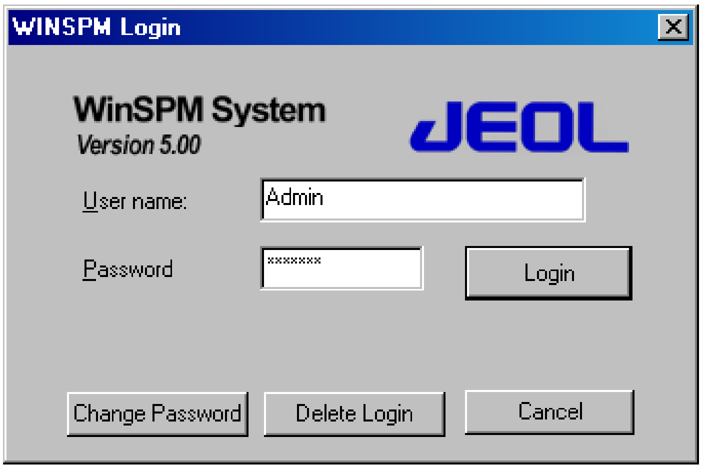


4. Click on the WinSPM System radio button and on the Install button.

The installer starts to operate. Follow the instructions issued by the installer. (Use the default settings throughout this process.)

5. When the SPM software is completely installed, restart the system, as the Administrator, in the WinSPM System measurement mode.

Make sure that the WinSPM software has started normally.



6. Set up the calibration values for the scanner and the stage positions.

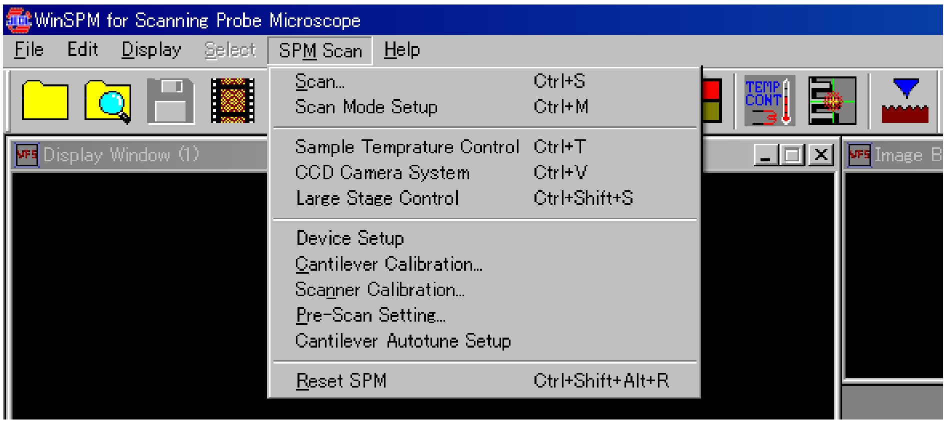
☞ For more information, refer to Sect. 7.2.2 and 7.2.3.

7.2 SETTING UP The WinSPM PROGRAM

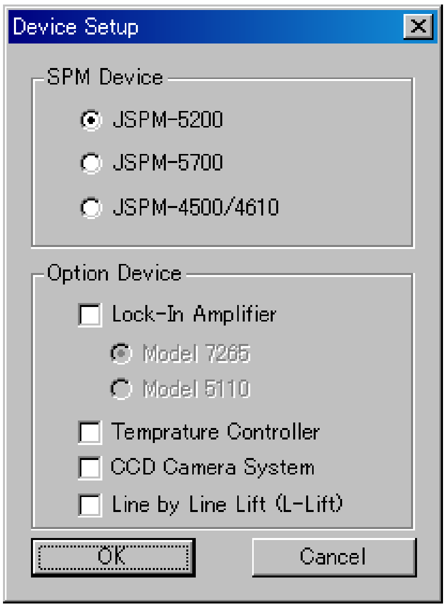
7.2.1 Selecting the instrument

The WinSPM program controls the JSPM-5200 by default and has to be reset when an instrument other than the JSPM-5200 is used. The administrator resets WinSPM. Also, when the WinSPM program controls optional attachments, all necessary information on the attachments should be given to the program. This can be accomplished using the Device Setup window.

1. Start the WinSPM program with system administrator privileges (log in using the user name Admin). The WinSPM for Scanning Probe Microscope window opens.



2. Click on SPM Scan on the menu bar to open the pull-down menu and click on Device Setup to open the Device Setup window.



3. Make sure that the radio button corresponding to the instrument being used, for example, JSPM-5200, is selected.

   ✍ The contents of the Option Device section vary depending on the instrument selected.

4. Check the boxes of the optional accessories to be used.

5. Click on the OK button.

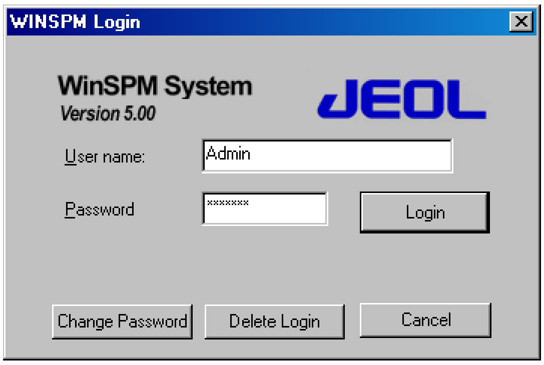
✍ If the instrument has been changed, the confirmation window opens, asking whether to save the inputs or not. If this happens, terminate and restart the WinSPM program; otherwise, there might be unexpected trouble.

7.2.2 Saving and Loading the Scanner-Sensitivity Settings

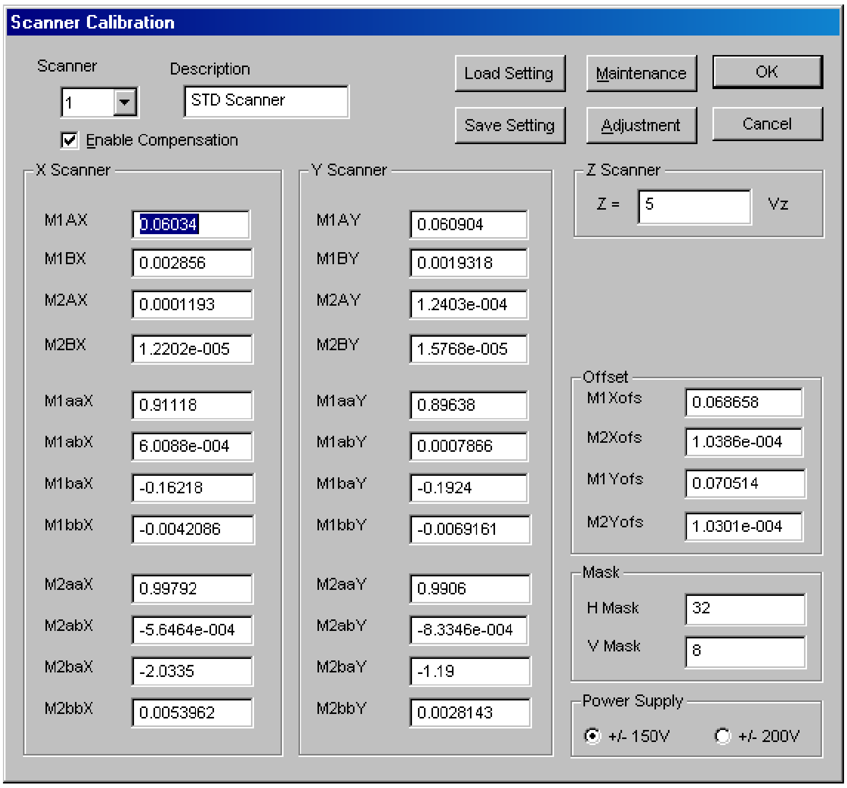
The scanner sensitivities are calibrated using the WinSPM software. For later use such as replacing the WinSPM software, record the values of the sensitivities on a floppy disk or another memory device other than the hard disk.

● Saving scanner-sensitivity settings

1. Start the WinSPM measurement mode with the system administrator privilege.



2. Select Scanner Calibration from the SPM Scan pull-down menu to open the Scanner Calibration window.



3. Click on the Scanner menu button (▼) to open the pull-down menu; select a number under which to record the scanner control settings; then click on the Save Setting button.

The Save As dialog box appears.

4. Specify the device in which you want to save the file, and the filename, and click the Save button.

The file extension for this file is *.clb.

● Loading scanner-sensitivity settings

1. Start the WinSPM measurement mode as the system administrator privilege.

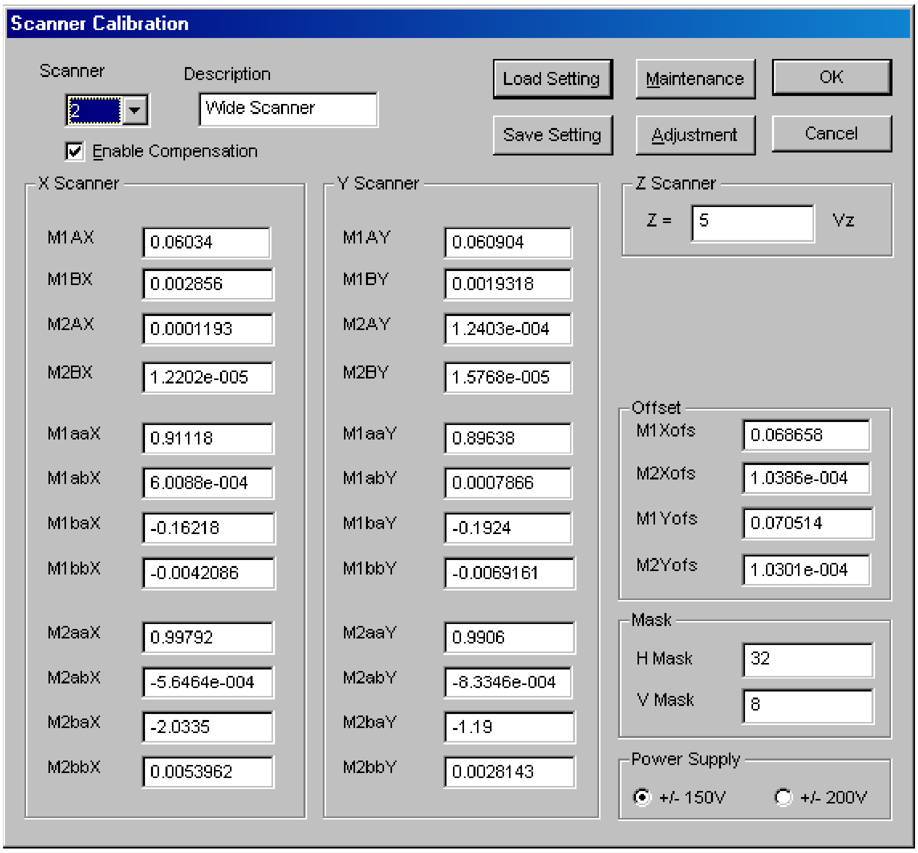
2. Select Scanner Calibration from the SPM Scan pull-down menu.

3. Select the scanner number of the settings you want to read from the menu in the Scanner box, and click on the Load Setting button.

The Open dialog box appears.

4. Select the file you want to load and click on the Open button.

The file extension is *.clb. The scanner-sensitivity settings previously saved in the file are loaded.



5. Enter an identification name for the scanner in the Description text box.

6. Click on the OK button to close the Scanner Calibration window.

7. Select Save Setting from the File menu.

The loaded settings will take effect the next time you start the system.

✍ If you skip step 7, you cannot use the loaded scanner-sensitivity settings the next time you start the system.

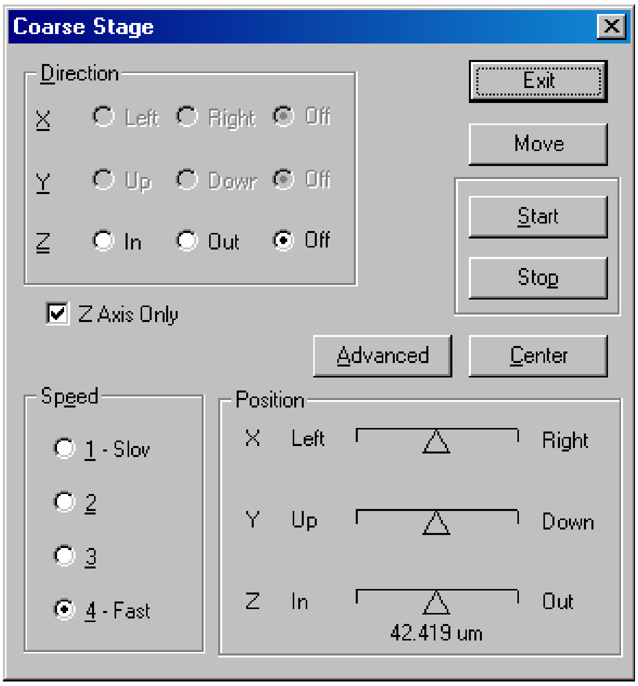
✍ The scanner-sensitivity settings and changes specified as the system administrator apply to all registered users.

