2024 Volume 1

NanoteQ News

Senior Editor Lindsey Gray
Lindsey is a graduate student in physics working at NanoteQ. She is now finishing her dissertation (grad date '24) and has specialized in novel solar technologies for use in extreme conditions. In March Lindsey leaves to take an ORISE Postdoctoral Fellowship at the U.S. Department of Homeland Security Transportation Security Laboratory in New Jersey.

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The return of NanoteQ News

NanoteQ News - formally *Nanotech News* – is a news and information service of the Center for Nanotechnology and Quantum Materials – formally the *Center for Nanotechnology and Molecular Materials* – at Wake Forest University. It is written and edited by faculty, postdocs, and students with a graduate student acting as senior editor. The senior editor position rotates yearly among interested graduate students and is used as an opportunity for experiential learning with the involvement of a faculty mentor.

NanoteQ News will be produced four times a year – roughly equivalent to its previous cycle and contains news of the research community, at WFU and outside, that is relevant to ongoing WFU initiatives in materials research, quantum computing, quantum devices, organic devices, etc. Inquiries and topical requests can be made to the Senior editor by anyone within the WFU community. Submission of news items for inclusion in the Newsletter is encouraged. There are no length requirements or content requirements but NanoteQ News reserves full editorial and publication rights to submitted materials.

Finally, you are likely receiving this copy of NanoteQ News because you are in a natural sciences or engineering department at WFU, you are affiliated with research in such a department, or you are affiliated faculty. If you wish to be removed from our mailing list, you will find the link to do so at the end of the Newsletter.

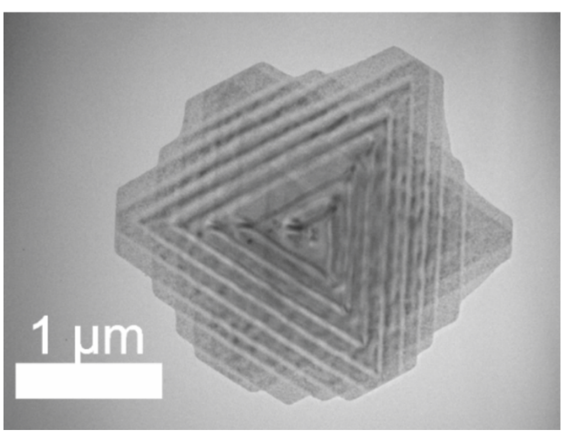
What is in a Name?

You may have noticed that Nanotech is now NanoteQ. The Center for Nanotechnology and Quantum Materials highlights our growing efforts and emphasis on quantum engineering and sciences, new programs in quantum materials, and broadening capabilities of the Center in these critical areas of research growth. That is not to say NanoteQ no longer engages in other activities. A quick look through our website (https://www.wake-nanotech.org) shows that our reorganization now emphasizes three main areas of research that the tools of NanoteQ may "impact." These include: Biomedical, Organic devices and wearable/conformal electronics, and quantum engineered devices. But, of course, with over 30 faculty and staff as regular users at NanoteQ, there are many things going on. We encourage anyone working within these length scales to look around our user pages and see if we can be of use to your research.

What's with that squirrel?

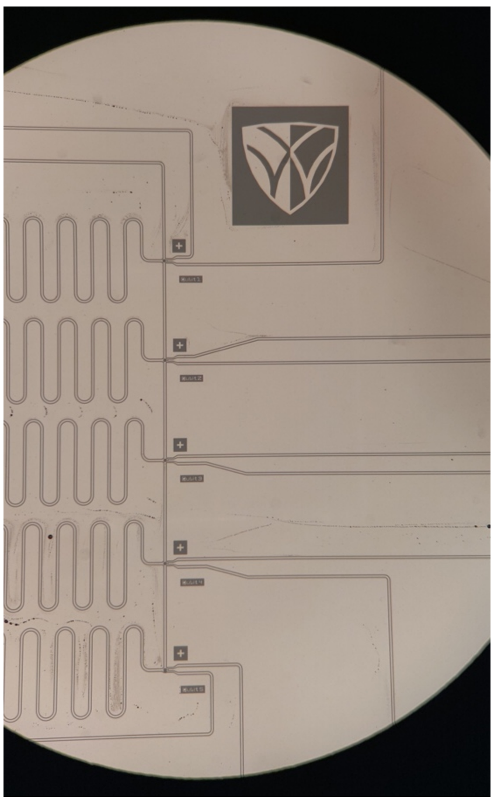
Aren't we all Demon Deacons? Yes, indeed we are. However, over the years the students and staff of NanoteQ have become rather fond of the large squirrel population that inhabits the woodland surrounding our building and sometimes our building itself! So, the Deacon Squirrel has become a regular part of NanoteQ visual identity. If you have ever visited or worked at 501 Deacon, you may have been scared late at night by him, chased by him, perhaps even bitten by him, but certainly you will recognize him. Fortunately, the squirrel intrusions are not so frequent or wide spread as to harm equipment or contaminate the cleanroom.

