NanoteQ News
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Editor Dr. David Carroll

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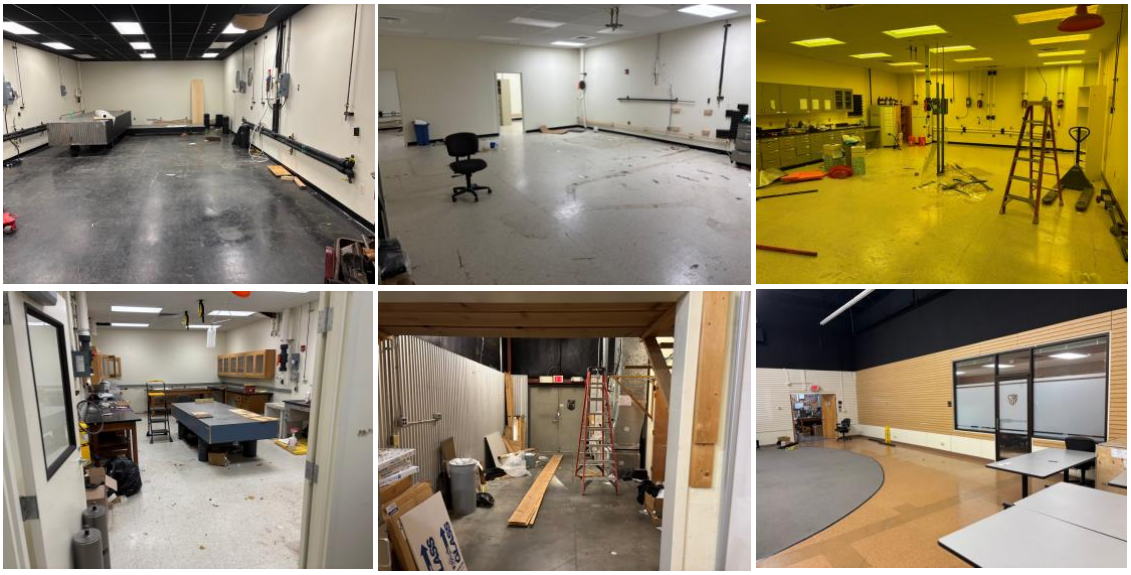
NANOTEQ
Nano and Quantum Technologies Laboratory

Vol.2 Iss.1 Winter 2025 edition

Moving NanoteQ

NanoteQ has moved its operations to 95 W 32nd Street and this has been a challenging few weeks. We have worked through the end of the semester, through the Christmas holidays, through the New Year, two building floods, and the snowpocalypse of 2025. The move has involved several moving companies, a team of contractors, Wake facilities, as well as students, staff, family and friends of the lab. And all of these people have been able to move 7 electron microscopes + FIB (2010F. 1200EX, 6330F, 6340F, Zeiss supra 25, Hitachi 3000N, Hitachi 4700, FEI 400M), 3 scanning probe microscopes (JEOL 5200, DI 3100, RHK VT STM 1000), 3 research optical microscopes, together with all of the backup equipment to support these instruments, a full MBE system, organics fab lab with gloveboxes, evaporators etc, a cleanroom with 30 process pieces including RIE, PECVD, e-beam evap, sputter deposition, 2 plasma systems etc., a full nanoparticle synthesis lab, a Raman lab with 2 full Raman systems, a fast optics lab with: lasers, optics, detectors, optical benches, etc., a full solar testing lab, a full XPS system, and a bunch more. The scale of the move was tremendous.



NanoteQ was a lot larger than we thought. Here are a few photos of the move as it was going on.

The 2010F arrives in the new facility

Timelines

Feb. 1
Unboxing and equipment placement. The STM and XPS should be operational.