7.2.3 Saving and Loading the Motor-Drive Position Calibration Values

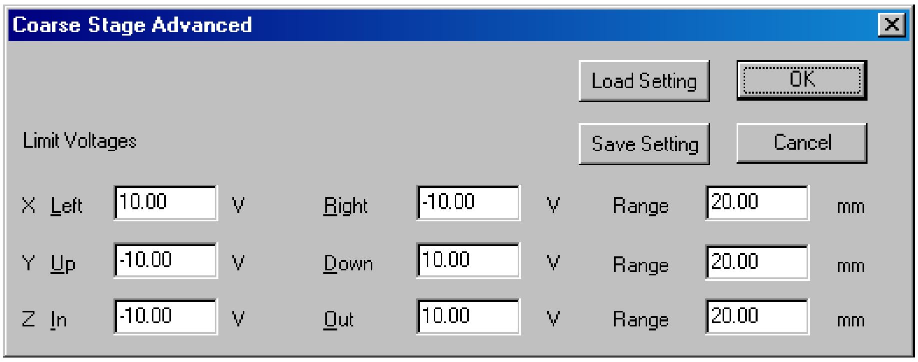
The WinSPM software allows the motor-drive positions to be calibrated. Similarly to scanner-sensitivity settings, record the calibrated values of the motor-drive positions on a floppy disk or another memory device other than the hard disk.

● Saving motor-drive position calibration settings

1. Start the WinSPM measurement mode as the system administrator privilege.
2. Select Measurement from the SPM Scan pull-down menu.
3. Click on Large Stage Control to open the Coarse Stage window.



4. Click on Advanced to open the Coarse Stage Advanced window.
   ✍ Unless the system is started as the system administrator privilege, the Advanced button will not function.



5. Click on Save Setting to display the Save As dialog box.
   The file extension becomes *.stg.

● Loading motor-drive position calibration settings

1. Start the WinSPM measurement mode with the system administrator privilege.
2. Follow Steps 2 to 4 above to open the Coarse Stage Advanced window.
3. Click on Load Setting to display the Open dialog box.
4. Select a file you want to load and click on the Open button.
   The file extension is *.stg.
5. Click the OK button to close the Coarse Stage Advanced window.
6. Select Save Setting from the File menu.
   The loaded motor-drive position calibration settings will take effect the next time you start the system.

✍ The scanner-sensitivity settings and changes specified as the system administrator apply to all registered users.

7.3 CANTILEVER

The cantilever is a consumable item. Select an appropriate cantilever according to the mode and purpose of the measurement.
The following are the specifications for the cantilevers manufactured by Olympus, Nanosensor, and MDT. Please consult your JEOL service office for purchasing.

● Olympus

Mode	Model	Lever shape	Length (µm)	Width (µm)	Thickness (µm)	Tip shape	Tip length (µm)	Spring constant (N/m)	Resonance frequency (kHz)	Metal coat	Tip diameter	Number of tips
AC mode	OMCL-AC120TS-1	Strap	120	30	4	Tetrahedral	10	57	300	Single side	< 10	15
	OMCL-AC120TN-1	Strap	120	30	4	Tetrahedral	10	57	300	None	< 10	15
	OMCL-AC240TS-1	Strap	240	30	4	Tetrahedral	10	7.2	65	Single side	< 10	15
Contact mode	OMCL-TR400PS-1	Triangle	100 200	—	0.4	Pyramidal	2.9	0.09 0.02	40 13	Single side	< 20	35
	OMCL-TR400PS-2	Triangle	100 200	—	0.4	Pyramidal	2.9	0.09 0.02	40 13	Single side	< 20	35
	OMCL-TR800PS-1	Triangle	100 200	—	0.8	Pyramidal	2.9	0.68 0.16	86 27	Single side	< 20	35
	OMCL-TR800PS-2	Triangle	100 200	—	0.8	Pyramidal	2.9	0.68 0.16	86 27	Single side	< 20	35
	OMCL-TR400PB-1	Triangle	100 200	—	0.4	Pyramidal	2.9	0.10 0.025	36 11	Double side	< 20	35
	OMCL-TR800PB-1	Triangle	100 200	—	0.8	Pyramidal	2.9	0.77 0.18	78 25	Double side	< 20	35
FFM	OMCL-RC800PS-1	Strap	100 200	20 40	0.8	Pyramidal	2.9	0.37,0.05 0.75,0.09	88 22	Single side	< 20	35
	OMCL-RC800PB-1	Strap	100 200	20 40	0.8	Pyramidal	2.9	0.37,0.05 0.75,0.09	88 22	Double side	< 20	35

* The above specifications are nominal and are subject to change. The values of the spring constant and resonance frequency were obtained by simulated.

● Nanosensor

Mode	Part name	Thick ness (µm)	Width (µm)	Length (µm)	Spring constant (N/m)	Reso-nance frequency (kHz)	Tip diame-ter (nm)
Contact mode	CONT	1–3	23–28	450	0.2	13	15 Guaran-teed value
Contact mode	CONTR	1–3	23–28	450	0.2	13	15
AC mode (High frequency)	NCH	3–5	23–38	125	42	330	15
AC mode (High frequency)	NCHR	3–5	23–38	125	42	330	15
AC mode (Low frequency)	NCL	6–8	30–45	225	48	190	15
AC mode (Low frequency)	NCLR	6–8	30–45	225	48	190	15

* Material is N-type silicon single-crystal. Resistivity is 0.01 to 0.025 Ωcm.
* An "R" at the end of the part name indicates an aluminum-coated (on the back) item. The thickness of the coating is about 30 nm.
* Number of cantilevers in one package is 16, 50 or 385.
* The nominal value of the tip diameter is 10 nm.

Mode	Part name	Thick -ness (µm)	Width (µm)	Length (µm)	Spring constant (N/m)	Reso-nance frequency (kHz)	Tip diame-ter (nm)
Magnet mode	MFMR	2–4	20–35	225	2.8	75	15 (Before being coated)

* Magnetic coating: Co-Cr-Ta/Random/50 nm thick

Part name	Thick-ness (µm)	Width (µm)	Length (µm)	Spring constant (N/m)	Resonance frequency (kHz)
EFM sensor [1]	2–4	20–35	225	28	75
SUPER SHARP sensor SSS-NCH SSS-SEIH [2]	 3–5 4–6	 23–38 30–35	 125 225	 42 15	 330 130
HIGH ASPECT RATIO sensor [3]	3–5	23–38	125	42	330
DIAMOND coat sensor [4]	2–4	20–35	225	28	75

[1] Cr (1st layer) and $PtIr_5$ (2nd layer) coated conductive sensor
[2] A sharp sensor with a tip radius of 2 nm (typical)
[3] Suitable for measurement of sidewalls with an aspect ratio of 1:7 (typical)
[4] A hard diamond-coated sensor with a resistivity of 0.1 to 0.2 Ωcm

● **MDT**

Model	Contact or Non-contact	Number of Tips	Coating
NSCS11	Non-contact	15	None
NSCH11	Non-contact	200	None
NSCF11	Non-contact	400	None
NSCS11/"Coating"	Non-contact	15	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
NSCH11/"Coating"	Non-contact	200	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
NSCF11/"Coating"	Non-contact	400	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni4
CSCS11	Contact	15	None
CSCH11	Contact	200	None
CSCF11	Contact	400	None
CSCS11/Si3N4	Contact	15	Si3N4
CSCH11/Si3N4	Contact	200	Si3N4
CSCF11/Si3N4	Contact	400	Si3N4
CSCS11/"Coating"	Contact	15	W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
CSCH11/"Coating"	Contact	200	W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
CSCF11/"Coating"	Contact	400	W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
NSC21	Non-contact	15	None
NSCH21	Non-contact	200	None
NSCF21	Non-contact	400	None
NSC21/"Coating"	Non-contact	15	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
NSCH21/"Coating"	Non-contact	200	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
NSCF21/"Coating"	Non-contact	400	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni4
CSCS21	Contact	15	None
CSCH21	Contact	200	None
CSCF21	Contact	400	None
CSCS21/ Si3N4	Contact	15	Si3N4
CSCH21/ Si3N4	Contact	200	Si3N4
CSCF21/ Si3N4	Contact	400	Si3N4
CSCS21/"Coating"	Contact	15	W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
CSCH21/"Coating"	Contact	200	W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
CSCF21/"Coating"	Contact	400	W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
NSCS21	Non-contact	15	None
NSCH21	Non-contact	200	None
NSCF21	Non-contact	400	None
NSCS21/"Coating"	Contact	15	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni

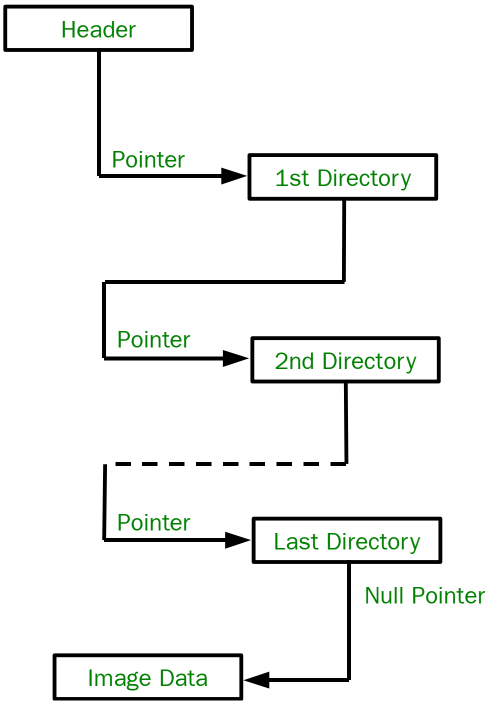
Model	Contact or Non-contact	Number of Tips	Coating
NSCH21/“Coating”	Contact	200	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
NSCF21/“Coating”	Contact	400	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni4
CSCS12	Contact	15	None
CSCH12	Contact	200	None
CSCF12	Contact	400	None
CSCS12/“Coating”	Contact	15	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
CSCH12/“Coating”	Contact	200	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni
CSCF12/“Coating”	Contact	400	Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni4

7.4 FILE FORMAT

In WinSPM, image data are handled in TIFF (Tagged Image File Format). The TIFF files contain not only graphic information, but also other information (SPM measurement parameters, history of measurements, and so forth). Therefore, the structure of those TIFF files is partly different from the standard TIFF file structure. As a result, the image display or processing software based on the standard TIFF might not accommodate SPM graphic data.

7.4.1 Standard TIFF File Structure

The figure below shows the structure of the standard TIFF schematically. The structure consists of a header and a few directories. The header contains a pointer to the 1st directory, a pointer in the 1st directory to the 2nd directory, a pointer in the 2nd directory … and so on. The last directory contains a null pointer that points to image data. WinSPM uses only the 1st directory.



■ Header-data structure

The structure of header data in the standard TIFF files is as follows.

Address	Note
0x0000	Byte order
0x0002	TIFF format version number
0x0004 0x0006	Pointer to 1st Directory

☞ Byte order: "II" (0x4949) Intel Format (LSB → MSB)

■ Directory-data structure

● Directory

The directory in TIFF files consists of multiple TAGs as shown below.

Number of TAGs
TAG [1]
TAG [2]
:
TAG [N]
Pointer to next directory

☞ Pointer to next directory becomes Null unless there is a directory after this one.