Quantum Engineering News

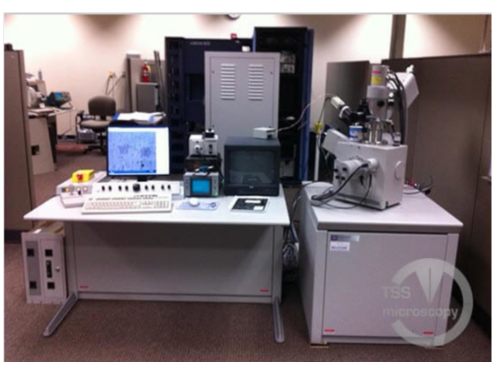


WFU's NanoteQ Center continues to build its capability in the creation of quantum engineered devices. These are devices and circuits – usually built on Si, SiNx or SiCx substrates – that exhibit quantum coherence and quantum behaviors in their function. A key example of this is the creation of a new type of Qubit that is based on a chiral topological insulator crystal with reflection symmetry. This crystal allows for the existence of robust topological quantum states along its perimeter and these states can be extremely long lived even at room temperature. That is, they are robust against perturbations from the local environments due to strong symmetry conditions. In fact, the perimeters of these crystals form what is essentially a Mobius strip. Due to a reflection plane in the center of the crystal, two persistent currents are formed based on charge-parity conservation laws. There are specific relationships between these two currents that constitute unique quantum states. And these, it is believed, can be used for quantum computation.

However, to use the crystals in such a way, a system must be designed to measure the quantum states. The QCWG team (https://www.qcwg-wake.online) and collaborators have decided to utilize the solution that IBM, and Google have taken from Yale, the quantum electrodynamic circuit. In the QED circuit, 3 Ghz photons are launched into an oscillator system that allows for coupling into the quantum crystal only under specific state conditions. This constitutes a quantum measurement and allows the useful transmission of information within the system. However, building such systems can be a precise and taxing endeavor. Dimensions and materials purity must be exact. Contacts, grounds, and shielding must all be carefully designed and built.



Over the past two/three years the cleanrooms at WFU have slowly been accumulating the capabilities and expertise in the creation of such exotic circuits and characterization of their bizarre physics (see for example: https://iopscience.iop.org/article/10.1088/1367-2630/ab9f6c). For 2023, thanks to sizable donations of capital and equipment by Streamline Automation LLC in Huntsville Al, and the International Technology Center in Raleigh NC, NanoteQ’s cleanroom has grown significantly.



Added this year has been:

1. A Focused Ion Beam (FIB) system (FEI)

2. A JOEL field emission SEM with NPGS for e-beam lithography

3. An Oxford Plasma 80 + reactive ion etcher

4. An Oxford Plasma 80 + plasma enhanced chemical vapor deposition system (PECVD)

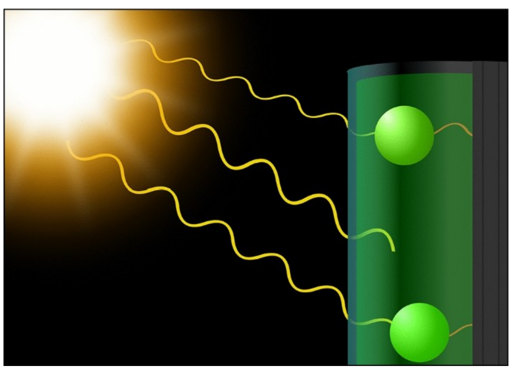
5. A Janus 300 mK cryostat with 12 Tesla magnet for low temperature transport measurements