Feb. 20
Cleanroom setups will begin. Equipment placement and air balance experiments. Cleanroom ratings. The RM98 thin films lab should also be online. Most of the microscopy facility will be up and running. This includes our SEMs, Optical microscopes and the 1200 EX. Because these microscopes were disassembled and then reinstalled, the opportunity was used to re-calibrate many of the instruments. Transport, Optics, Raman, Organics, Synthesis, should all be back online.

March 1
Cleanroom goes online. Installation of the FIB and Nabity system is scheduled.

April 1
HRTEM goes online

Changes coming to the Facility

Along with new equipment, new facilities, new capabilities, users of the NanoteQ lab will notice several other changes. For instance, the building is far more secure, and facilities are now being setup as a recharge center. Let's take a look at a few changes…

1. Equipment or tools are located within a ***Facility*** like *RM98* or the *Microscopy Facility* or a ***Core*** which is a smaller set of labs. Generally, these facilities contain all the backup equipment you need to prepare and use the specialized tools of the lab, including: sample preparation, cleaning and diagnostics, optical characterization, film thickness and composition and so on. So, before you use a Facility/Core, you must sign in though the OneTap system. You can get an account from the Director or Deputy director of the Lab. With this you have access to all the support you need in creating samples for imaging, substrates for lithography, determining the outcomes of processes, etc.
2. To use the larger tools of the lab – such as microscopes, e-beam evaporators, etc., you must have a user account that grants access to the tool. This ensures that you have the safety training and user clearance to use any specific tool in our inventory. To get access on your lab account, you meet with the director or deputy director to schedule training sessions or a checkout. Once you have clearance, go to our website www.wake-nanotech.org and click on the ***schedule a tool*** link:

https://labshake.com/sign-in?next=http%3A%2F%2Flabshake.com%2Fuser%2Fmylab

3. Then all you do is use the tool at the time you have scheduled and pay your bill at the end of the month. A few things that should be noted:

- Like usual NanoteQ can provide *people*-help for your project. You must schedule this ahead of time with the technical staff member you want. The cost for a staff member's help as well as for tool time is listed on the website and is subject to yearly review.
- NanoteQ will provide aid to tool users that have not budgeted for some specific use, but has a clear need for an instrument. We can help you if you are getting preliminary data for some proposal or working toward a demonstration that can lead to potential funding at Wake. Just tell us and we will help.
- NanoteQ requests acknowledgement of facility use on publications and presentations. Some wording can be found on the website, but you may certainly use your own as well.

The NanoteQ Mission

Taken from the planning document of NanoteQ strategic plan

We have Arrived?

The NanoteQ facility has grown to become competitive with the capabilities of many of our overlap schools: Duke, Vandy, Emory, Tufts, Boston College, and Dartmouth. As a research center, NanoteQ is beginning to fulfill the goals for which it was created, to bring infrastructure and capabilities to the WFU campuses in the area of nanosciences. Now, with a new administration and a new strategic framework around which to build, where do we take this facility and its capability? What are our next steps? What are our long-range plans for NanoteQ and how do they speak to a vision of WFU among the top research universities in the nation?

The Future Challenge

The last two decades has seen the emergence of technologies with disruptive potential on a planetary scale. As the pace of this technological development continues to quicken it challenges our ability to understand its impacts and its opportunities. Yet this innovation, driven by new modalities in multidisciplinary collaborative development, has given rise to surprisingly novel avenues of thought and it represents exciting new possibilities for mankind to live sustainably, to grow into more equitable societies and to address threats to our survival.

But it is the rate and reach of today's innovation that defines a creative environment and sets the stage for future transformative technological advancement. With breakthroughs in nanoelectronics, AI and machine learning, quantum information sciences, restorative and regenerative biotechnologies, green-worlds tech, human-technology interfaces, and advanced manufacturing, we face a revolution in *how* we innovate and *how* we create. This will reshape our world, transform our economies, and establish industries and communities in ways we could have never imagined. Our technologies are quickly becoming inextricably linked with *who we are* as people; our ethics, our morals, the so-called *human condition*.