● TAG

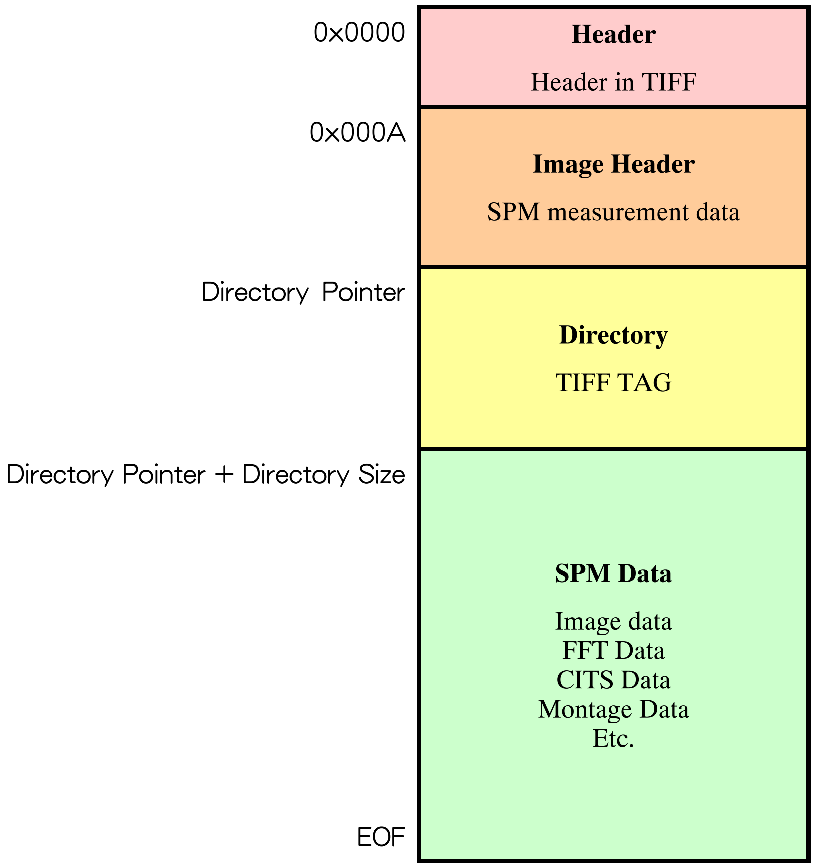
TAGs can record various parameters of TIFF images.

Structure of TAG	
TAG type	Kind of TAG Specified by the number 0x00FF to 0x012D in accordance with the TIFF specifications.
Data type	Type of TAG information data 0x0001 : byte (8 bits), 0x0002 : ASCII (8 bits) 0x0003 : short (16 bits) , 0x0004 : long (32 bits) 0x0005 : rational (Long×2)
Length of data	Length of TAG data (specified by the number of units) For instance, the length of data 1 for the data type long is 32 bits (4 bytes).
Data or pointer	TAG data or pointer If the length of TAG data is below 4 bytes, the data is stored here and if it is above 4 bytes, a pointer is stored.

7.4.2 WinSPM image file

Although WinSPM image files are based on the standard TIFF, the structure of WinSPM TIFF files is partly different from the standard TIFF file structure.

7.4.2a Overall structure of WinSPM image file



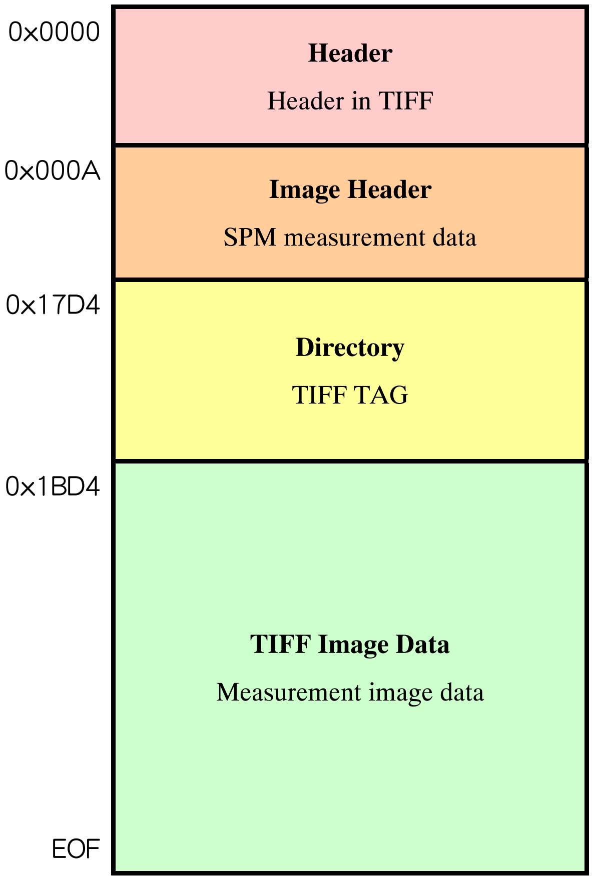
☞ The data address and file size depend on the kind of image data. In principle, however, the WinSPM image file is compliant with the structure shown above.

■ Image Header

As can be seen from the above illustration, in WinSPM, Image Header is inserted between Header and Directory. This file area contains information on measurement conditions in SPM measurement. Refer to 7.4.2b for further details of the Image Header data structure.

7.4.2b WinSPM image file［1］(SPM Image)

The data structure of a typical image file (e.g., for topographic images) is shown below.



■ Header-data structure

The Header structure of a TIFF file to be created by WinSPM is the same as that of the standard TIFF file with additional 2 bytes of data.

Address	Data		Data Type	Note
0x0000	49	49	short	“II” (0x4949)
0x0002	2A	00	short	TIFF Version 4.2
0x0004	D4	17	long	Address (0x000017D4) prepended to Directory
0x0006	00	00		
0x0008	00	04	unsigned short	Directory size
0x000A ::	Image Header			

■ Image Header data structure

● Data structure

Image Header data structure

Address	Data Type	Data Size	Note
0x000A	short	2 bytes	WinSPM Version
0x000C :	char [80]	80 bytes	Image internal filename in Ver 4.00 or earlier
0x005C	short	2 bytes	Image width (128,256,512)
0x005E	short	2 bytes	Image height (128,256,512)
0x0060	float	4 bytes	Scan size X [nm]
0x0064	float	4 bytes	Scan size Y [nm]
0x0068	float	4 bytes	Value of pixel 0 [nm or nA]
0x006C	float	4 bytes	Value of pixel 255 [nm or nA]
0x0070	short	2 bytes	A/D converter minimum value during scan
0x0072	short	2 bytes	A/D converter maximum value during scan
0x0074	float	4 bytes	Scale value during initial scan
0x0078 :	char [40]	40 bytes	Image internal filename
0x00A0 :	char [40] [5]	200 bytes	Image information (EOL CR)
0x00168 :	unsigned char [50]	50 bytes	History that the image has been processed during a given period.
0x019A	short	2 bytes	current/voltage, with information:1 current/voltage, without information:0
0x019C	float	4 bytes	Bias voltage [V]
0x01A0	float	4 bytes	Reference value [nA or V]
0x01A4	char	1 byte	Dummy data (0x00)
0x01A5	char	1 byte	Dummy data (0x00)
0x01A6	struct dosdate_t	5 bytes	Year, month, and day on which image measurement was performed.
0x01AB	struct dosdate_t	5 bytes	Year, month, and day on which the image file was saved.
0x01B0	struct dostime_t	4 bytes	Time image measurement was made.
0x01B4	struct dostime_t	4 bytes	Time the image was saved.
0x01B8 :	unsigned char [256]	256 bytes	Lookup table (0x00～0xFF)
0x02B8	struct FFTHeadType*	4 bytes	Pointer to FFT data (NULL if there is no data)

Address	Data Type	Data Size	Note
0x02BC	short	2 bytes	Transform off
0x02BE	union ExtraType	8 bytes	Region selected from image
0x02C6	char	1 byte	Image compressed or not (When compressed: TRUE)
0x02C7	char	1 byte	Number of bits per pixel (0 = 8 bits)
0x02C8	struct CITSHeaderType*	4 bytes	Pointer to CITS data (NULL if there is no data)
0x02CC	float	4 bytes	Tip voltage during back scan (Floating maximum value without setting)
0x02D0	short	2 bytes	STS measurement point X (or -1,-1) in the image
0x02D2	short	2 bytes	STS measurement point Y (or -1,-1) in the image
0x02D4	unsigned char [10]	10 bytes	(^010)
0x02DE	unsigned char [10]	10 bytes	(^010)
0x02E8	float	4 bytes	Tip speed X [nm/s] during image measurement
0x02EC	float	4 bytes	Tip speed Y [nm/s] during image measurement
0x02F0 :	CalibType	42 bytes	Piezoelectric element sensitivity
0x031A :	SPMParamType	60 bytes	Detailed SPM parameters
0x0356	MontageHeaderType*	4 bytes	Pointer to Montage data (NULL if there is no data)
0x035A :	char [260]	260 bytes	Image file location (full-path specification)
0x045E :	SPMParamType 1	118 bytes	Miscellaneous SPM parameters
0x04D4 : : :	unsigned char [3] [256]	768 bytes	RBG Lookup Table [0] [ ] : RED [1] [ ] : GREEN [2] [ ] : BLUE
0x07D4	long	4 bytes	Sub Revision No.
0x07D8	enum ImageType 1	4 bytes	Kind of image (☞ Table 1)
0x07DC	DataSourceType	4 bytes	Kind of data source (☞ Table 2)
0x07E0	DisplayModeType	4 bytes	Kind of indication (☞ Table 3)
0x07E4	FILETIMEUUnion	8 bytes	Measurement starting time
0x07EC	FILETIMEUUnion	8 bytes	Measurement ending time

Address	Data Type	Data Size	Note
0x07F4	ProfileDefType	254 bytes	Profile and surface roughness analyses
0x08F2	_3DSettingType	446 bytes	3-dimensional display
0x0AB0	float	4 bytes	LUT Brightness
0x0AB4	float	4 bytes	LUT Contrast
0x0AB8	short	2 bytes	Software version used for measurement
0x0ABA	long	4 bytes	Software sub-version used for measurement
0x0ABE	ExtractType	20 bytes	Region extracted from the image
0x0AD2	float	4 bytes	LUT Gamma
0x0AD6	short	2 bytes	Number of SPS data saved together
0x0AD8	ImageHeaderType*	4 bytes	Pointer to SPS data
0x0ADC :	char [3320]	3320 bytes	Buffer
0x17D4 :	Directory		

Table 1 Kind of image

1	Image
2	Spectrum
3	Profile
4	Histogram
5	VCO
6	Invalid

Table 2 Kind of data source

1	Z	11	Phase
2	Log I	12	MFM
3	Lin I	13	Elasticity
4	AUX1	14	Viscosity
5	AUX2	15	FFM_Friction
6	AUX3	16	Surface_V
7	EXT (Voltage)	17	Prescan
8	Force	18	RMS
9	AFM	19	FMD
10	Friction	20	Capacitance Force

Table 3 Kind of indication

1	Default
2	BMP
4	3D

● Internal data structure

Data structures in Image Header

• Year, month, and day: dosdate_t

Data Type	Data Size	Note
unsigned char	1 byte	Day (1 to 31)
unsigned char	1 byte	Month (1 to 12)
unsigned short	2 bytes	Year (1980 to 2099)
unsigned char	1 byte	Day of the week (0 to 6 : 0→Sunday)

• Time: dostime_t

Type	Size	Note
unsigned char	1 byte	Hour (0 to 23)
unsigned char	1 byte	Minute (0 to 59)
unsigned char	1 byte	Second (0 to 59)
unsigned char	1 byte	1/100 s (0 to 99)

• Structure to record the region selected from the image: union ExtraType

Type	Size	Note
struct ImageExtraType	8 bytes	Image selection range
struct CITSImageExtraType	7 bytes	CITS measurement parameters

• Structure to record the range selected from the image: ImageExtraType

Type	Size	Note
short	2 bytes	X1
short	2 bytes	X2
short	2 bytes	Y1
short	2 bytes	Y2

• Structure to record CITS measurement parameters: CITS ImageExtraType

Type	Size	Note
unsigned char	1 byte	ADC source
short	2 bytes	ADC offset [mV]
unsigned short	2 bytes	ADC gain
unsigned short	2 bytes	Head amp gain

• Structure to record the piezoelectric-element sensitivity: CalibType

Type	Size	Note
float	4 bytes	Dummy data
float	4 bytes	Dummy data
float	4 bytes	Dummy data
float	4 bytes	Dummy data
float	4 bytes	Proximity coefficient Z term
float	4 bytes	Dummy data
float	4 bytes	Dummy data
float	4 bytes	Dummy data
float	4 bytes	Dummy data
float	4 bytes	Reference Voltage [V]
short	2 bytes	Stage

• Structure to record the detailed SPM parameters: SPMParamType

Type	Size	Note
float	4 bytes	Clock [ms]
float	4 bytes	Measurement rotation angle [°]
float	4 bytes	Feedback filter [Hz]
float	4 bytes	Present filter [kHz]
float	4 bytes	Head amp gain [V/nA]
short	2 bytes	Loop gain (1 to 4)
float	4 bytes	X offset [nm]
float	4 bytes	Y offset [nm]
float	4 bytes	Z gain
float	4 bytes	Z offset [V]
float	4 bytes	O gain
float	4 bytes	O offset [V]
float	4 bytes	Back scan bias [V]
enum mode type	4 bytes	Measurement mode (☞Table 4)
short	2 bytes	Dummy data

Table 4 Measurement mode

1	Line1024	13	S-V	25	Topo3_lm_ffm
2	Topo Mirror	14	I-S	26	Topo2_kfm
3	Topo512	15	F-C	27	Topo2_ffm
4	Topo256	16	FFC	28	TOPO1024
5	Topo128	17	Montage128	29	TOPO2x512
6	Line512	18	Montage256	30	Topo2_scfm
7	Line256	19	LSTS	31	Topo2_mfm_l
8	Line128	20	Topo SPS	40	Phaseshift
9	Topo×2	21	VCO	50	CS3DScan
10	Topo×4	22	Topo Image		
11	CITS	23	Topo3_ve_afm		
12	I-V	24	Topo4_mfm		

• Structure to record miscallaneous SPM parameters: SPM Param Type 1

Type	Size	Note
enum wint_SourceType	4 bytes	Dummy data
enum wint_SourceType	4 bytes	Dummy data
float	4 bytes	DDS Frequency
short	2 bytes	DDS Low Filter
short	2 bytes	DDS High Filter
short	2 bytes	DDS Center Filter
short	2 bytes	DDS Enable
short	2 bytes	Scan filter
enum wint_AFMModeType	4 bytes	AFM mode (☞Table 5)
long	4 bytes	Slope gain
short	2 bytes	X addition signal
short	2 bytes	Y addition signal
short	2 bytes	Z addition signal
short	2 bytes	Bias addition signal
enum wint_activeDialogType	4 bytes	Active Dialog (☞Table 6)
enum wint_SPMScanModeType	4 bytes	SPM Scan Mode (☞Table 7)
enum wint_SourceType	4 bytes	Measurement signal (☞Table 8)
short	2 bytes	Phase during VCO Scan
enum modeType	4 bytes	SPS measurement mode
double	8 bytes	DDS Amplitude
double	8 bytes	DDS Center Locked Freq
float	4 bytes	DDS Phase Shift
short	2 bytes	DDS High Gain
short	2 bytes	DDS Phase Polarity
short	2 bytes	DDS PLL Excitation
short	2 bytes	DDS External
long	4 bytes	DDS RMS Filter
long	4 bytes	DDS PLL Loop Gain
long	4 bytes	DDS Beat Noise
enum wint_VCOFMDynamicRangeType	4 bytes	DDS Dynamic Range
float	4 bytes	Cantilever Freq Peak
float	4 bytes	Cantilever Q Factor
char [10]	10 bytes	Buffer area

Table 5 AFM mode

1	Contact Mode
2	Slope
4	FM
8	FMS
16	Phase

Table 6 Active Dialog

1	Advanced
2	STM
4	AC Mode
8	Contact
16	Option

Table 7 SPM Scan Mode

1	Normal
2	VE-AFM
4	LM-AFM
8	KFM
16	MFM
32	MFM Line

Table 8 Measurment signal

0x000000	Off	0x000800	AUX 2
0x000001	Topography	0x001000	AFM Contact
0x000002	Bias	0x002000	Motor X/20
0x000004	Linear Current	0x004000	Motor Y/20
0x000008	Log Current	0x008000	Motor Z/20
0x000010	Force	0x010000	(A-B)/(A+B)
0x000020	Friction Force	0x020000	AFM
0x000040	A+B (SUM)	0x040000	Pre Scan
0x000080	RMS	0x080000	Lateral Force
0x000100	FMD	0x100000	(C-D)/(C+D)
0x000200	Phase	0x200000	(None)
0x000400	AUX 1		

• Structure to record setting for profile and surface roughness analyses: ProfileDefType

Type	Size	Note
POINTs [5] [2]	40 bytes	Coordinates of the line
float [3] [2]	24 bytes	Location of the marker
short	2 bytes	Dummy data
short [5]	10 bytes	Line indication
short [3]	6 bytes	Marker indication
short [5]	10 bytes	Active line
POINTs [2]	8 bytes	Coordinates of Single Profile to be recorded
POINTs [2]	8 bytes	Coordinates of Multi Profile to be recorded
COLORREF [5]	20 bytes	Color of each line
short [3]	6 bytes	Indication of marker to be recorded
bool	1 byte	Rz marker indicated/not indicated
bool [5]	5 bytes	Broad Line setting
short [5]	10 bytes	Broad Line width
CRect	16 bytes	Selected area for roughness analysis
short	2 bytes	Setting of selected area for roughness analysis
short	2 bytes	Amount of movement by cursor （X）
short	2 bytes	Amount of movement by cursor （Y）
POINTs [2]	8 bytes	Coordinates of Extra Profile to be recorded
bool	1 byte	Broad Line setting (Single Profile)
bool	1 byte	Broad Line setting (Extra Profile)
bool [5]	5 bytes	Broad Line setting (Multi Profile)
short	2 bytes	Broad Line width (Single Profile)
short	2 bytes	Broad Line width (Extra Profile)
short [5]	10 bytes	Broad Line width (Multi Profile)
short	2 bytes	Direction of Extra Profile（TRUE : Vertical）
enum wint_DialogControlSttsType	2 bytes	Application of “Rz On/Off” menu（☞Table 9）
char [49]	49 bytes	Buffer area

Table 9 “Rz On/Off” menu application

1	Enable	2	Disable	3	Invisible

- Structure to record line coordinates: POINTs

Type	Size	Note
short	2 bytes	X coordinates
short	2 bytes	Y coordinates

• Structure to record 3-dimensional display settings: _3DsettingsType

Type	Size	Note
_3D_Mode	4 bytes	3-dimensional display mode (☞Table 10)
float [3]	12 bytes	XYZ rotation angles
float	4 bytes	Z Scale
float	4 bytes	Z Offset
float	4 bytes	XYZ Scale
float	4 bytes	X shift
float	4 bytes	Y shift
float	4 bytes	Perspective
float	4 bytes	Mesh size X
float	4 bytes	Mesh size Y
float	4 bytes	Dispersion (Specular Level)
float	4 bytes	Reflection (Diffuse Level)
float	4 bytes	Brightness (Reflectivity)
short [2] [3]	12 bytes	Surface display color (2 sheets)
float [2]	8 bytes	Light Azimuth
float [2]	8 bytes	Light Elevation
float [2]	8 bytes	Light Brightness
short [3]	6 bytes	XYZ scale display
short	2 bytes	Side display
short	2 bytes	Base display
short	2 bytes	Light source display
LOGFONT	60 bytes	Scale indication font
COLORREF	4 bytes	Scale indication color
short	2 bytes	3-dimensional display: TRUE
float	4 bytes	XY Aspect ratio
COLORREF	4 bytes	Background color
float	4 bytes	Scale indication font size
float	4 bytes	Title indication font size
float	4 bytes	α value
short [3]	6 bytes	Indication of title scan size path
char [246]	246 bytes	Buffer area

Table 10 3-dimensional display mode

00	Invalid	08	Merge
01	Illuminate	10	Shade/Illuminated
02	Shade	20	Alpha
04	Grid		

■ Directory data structure

● TAG structure

The WinSPM directory lies in the 1st directory of the TIFF file and it occupies 300 bytes in the header. There are 16 TAG structures in the directory, each having 12 bytes.

• TAG structure: TIFF_TAG

Type	Size	Note
short	2 bytes	TAG type
short	2 bytes	Data type
long	4 bytes	Length of data
long	4 bytes	data or pointer

● Data structure

Address	Data Type	Size	Data		Note
0x17D4	short	2 bytes	11	00	Total no. of TAGs (0x0011 = 17)
0x17D6	struct TIFF_TAG	12 bytes	00	01	TAG 256 “Image Width”
:			04	00	Data type: long
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 4 bytes)
:					Image width
:					128 or 256 or 512
0x17E2	struct TIFF_TAG	12 bytes	01	01	TAG 257 “Image Height”
:			04	00	long type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 4 bytes)
:					Image height
:					128 or 256 or 512

Address	Data Type	Size	Data		Note
0x17EE	struct TIFF_TAG	12 bytes	02	01	TAG 258 “Bit Per Sample”
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:			10	00	No. of bits per sample
:			00	00	“SPM Image” = 16 bits
0x17FA	struct TIFF_TAG	12 bytes	03	01	TAG 259 “Compression”
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:			01	00	Data compressed or not (1 = not compressed)
:			00	00	
0x1806	struct TIFF_TAG	12 bytes	06	01	TAG 262 “Photometric interpretation”
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:			01	00	Gradation per pixel
:			00	00	(1 : 00→black FF→white)
0x1812	struct TIFF_TAG	12 bytes	0E	01	TAG 270 “Image Description”
:			02	00	ASCII data
:					No. of characters in internal filename
:					
:			20	08	Pointer to internal filename data
:			00	00	
0x181E	struct TIFF_TAG	12 bytes	0F	01	TAG 271 “Make”
:			02	00	ASCII data
:			0B	00	Data unit: 11
:			00	00	(TAG Data length = 11 bytes)
:					Pointer to Make data
:					

Address	Data Type	Size	Data		Note
0x182A	struct TIFF_TAG	12 bytes	10	01	TAG 272 “Model”
:			02	00	ASCII data
:			0A	00	Data unit: 10
:			00	00	(TAG Data length = 10 bytes)
:					Pointer to Model data
:					(default data = “JEOL SPM “)
0x1836	struct TIFF_TAG	12 bytes	11	01	TAG 273 “Strip Offset”
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:					Strip Offset data
:					
0x1842	struct TIFF_TAG	12 bytes	15	01	TAG 277 “Samples per Pixel”
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:			01	00	No. of samples per pixel
:			00	00	
0x184E	struct TIFF_TAG	12 bytes	16	01	TAG 278 “Rows per Strip”
:			04	00	long type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 4 bytes)
:					Rows per Strip data
:					
0x185A	struct TIFF_TAG	12 bytes	17	01	TAG 279 “Strip Byte Count”
:			04	00	long type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 4 bytes)
:					Strip Byte Count data
:					

Address	Data Type	Size	Data		Note
0x1866	struct TIFF_TAG	12 bytes	1A	01	TAG 282 “X Resolution”
:			05	00	Data type: rational
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 8 bytes)
:					Pointer to X Resolution data
:					Resolution in the X direction
0x1872	struct TIFF_TAG	12 bytes	1B	01	TAG 283 “Y Resolution”
:			05	00	Rational type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 8 bytes)
:					Pointer to Y Resolution data
:					Resolution in the Y direction
0x187E	struct TIFF_TAG	12 bytes	28	01	TAG 296 “Resolution Unit”
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:					Resolution unit
:					
0x188A	struct TIFF_TAG	12 bytes	3C	01	TAG 316 “Host Computer”
:			02	00	ASCII data
:			19	00	Data unit: 12
:			00	00	(TAG Data length = 12byte)
:					Pointer to Host Computer data
:					(“IBM Compatible(Windows) “)
0x1896	struct TIFF_TAG	12 bytes	00	00	No TAG data for SPM Image
:			00	00	
:			00	00	
:			00	00	
:			00	00	
:			00	00	

Address	Data Type	Size	Data		Note
0x18A2	long	4 bytes	00	00	End of Directories
			00	00	(NULL Pointer)
0x18A6 : : : :	char [814]	814 bytes			Buffer area When the length of data excceds 4 bytes, TAG data is written here.
0x1BD4 :	TIFF Image Data :				

■ TIFF Image Data structure

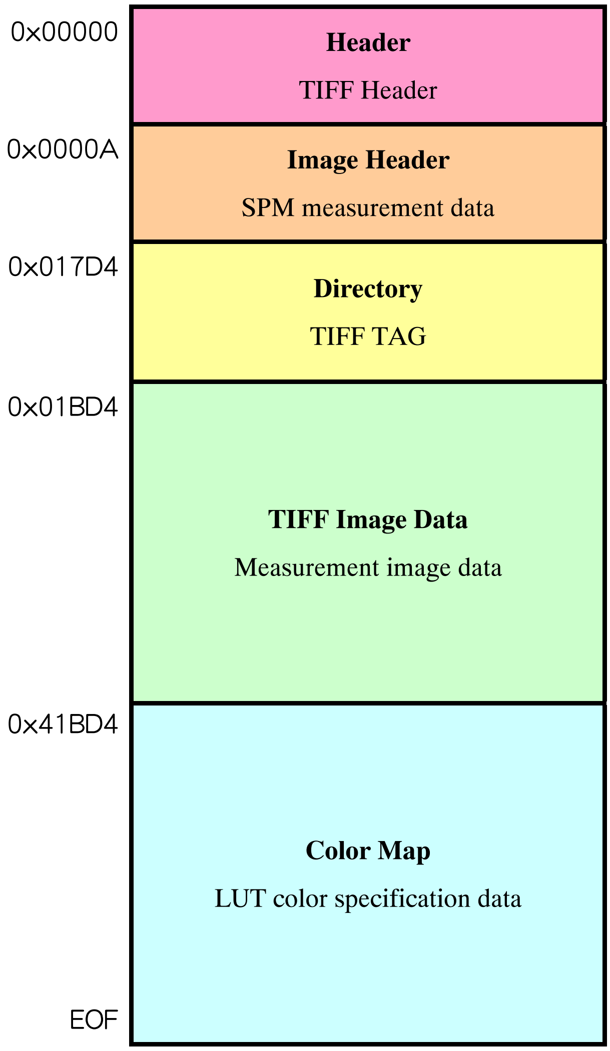
The directory is followed by a file (TIFF image data area) containing the actual image data. The amount of data per pixel is 16 bits (2 bytes). For instance, the size of the image data file containing a 512×512 pixel image with 16 bits per pixel is 512 pixels×512 pixels×2 bytes = 524,288 bytes.