The If/Then World

If Wake Forest University is to remain relevant in this new world, if it is to train leaders of the new economies and citizens of the new communities, and if it will contribute scholarship to the development and implementation of new technologies, then it will be required to adopt and embrace a deeper engagement with frontier tech. Wake must lead by doing, it must become an integral and undeniable part of the world-conversation.

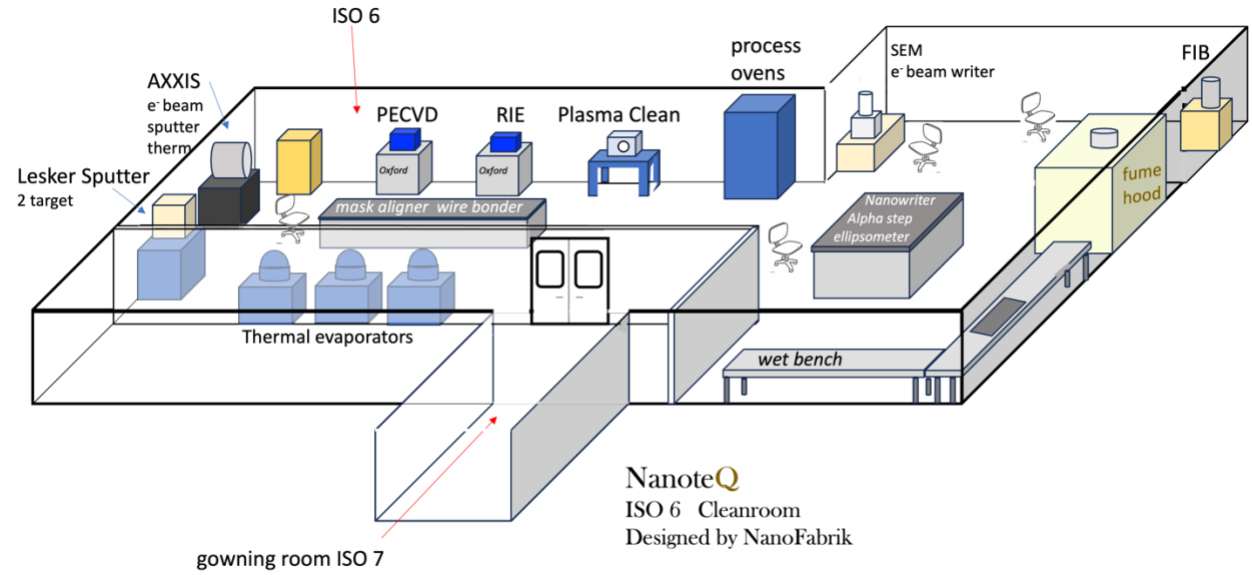
A New Horizon

The WFU research community now has a significant resource for advanced scientific investigations into the promises of this revolution: NanoteQ. But we must do more if Wake is to have a part in this world-wide re-alignment. NanoteQ must evolve toward an instrument that fosters deeper campus awareness and understanding of this new environment and its technologies. We must promote greater collaboration among the disciplinary silos, we must use innovative approaches to understand how new technologies impact world societies. We must create an ecosystem of innovation and discovery around these rapidly evolving frontier technologies and lead in key technology areas beginning with: Quantum Machines, AI, Green Worlds, and Restorative Biotech.

NanoteQ will continue to develop and provide access to state of the art research capabilities through laboratory user facilities as a resource for individual researchers across Wake's campuses. This follows the vision of central facilities used everywhere. But unlike those facilities, NanoteQ will build upon its enablement. It will begin by building communities through promotion of discourse in conferences and courses. It will lead new efforts to support collaborative groups of researchers through grants and donations. And its technological innovations will fully embrace the changing nature of the human condition by using multi-disciplinary modalities in building its research teams. NanoteQ will replace the traditional approach of the "central facility" and "research center" with a more purposeful vision of ecosystem development.