■ Overall file size

The size of the topographic image file is given by Header (10 bytes) + Image Header (6,090 bytes) + Directory (1,024 bytes)
+ Image Data (524,288 bytes) = 531,412 bytes.

7.4.2c WinSPM image file [2] (Compressed TIFF)

Below is the format of a WinSPM image file when an SPM image is recorded in compressed TIFF. The WinSPM compressed TIFF is a file format consisting of the conventional 8 bit TIFF plus SPM measurement data and compatible with applications other than WinSPM. The file structure is the same as that of the SPM image file except that the TIFF image data is recorded as 8 bit data per pixel and followed by the color map section with LUT color specification data.



■ Header data structure

Same as “SPM Image”.

■ Image Header data structure

Same as “SPM Image”.

■ Directory data structure

Same as “SPM Image” except that Tag320 “Color Map” is added.

Address	Data Type	Size	Data		Note
0x17D4	short	2 bytes	11	00	Total no. of TAGs (0x0011 = 17)
0x17D6			00	01	TAG 256 “Image Width”
:			04	00	long type data
:	struct	12 bytes	01	00	Data unit: 1
:	TIFF_TAG		00	00	(TAG Data length = 4 bytes)
:					Image width
:					128 or 256 or 512
0x17E2			01	01	TAG 257 “Image Height”
:			04	00	long type data
:	struct	12 bytes	01	00	Data unit: 1
:	TIFF_TAG		00	00	(TAG Data length = 4 bytes)
:					Image height
:					128 or 256 or 512
0x17EE			02	01	TAG 258 “Bit Per Sample”
:			03	00	short type data
:	struct	12 bytes	01	00	Data unit: 1
:	TIFF_TAG		00	00	(TAG Data length = 2 bytes)
:			08	00	No. of bits per sample
:			00	00	8 bits for “Compressed TIFF”
0x17FA			03	01	TAG 258 “Compression”
:			03	00	short type data
:	struct	12 bytes	01	00	Data unit: 1
:	TIFF_TAG		00	00	(TAG Data length = 2 bytes)
:			01	00	Data compressed or not (1 = compressed)
:			00	00	

Address	Data Type	Size	Data		Note
0x1806	struct TIFF_TAG	12 bytes	06	01	TAG 262 "Photometric interpretation "
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:			01	00	Gradation per pixel
:			00	00	(1 :　00→black FF→white)
0x1812	struct TIFF_TAG	12 bytes	0E	01	TAG 270 "Image Description"
:			02	00	ASCII data
:					No. of characters of internal filename
:					
:			20	08	Pointer to internal filename data
:			00	00	
0x181E	struct TIFF_TAG	12 bytes	0F	01	TAG 271 "Make"
:			02	00	ASCII data
:			0B	00	Data unit: 11
:			00	00	(TAG Data length = 11 bytes)
:					Pointer to Make data
:					(default data = "WinSPM407(22) R.B. Leane ")
0x182A	struct TIFF_TAG	12 bytes	10	01	TAG 272 "Model"
:			02	00	ASCII data
:			0A	00	Data unit: 10
:			00	00	(TAG Data length = 10 bytes)
:					Pointer to Model data
:					(default data = "JEOL SPM ")
0x1836	struct TIFF_TAG	12 bytes	11	01	TAG 273 "Strip Offset"
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:					Strip Offset data
:					

Address	Data Type	Size	Data		Note
0x1842	struct TIFF_TAG	12 bytes	15	01	TAG 277 “Samples per Pixel”
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:			01	00	No. samples per pixel
:			00	00	
0x184E	struct TIFF_TAG	12 bytes	16	01	TAG 278 “Rows per Strip”
:			04	00	long type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 4 bytes)
:					Rows per Strip data
:					
0x185A	struct TIFF_TAG	12 bytes	17	01	TAG 279 “Strip Byte Count”
:			04	00	long type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 4 bytes)
:					Strip Byte Count data
:					
0x1866	struct TIFF_TAG	12 bytes	1A	01	TAG 282 “X Resolution”
:			05	00	Data type: rational
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 8 bytes)
:					Pointer to X Resolution
:					Resolution in the X direction
0x1872	struct TIFF_TAG	12 bytes	1B	01	TAG 283 “Y Resolution”
:			05	00	Rational type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 8 bytes)
:					Pointer toY Resolution
:					Resolution in the Y direction

Address	Data Type	Size	Data		Note
0x187E	struct TIFF_TAG	12 bytes	28	01	TAG 296 “Resolution Unit”
:			03	00	short type data
:			01	00	Data unit: 1
:			00	00	(TAG Data length = 2 bytes)
:					Resolution unit
:					
0x188A	struct TIFF_TAG	12 bytes	3C	01	TAG 316 “Host Computer”
:			02	00	ASCII data
:			19	00	Data unit: 12
:			00	00	(TAG Data length = 12 bytes)
:					Pointer to Host Computer data
:					“IBM Compatible(Windows) “
0x1896	struct TIFF_TAG	12 bytes	40	01	TAG 320 “Color Map”
:			03	00	Short type data
:			00	03	Data unit: 768
:			00	00	(Data length = 1536 bytes)
:			D4	1B	Pointer to Color Map data
:			04	00	(default data = “0x41BD4 “)
0x18A2	long	4 bytes	00	00	End of Directories
			00	00	(NULL Pointer)
0x18A6 : : : :	char [814]	814 bytes			Buffer area If the length of data exceeds 4 bytes, TAG data is written here.
0x1BD4 :	TIFF Image Data :				

■ TIFF image data structure

The actual image data is stored in the TIFF image data structure. The amount of data per pixel is 8 bits (1 byte). For instance, the size of a 512×512 pixel image is 512 pixels× 512 pixels×1 byte= 262,144 bytes.

■ Color map data structure

The LUT color data is recorded in the Color Map structure as 256 level data for each color (RGB). The amount of data per level is 16 bits (2 bytes) and, therefore, Color Map = 256 (levels)×2 bytes×3 (colors—RGB) = 1,536 bytes.

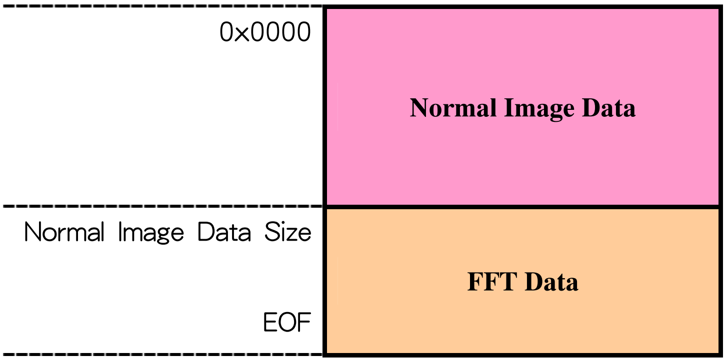
■ Overall file size

The size of the topographic image file is given by Header (10 bytes) + Image Header (6,090 bytes) + Directory (1,024 bytes)
+ Image Data (262,144 bytes) + Color Map (1536 bytes) = 270,804 bytes.

7.4.2d WinSPM image file [3] (FFT image file)

The following describes the FFT image file data structure.

In the FFT image file, the SPM Image data structure (Normal Image Data section) precedes FFT calculation results (FFT data). The FFT spectrum is recorded as a TIFF image.



■ FFT image file data structure

The data structure up to the FFT data recording section in the FFT data structure is identical to that of the SPM image file data. The FFT data structure, however, contains FFT data that correspond to each point of the normal image data and the real part and imaginary part of complex numbers in the data are floating-point.

- FFT data recording structure: complex8

Type	Size	Note
float	4 bytes	**Real part**
float	4 bytes	**Imaginary part**

The FFT data size of a 512×512 pixel FFT image is {real part (4 bytes) + imaginary part (4 bytes) }×512 pixels×512 pixels = 2,097,152 bytes.

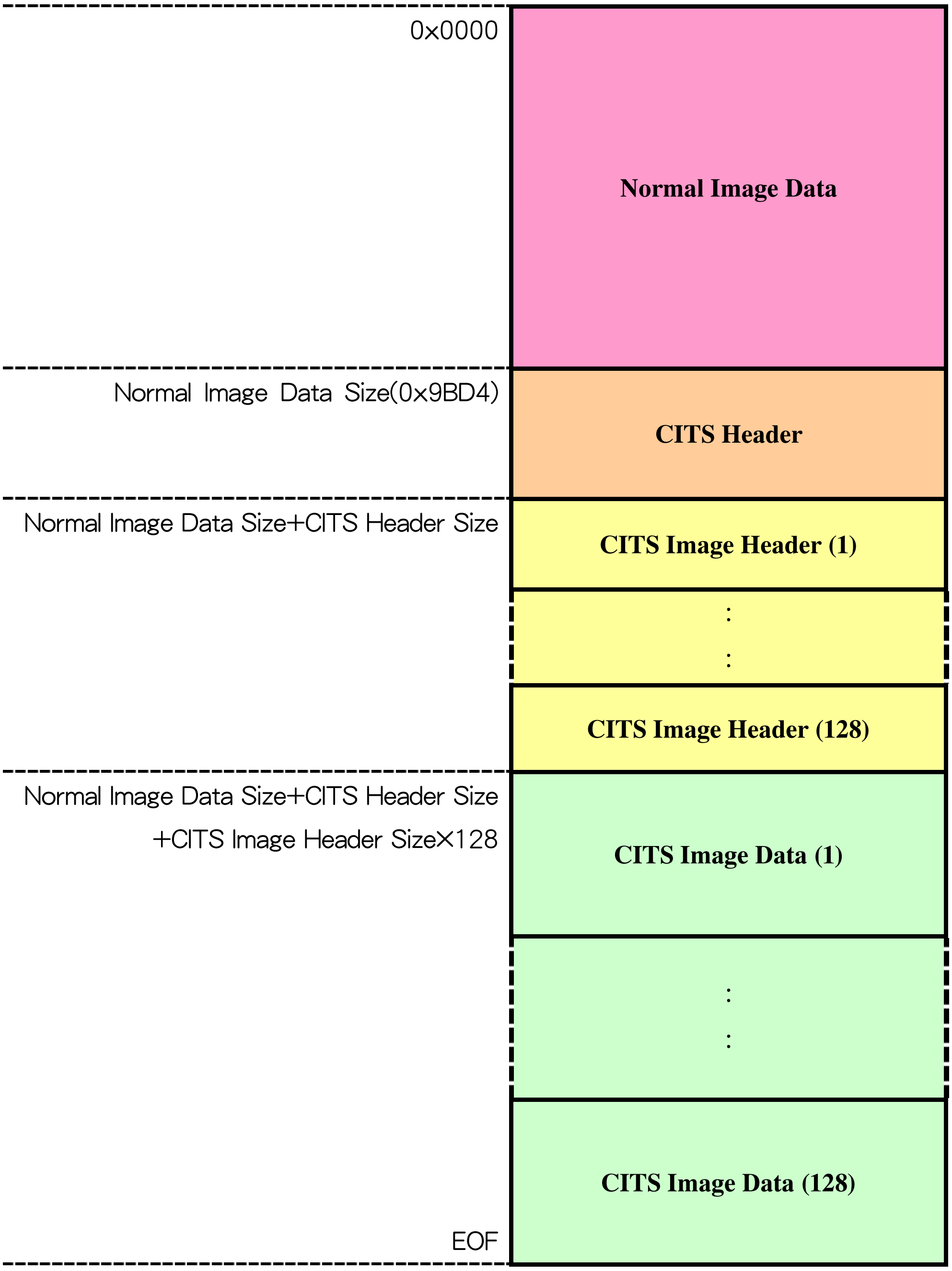
■ Overall file size

The size of the FFT image file is the normal image data size (531,412 bytes) + FFT data size (2,097,152 bytes) = 2,628,564 bytes.

7.4.2e WinSPM image file［4］(CITS image file)

■ CITS image file data structure

The illustration below is the CITS image file data structure. The topographic (TOPO) image (128×128 pixels) is recorded in the normal image data section as TIFF image data whose structure is the same as that of the SPM image file.



■ CITS Header data structure

The following is information on the CITS header data structure and overall CITS image information is presented.

Address	Type	Size	Note
0x9BD4	short	2 bytes	WinSPM Revision number
0x9BD6	short	2 bytes	No. of CITS images
0x9BD8	short	2 bytes	CITS image width (128 pixels)
0x9BDA	short	2 bytes	CITS image height (128 pixels)
0x9BDC	short	2 bytes	No. of current images
0x9BDE	CITSDispOptType	250 bytes	Options for display
0x9CD8	Char [128]	128 bytes	Buffer
0x9D58	short	2 bytes	(Intrinsic) reference number
0x9D5A :	CITS Image Header (1)		

• CITS image display option recording structure: CITS DispOptType

Type	Size	Note
short	2 bytes	Check flag (☞Table 11)
short	2 bytes	No. of CITS images to display
unsigned char	1 byte	Display mode (☞Table 12)
double	8 bytes	Conductance at level 0
double	8 bytes	Conductance at level 255
unsigned char	1 byte	Selection of display (☞Table 13)
short[64]	128 bytes	Number of CITS image
char[100]	100 bytes	Buffer

• Table 11 Check flag

	bit			
	0	1	2	…
TOPO display: ON (1)/OFF (0)	○			
Voltage display on the image: ON (1)/OFF (0)		○		
Overlay: (1)/Opaque: (0)			○	

Default value $(00000000\ 00000011)_2 = (0003)_{16}$

• Table 12 Display mode

0	normal
1	difference
2	normalize difference
3	normalized ADC
4	conductance

•Table 13 Display mode

0	none
1	spaced
2	first
3	last
4	mix up

CITS Image Header data structure

In the CITS image header data structure, CITS image data according to the number of CITS images are successively recorded. When the number of CITS images is 128, the size of the CITS image header file is given by:
CITS Image Header (165 bytes)×128 = 21,120 bytes.

Type	Size	Note
short	2 bytes	ADC minimum value
short	2 bytes	ADC maximum value
unsigned char	1 byte	ADC Source (not used)
short	2 bytes	ADC Offset [mV]
unsigned short	2 bytes	ADC Gain
int	4 bytes	Head Amp Gain (1, 10, 100)
float	4 bytes	Image Voltage
float	4 bytes	Current at Image Data=0
float	4 bytes	Current at Image Data=64
char[40]	40 bytes	CITS image title
wint_SourceType	4 bytes	Measurement signal (☞Table 8)
char[96]	96 bytes	Buffer

CITS image data structure

The CITS image header is followed by information on a CITS image (current image at each voltage) whose sequence is dependent on the CITS image header. When the number of CITS images is 128, the size of the CITS image data file is as follows:
128 pixels×128 pixels×2 bytes×128 = 4,194,304 bytes.

Overall file size

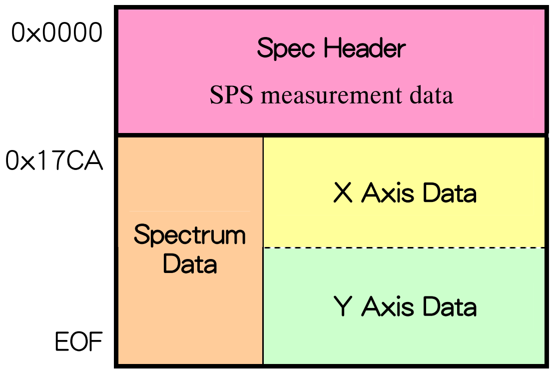
The overall size of the CITS image file is
Normal Image Data (39,892 bytes) + CITS Header (390 bytes) +
CITS Image Header (21,120 bytes) + CITS Image Data (4,194,304 bytes)
= 4,255,706 bytes.

7.4.3 Spectrum data file

The spectrum data file is a file in which spectrum data relating to WinSPM I-V characteristics, force curve, etc. are recorded.

■ Spectrum data file structure

The spec header is identical to the image header in the WinSPM image file and followed by all of the X and Y axis data. The data size varies depending on the kind of spectrum measurement and the number of measurement points.



■ Spec header data structure

Same as image header in the SPM image file

■ Spec data structure

The actual spectrum data are recorded in the file section (beginning with 0x17CA) after the spec header. Each measurement point (4 bytes) is floating-point.

■ Spectrum Data file size

Spectrum data consist of X and Y axis data and the number of bytes of the data is given by:

Spectrum Data = Number of measurement points×4 bytes×2 (axes)

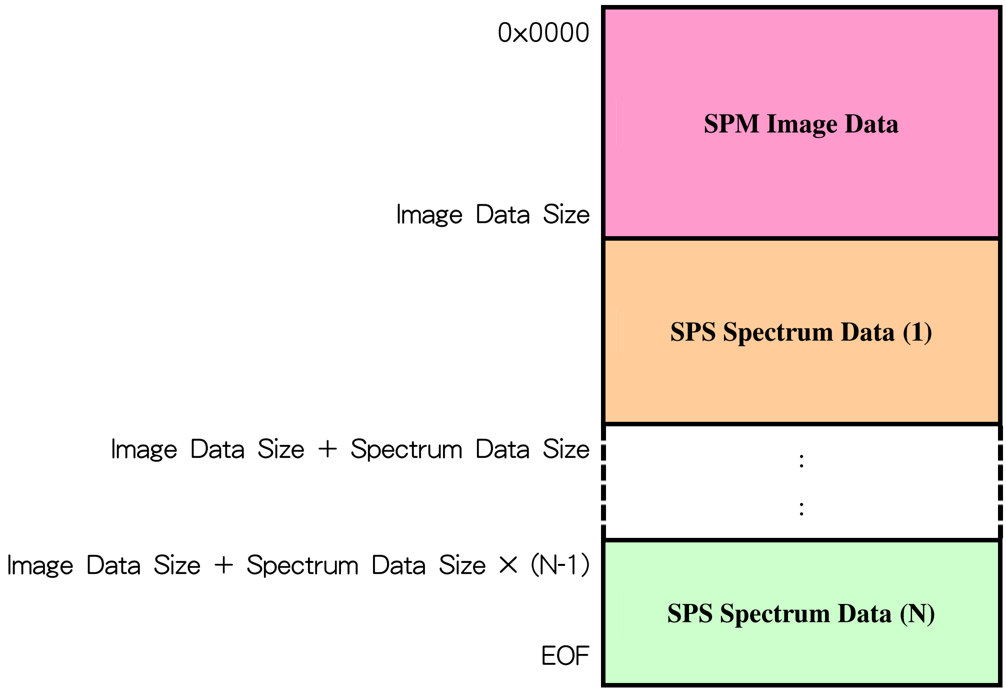
Therefore, if, for instance, the number of measurement points is 2,048, the amount of data is 16,384 bytes. Since the number of bytes of spec header data is 6,090 bytes, the overall size of the spectrum data file is given by

Spec Header (6,090 bytes) + Spec Data (16,384 bytes) = 22,474 bytes

7.4.4 Image file with spectrum data

Spectrum (SPS) data can be recorded together with image data. The structure is illustrated below.

■ Structure of Image file with spectrum data



The structure of the image file with spectrum data is rather simple, spectrum data files being added to the end of an image file. The file format of the image and spectrum data is the same as the one discussed earlier. The number of added spectrum data files is recorded in the image header file (short type variable at the address 0x0AD6).

■ Size of image file with spectrum data

File Size = SPM Image Data Size + N×SPS Spectrum Data Size

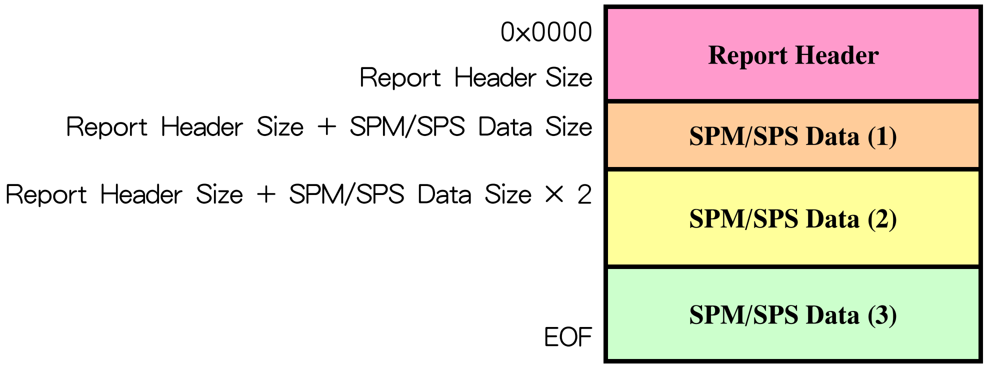
If, for instance, SPM image data = 512×512 pixels (normal measurement image) and SPS spectrum data with 2048 measurement points = 2, the overall file size is:
SPM Image Data (531 412 bytes) + 2×SPS Spectrum Data (22 474 bytes)
= 576 360 bytes

7.4.5 Report file

A report file is a file in which an output sheet is recorded.

■ Report file structure

The illustration below schematically shows a report file structure with an output sheet that contains a maximum of 3 SPM/SPS data files.



The report header section is situated at the beginning of the file, containing information on the number of data files, kinds, and so forth in the output sheet and followed by image and spectrum data files in each respective format.

■ Report Header data structure

Type	Size	Note
int	4 bytes	No. of data files in the output sheet
short [n]	2 bytes × n	Data configuration for each data (☞Table 14)
BOOL [n]	4 bytes × n	Flag to indicate image data for each data
DWORD [n]	4 bytes × n	Length of each data

n: Number of data files in the output sheet

• Table 14 Report configuration

0	Normal output sheet	4	Multiple profile output sheet
1	Multiple image profile output sheet	5	Extra profile output sheet
2	3 dimensional image output sheet	6	Suface roughness analysis output sheet
3	Single profile output sheet		

■ Report file size

The size of the report file depends on the number of data files and kinds in the output sheet and is given by:
Total SPM/SPS data file size + Report Header (37 bytes)

8

GENERAL

8.1 STORAGE 8-1
8.1.1 Instrument 8-1
8.1.2 Cantilever 8-1
8.1.3 Handling the Instrument 8-1
8.1.4 Maintenance Parts 8-1
8.2 VIBRATION ISOLATOR 8-2
8.2.1 Compressor （optional） 8-2
8.2.2 Vibration-Isolation Table 8-2
8.3 SPM HEAD 8-3
8.3.1 Laser Beam Focusing 8-3
8.3.2 Mirror Angle Adjustment 8-4
8.4 CCD CAMERA (OPTIONAL) 8-5
8.4.1 Installing the CCD Camera 8-5
8.4.2 Replacing the Source Lamp 8-8
8.5 LOCATIONS OF PORTS 8-10
8.6 USER PORTS 8-10
8.7 PIN CONNECTION 8-11
8.8 TOOL SET (OPTIONAL) 8-12

8.1 STORAGE

8.1.1 Instrument

When the instrument is not in use, put the provided glass bell-jar on the top of the SPM base.
If the ambient humidity is very high, dehumidify the room or evacuate the instrument if the optional evacuation system is installed.
Head units, scanners, cantilevers, specimen holders must be stored in a desiccator when they are not in use.

⚠ WARNING

When storing the instrument, avoid high humidity. Excess humidity brings deterioration of insulation at the tunneling current detector and scanner high-voltage circuits, causing insufficient instrument performance or electric shock.

8.1.2 Cantilever

⚠ CAUTION

Cantilevers must be stored in a desiccator when they are not in use. If they are stored at high humidity, the cantilevers could bend, causing the reflected laser beam not to reach the correct position. Especially, a gold-coated Si_3N_4 cantilever is prone to deteriorate with humidity.