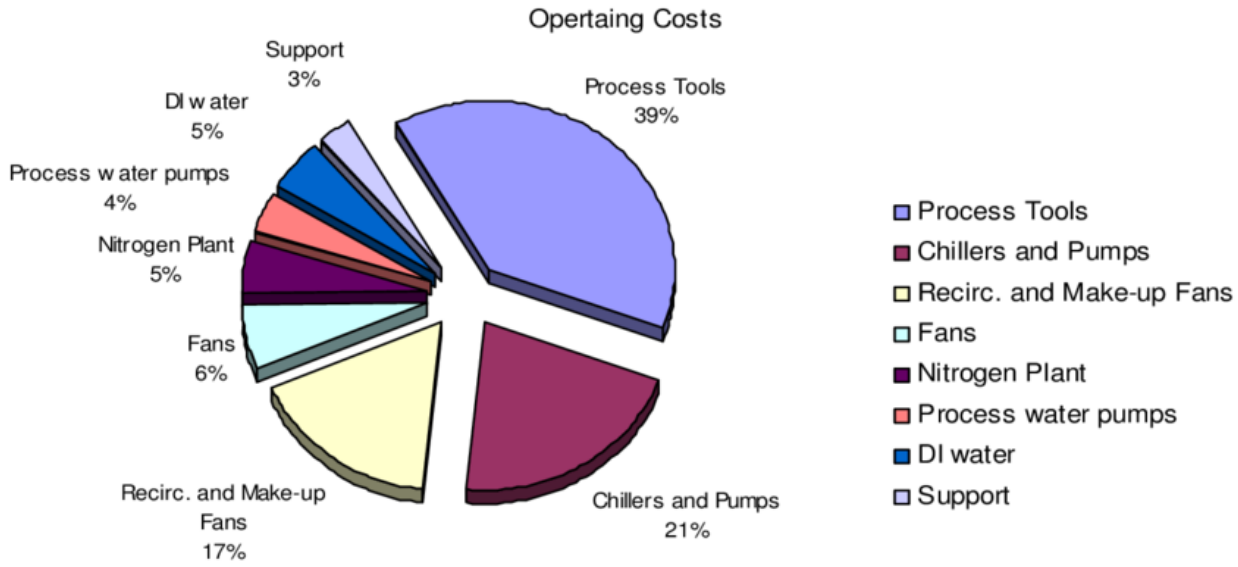
These are big plans, and a bold course. We must find resources, we must provide leadership, and we must see Wake for its possibilities. We are going to re-imagine ourselves as a laboratory, *cut from the same cloth* as the Institute for Advanced Studies, the Applied Physics Lab, the Frontier Technology Lab, or the Media Lab, perhaps smaller but with the same aspirations. Over the coming semester, NanoteQ leadership will be reaching out to users, members, stakeholders and administration to develop a 10 year roadmap that will guide our evolution and integrate us more completely with the long term strategic goals of the University. We are confident that voices from across our university will help us to make NanoteQ a more inclusive and meaningful part of the Wake Forest experience.

A new type of cleanroom



The research at NanoteQ requires a cleanroom. We have operated at the 501 Deacon site for many years with a cleanroom that a modified and rigged series of air cleaners and air handlers. At the new site the cleanroom has been specifically designed for its purpose.

The Wake Cleanroom (also referred to as RM98) has 1000 sq ft. of ISO 6 working space with 500 sq ft of ISO 8, plus 1500 sq ft of mechanical room to handle the airflow and other necessities making a total of 3000 sq ft. Unlike the popular clean-chase design used at many universities, essentially the NanoteQ cleanroom is a cleanroom inside of a pressurized cleanroom. Its airflow system is designed for the monitoring and management of air velocities within the whole room volume based upon side-wall and ground level, laminar removal and directed HEPA filtered overhead plenums. This does limit equipment placement and the total number of users at a given time, but it also allows for easy upgrades to ISO 5 (class 100) later on should we need it.