8.1.3 Handling the Instrument

⚠ WARNING

**When handling the instrument, be sure to wear nylon gloves.
Grease from hands may cause deterioration of the vacuum especially when you observe a specimen in the vacuum using an optional evacuation system. At the worst, there is a risk of deterioration of insulation at the tunneling current detector and scanner high-voltage circuits, causing insufficient instrument performance or electric shock.
If any parts happen to have hand grease on them, softly wipe it off with ethanol-soaked lint-free tissue or cloth.**

8.1.4 Maintenance Parts

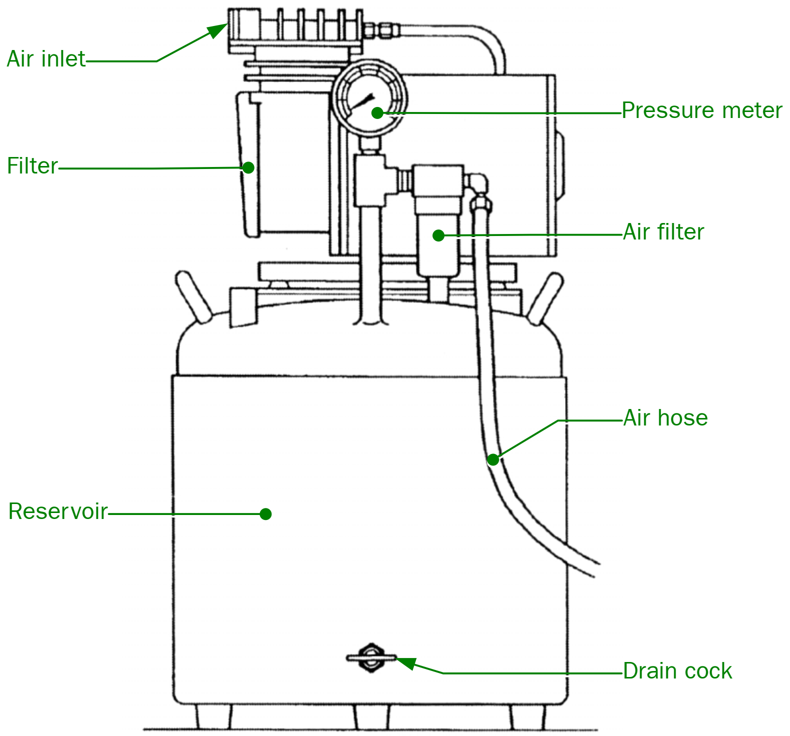
Vacuum-seal O rings are built into the instrument and they deteriorate with time. Replace them every ten years.

8.2 VIBRATION ISOLATOR

8.2.1 Compressor (optional)

Inspect the compressor and clean the filters periodically.

Drain: Shut down the entire instrument and open the drain cock to discharge water at least once a month. Be sure to close the cock after draining off the water.
Filter cleaning: At least once or twice a year, shut down the entire instrument; remove the air inlet using a screwdriver; take the filter out; and either replace it with a new one, or wash and dry the filter and remount it.
Air filter: When water collects in the glass container of the air filter, push up the pin at the bottom of the container to drain the water off.



8.2.2 Vibration-Isolation Table

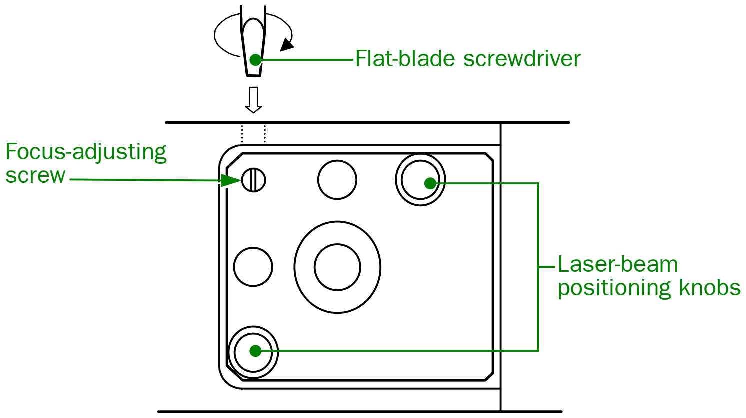
The vibration-isolation table should be kept level even after it is pneumatically elevated 5 mm to 15 mm above the floor. Periodically inspect the table to make sure it is level and at an appropriate height. If you find that the table is too low or not horizontal, contact your local JEOL service personnel.

8.3 SPM HEAD

8.3.1 Laser Beam Focusing

The laser beam has been adjusted in the factory before shipment so that it is focused on the tip of the cantilever. If, however, the beam becomes out of focus for some reason, re-adjust the focus according to the following procedure.
Due to scattering, the spot size of the laser beam looks considerably larger than its real size when it illuminates an object (specimen or cantilever). If you feel any abnormality with focusing, check the position and angle of the cantilever again before adjusting the focus.

1. Loosen the locking screw of the focus-adjusting screw using the provided flat-blade screwdriver.



2. Mount a specimen stub, with no specimen on it, on the standard specimen holder. Elevate the specimen stub using the manual approach thumbscrew until it rises flush with the cantilever tip.
3. The optical microscope with CCD adjust the laser beam by turning the two laser-beam positioning knobs and the focus adjusting screw by the same amount in the same direction so that the beam spot size becomes as small as possible on the specimen stub.
4. Install the cantilever as usual and illuminate the tip of the cantilever with the laser beam.
5. Maximize SUM by adjusting the laser-beam position using two laser-beam positioning knobs. Make a note of the SUM value at that time.
6. Adjust the focus-adjusting screw and the two laser-beam positioning knobs by one half revolution in the same direction and then maximize SUM again.
7. Repeat steps 5 and 6 above until the largest SUM value is obtained.
8. Tighten the locking screw after adjustment.

⚠ WARNING

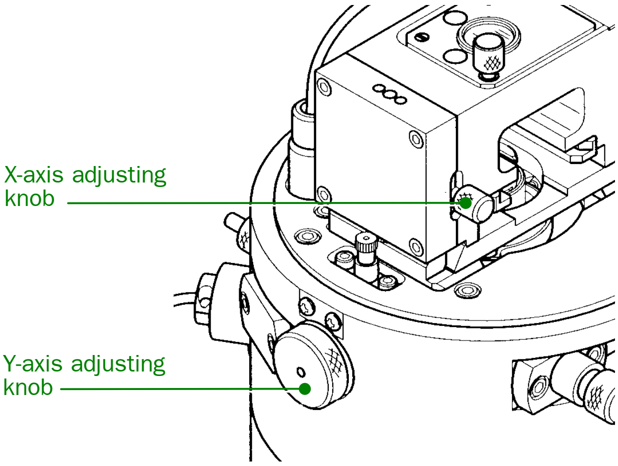
Be careful not to get irradiation bombardment from the laser radiation aperture locating near the laser source position adjusting knobs.

8.3.2 Mirror Angle Adjustment

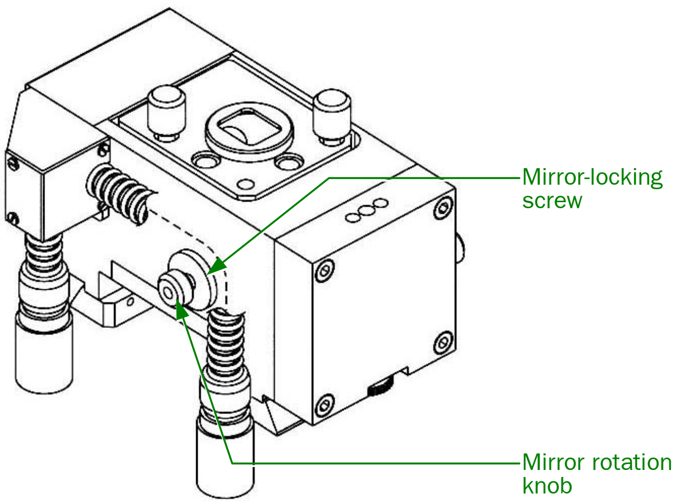
Cantilevers vary slightly in inclination, depending upon their production lot. If the detector photodiode cannot be aligned correctly, adjust the mirror angle according to the following procedure:

1. Install the cantilever in the usual manner and illuminate the tip of the cantilever with the laser beam.
2. Adjust the photodiode position-adjusting knobs so that the photodiode is positioned at the center point.

   The total number of revolutions of the X-axis adjusting knob is 20 and that of the Y-axis knob is 52. Therefore, the center position is at 10 (X-axis) and 26 (Y-axis) revolutions back from the fully rotated positions.



3. Loosen the mirror-locking screw; then adjust the mirror angle so that the SUM value on the AFM amplifier becomes the largest value and the AFM value becomes nearly 0.



4. Tighten the mirror-locking screw to lock the mirror angle.

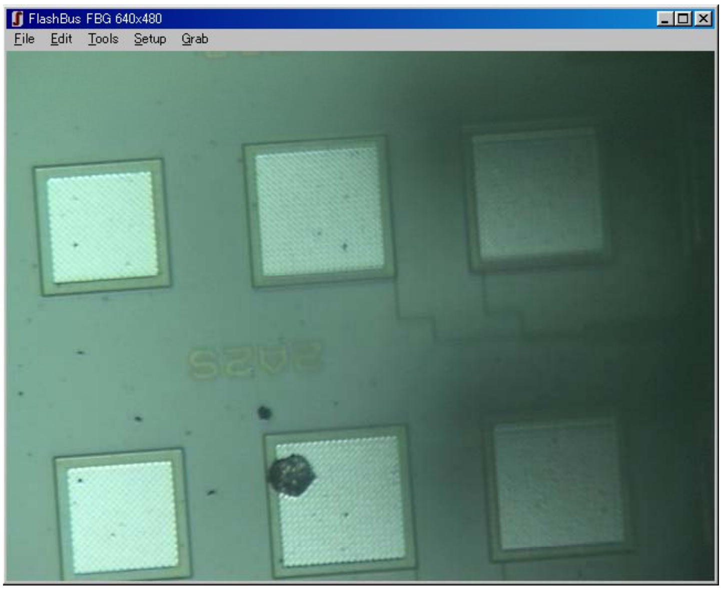
8.4 CCD CAMERA (OPTIONAL)

8.4.1 Installing the CCD Camera

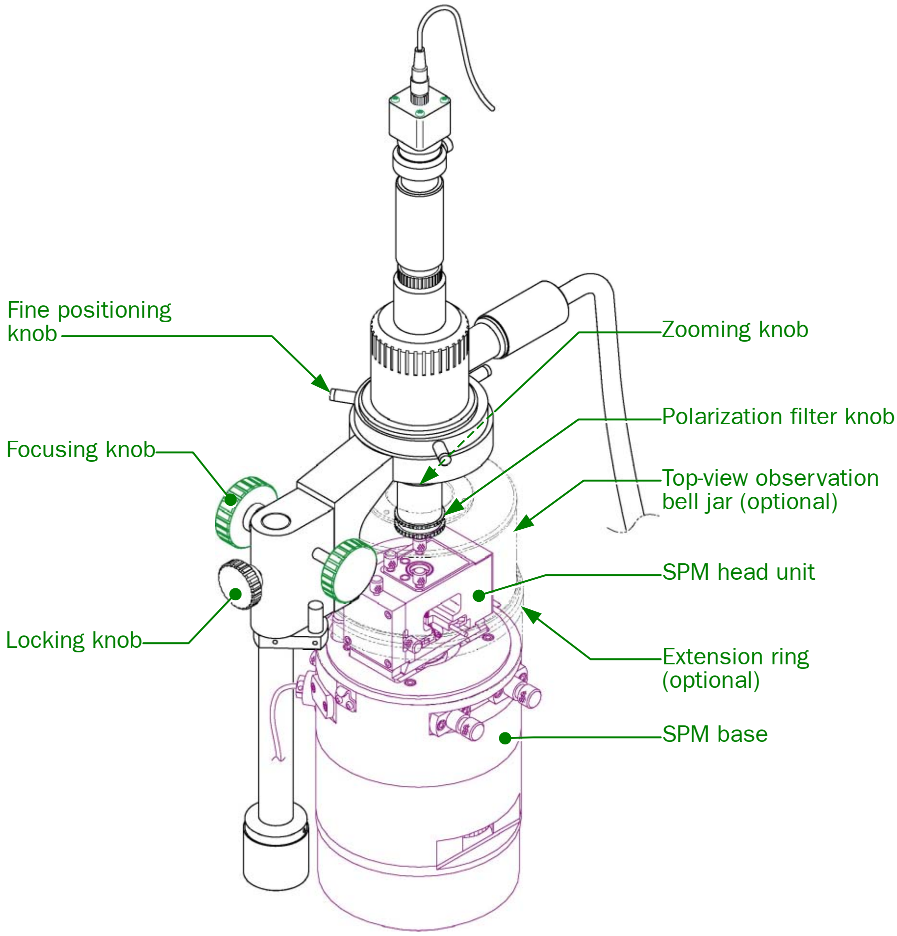
You can position the laser-beam spot and perform coarse approaching to the specimen using the CCD camera.

● Zoomable CCD camera

1. Open the Windows start menu and run the programs "Flash Bus MV" and "FBG32".



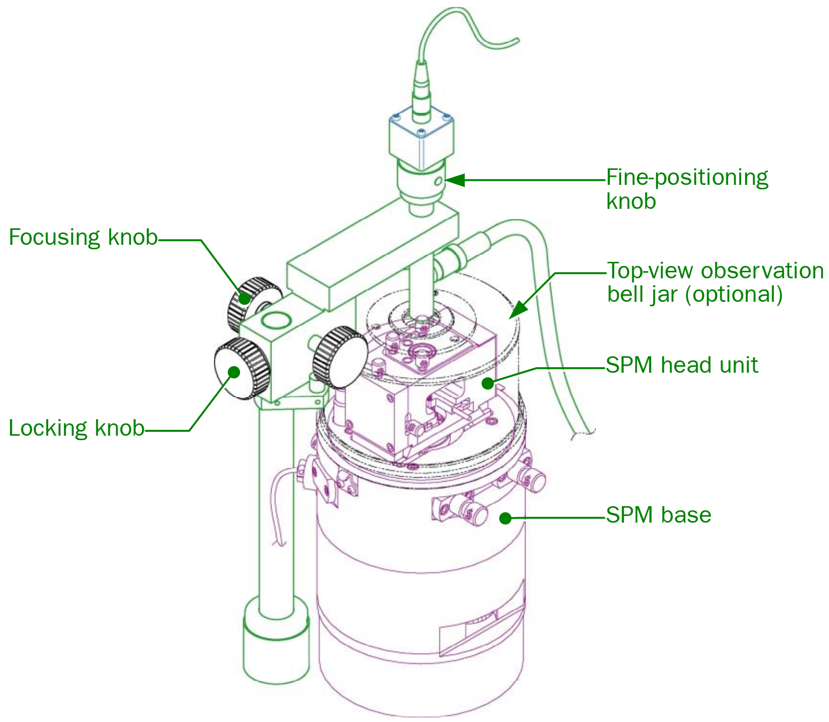
2. Move the CCD camera to a location above the SPM head, and lock it using the locking knob.



3. Turn the zooming knob to set the magnification to the minimum.
4. Adjust the fine positioning knob so that the cantilever comes to the center of the image.
5. Adjust the focusing knob so that correct focus is achieved on the cantilever.
6. Turn the polarization filter knob so that you can see a high-quality image.
7. Turn the zooming knob to obtain the desired magnification.

● Fixed-Magnification CCD camera

Manipulating the focusing knob and the fine positioning knob of this CCD camera, you can position the laser beam spot and perform coarse approaching to the specimen in the same manner as for the zoomable CCD camera.



8.4.2 Replacing the Source Lamp

When the filament of the light-source lamp has burned out, replace it, following the procedure below. Please ask our service personnel concerning information about how to procure the replacement lamps.

1. Turn off the power to the instrument.

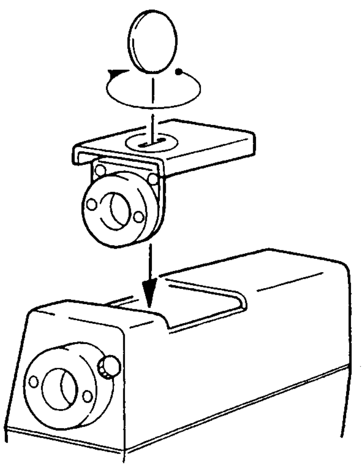
   Wait for 30 minutes or longer after the lamp is turned off. Then, go on to the next step.

> ⚠ **WARNING**
>
> **To avoid burns, allow the lamp to cool down for at least 30 minutes before removing it. Never touch the lamp with bare hands because it is very hot immediately after the filament burns out.**

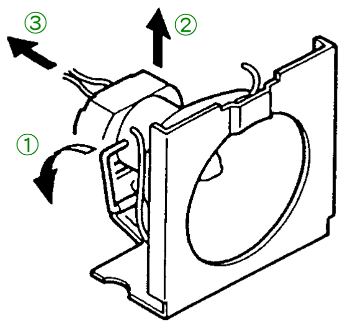
2. Remove the left-side panel of the main unit using a hexagonal wrench.

> ⚠ **WARNING**
>
> **Be careful not to put your hand under the base plate. You might get your fingers caught.**

3. Turn the lock of the lamp-exchange door to OPEN using a coin.
4. Remove the lamp exchange door.

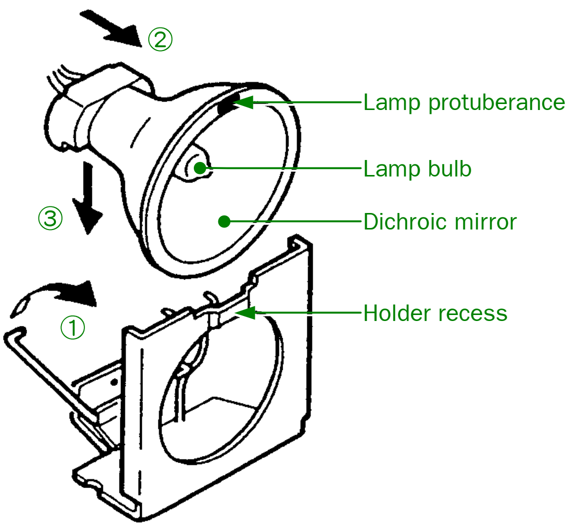


5. Throw the lever down; take out the lamp and remove it from the lamp socket.

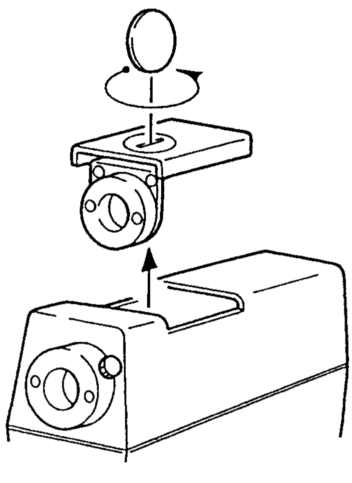


6. Install a new lamp in the lamp socket and insert it into the lamp holder.

Insert the lamp socket deeply into the lamp holder so that the lamp protuberance engages the recess in the lamp holder.

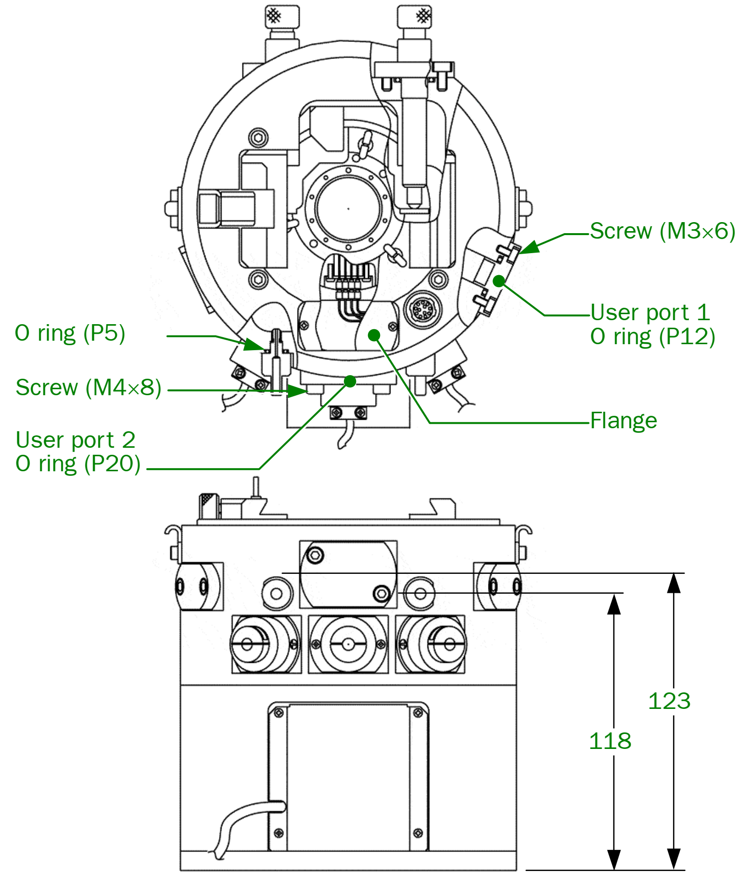


7. Install the lamp-exchange door on the main unit and turn the lock to CLOSE using a coin.

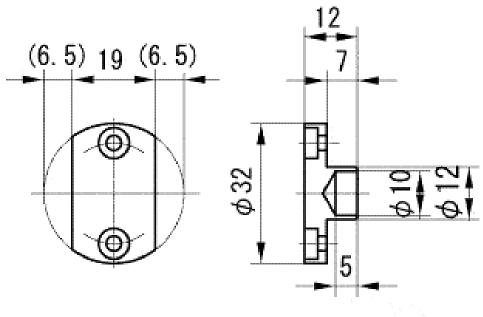


8.5 LOCATIONS OF PORTS

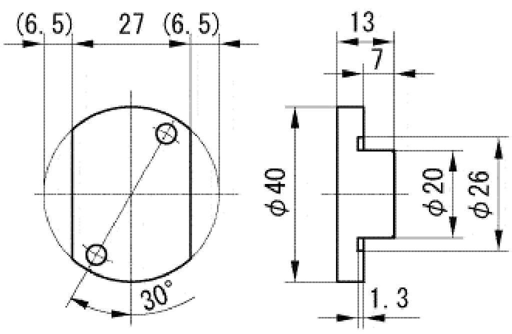
The illustration below shows the positional relationship of utility ports.



8.6 USER PORTS



Small port

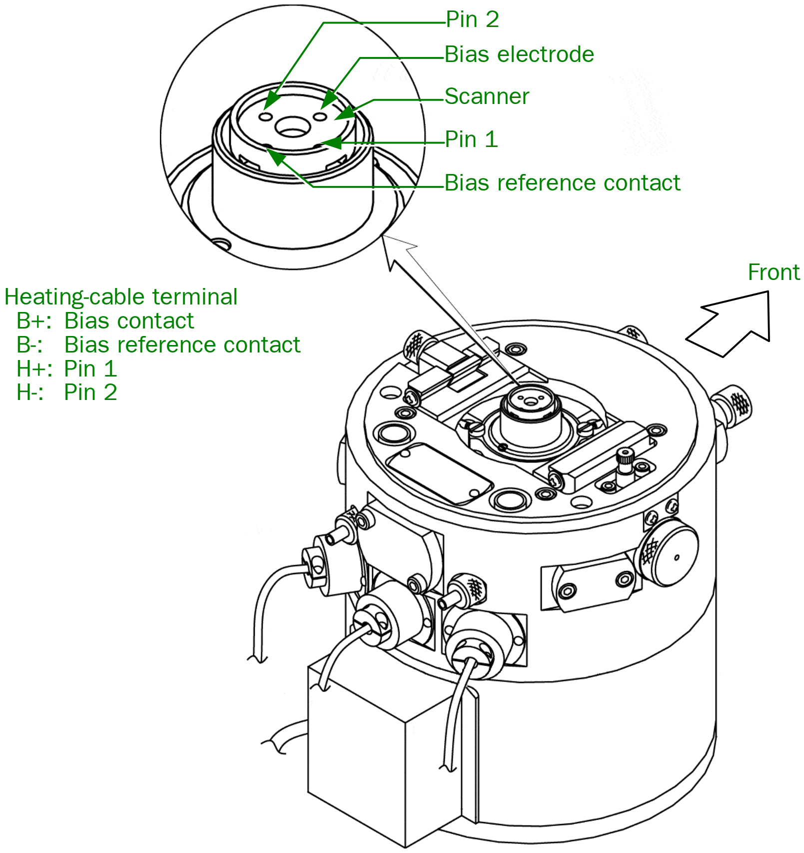


Large port

The sizes of the extension rings correspond to those of the user ports here.

8.7 PIN CONNECTION

The illustration below shows how the heating-cable terminals on the AFM amplifier correspond to the screw holes on the scanner holder tip.



8.8 TOOL SET (OPTIONAL)

An optional tool set is available. It is useful in routine operation and simple maintenance. This set includes the following items:

Tool box

• Hexagonal wrench set	1 set
• Jeweler's screwdriver set	1 set
• Phillips screwdriver (large)	1
• Flat-blade screwdriver (large)	1
• 24 mm single-head wrench	1
• 17 mm single-head wrench	1
• Double-head wrench set	1 set
• Open-end adjustable wrench (medium)	1
• Tweezers	1
• Nylon gloves	1 pair