The Wake Cleanroom is smaller than the facilities at Vandy and/or Duke for example. However, Wake estimates a steady user base of 5 faculty groups (around 15 people) plus 5 external users (around 10 people) per year. Costing a cleanroom can be tricky and it depends on the size and number of people using the room as well as its ISO class.

Levelized costs for running Wake's ISO 6, 1000 sq ft room, (filter exchanges, water and power use, cleaning and monitoring), can be estimated using the graphic (Energy Analysis, Diagnostics, and Conservation in Semiconductor Manufacturing by Yogesh Mardikar, thesis West Virginia University) based upon expected user load of 25 people. To do this, estimates of how long people will work, the number of times they enter and leave the room in a day, number of changes of gowning, etc. must be made. This is added to utilities breakdown from the chart to get a complete hourly run rate of $10/1000 sq ft. 8760 hours/year gives a full cost of roughly $88,000/year for operations. (this is nearly twice the cost of the rest of the lab per square foot but far less than the nearly $100/1000 sq/ft per hour of an ISO 4). The costs include equipment maintenance, power, water, DI water, chillers, air handler operations, inspections and monitoring, gowns, and so forth. It does not include major equipment repair which runs approximately $20,000/year on average from historical records. Repair costs and many of the hourly operating costs such as gowning are handled as needed and varies strongly with user number. Notice though that the Vanderbilt cleanroom which has triple (EST) our number of users but is nearly 6000 sq. ft. of workspace (10,000 total sq. ft.) is closer to $ 530,000/year to operate. This is: $7040/person (Vandy) vs. $3520/person (Wake) each year in costs. By allowing us to charge less per person per year for use, we make facilities available to more users with no loss of functionality.

Much of the process equipment has been through grants and/or donations to the university. We wish to thank the forward-looking sponsorship of Quoherent Inc. International Technology Center, AFOSR, Data-Max Foundation and Yazaki Corporation. A complete cross comparison for the age, functionality, and cost to operate the process equipment at Wake vs. our overlaps is available upon request.

The key capabilities of the Cleanroom are:

***i*-line lithography:** This uses 365 nm light, a mask aligner (Karl Suss) with a contact mask, developer and fixer, and e-beam (Kurt Lesker) or otherwise evaporated metals to create a pattern on a substrate (usually Si). Its resolution is about 0.5 microns

FIB: This technique uses focused ion beam of Gd along with a background gas to create patterns on substrates like Si or GaAs. The FEI 400M system at NanoteQ can be used to cut TEM samples, mill nanostructures into Si, or lay down metal lines for circuits. The resolution is about 200 nm.

e-beam lithography: NanoteQ uses a Nabity system attached to a Zeiss Supra 25. Using a resist in analogy to the optical lithography, the ebeam write the pattern desired into the resist and then a lift and process procedure is used to create the pattern. Again, this is typically coupled with e-beam evaporation of AC sputtering. Typically, this system can achieve line resolutions of about 10 nm. Because we are using a Nabity instead of a Wraith or JEOL JXN, patterns are limited to 4 inch wafers.

Pattern refinement: the cleanroom has plasma ashing/etching (Hummer X) and reactive ion etching (Oxford PlasmaLab 80+ RIE system), capabilities. These are used to clean substrates before patterning, and to refine the pattern after liftoff or resist removal.

Heterogeneous integration: the cleanroom tools also include an Oxford PlasmaLab 80 PECVD system that allows for the addition of epitaxial think films for dielectrics into Si circuits. For multistep fabrication processes this can be essential.

Exciting New Research from the Facility

Solution-based iron doping of solvothermally grown 2D hexagonal bismuth telluride by Gabriel E. Marcus, Timothy W. Carlson, Kadaba Swathi, David Carroll APL Mater. 12, 081102 (2024)

This work identifies distinct magnetic phases using MFM, in the structure of this Fe doped 2D topological insulator. The introduction of such time-symmetry-breaking dopants has been of major interest to the condensed matter community. But the formation of new magnetic phases is surprising.