6. Updates to our wire bonder, mask aligner, and probe station Updates to our low temperature STM system

7. New particle counters for the clean room together with new ceiling gasketing and entrance filters

Together with the capabilities already in place, NanoteQ has been able to create sophisticated, additive – fabrication, 5-qubit registers as seen above. These represent the first fully functional quantum engineered computational devices created at WFU. They are currently being tested by collaborators off site as well as at our own labs.

Saving the Planet News



Naturally, quantum device fabrication is not the only thing going on at NanoteQ. Work in *conformal systems* was featured in 2023 in the MRS Bulletin – the official publication of the Materials Research Society. This research focused on the development of a thermal – photovoltaic hybrid power collector. The system combines the strengths of thermal collectors used for hot water production from the sun and photovoltaics which produce electricity directly from solar radiation. The key innovation in this work was the use of 3D optical collectors and Stokes shifting dyes that allow for an efficient partitioning of photons in the system – a sort of thermal version of spectral splitting. This makes the solar collector more efficient than their Si equivalents and far cheaper to make than the multijunction systems used in top of the line spectral splitters. (https://link.springer.com/article/10.1557/s43577-022-00444-w)

This work is a part of a broader effort to understand the ramifications of Onsager Entanglement (OE). OE occurs when multiple heat engines are coupled together effecting the efficiency of each other. In doing so Carnot limits to heat scavenging in these systems can apparently be circumvented but in actuality such systems are still perfectly consistent with nonequilibrium thermodynamics.

In BioNanoMedical News

At the end of 2023 NanoteQ announced the discovery of a new type of ionic conductor. In these new materials an interplay between ion mobility within the layers of 2D chalcogenides and thermoelectric currents due to applied temperature gradients leads to large ion fluxes. This work is thought to be the initial steps in the creation of natural ion pumps for biomedical applications. What is envisaged are devices to be embedded within the body and that derive their power from the body's own metabolism. Imagine insulin pumps, filtration systems and more all based on such principles. The work is currently in press.

Announcements

PHY 354/654 Quantum Computing to be offered in Spring 2024. Quantum Computing for Beginners is an introduction to the foundations and hardware of Quantum Computers. It covers basic algorithms, the theory of Qubits and registers, gate structure, and the physical systems that have been achieved. Course format is lecture with a lab taught in Qiskit.

PHY 656 Electron Microscopy to be offered in Fall of 2024. An introduction to the basic theory and practice of electron microscopy. The course is taught in a combination lecture/lab format and runs for 1/2 a semester. Lab reports are the only graded components. Full attendance is required.

Book Review

Fundamentals of Quantum Computing: Theory and Practice
by Venkateswaran Kasirajan | Jun 23, 2022

Andreas Wichert, zbMATH 1477.68005, 2022 said "The book represents a new and fresh approach to quantum computing, starting with theoretical physical knowledge that is highlighted by beautiful figures. Then, quantum computing is explained by quantum programing languages and extensive languages. It is recommended to everyone interested in quantum computing. It is easy to follow through a beautiful and clear presentation, programming examples and additional exercises."

From the Back Cover

"This introductory book on quantum computing includes an emphasis on the development of algorithms. Appropriate for both university students as well as software developers interested in programming a quantum computer, this practical approach to modern quantum computing takes the reader through the required background and up to the latest developments.

Beginning with introductory chapters on the required math and quantum mechanics, Fundamentals of Quantum Computing proceeds to describe four leading qubit modalities and explains the core principles of quantum computing in detail. Providing a step-by-step derivation of math and source code, some of the well-known quantum algorithms are explained in simple ways so the reader can try them either on IBM Q or Microsoft QDK. The book also includes a chapter on adiabatic quantum computing and modern concepts such as topological quantum computing and surface codes.

Features:

o Foundational chapters that build the necessary background on math and quantum mechanics.

o Examples and illustrations throughout provide a practical approach to quantum programming with end-of-chapter exercises.

o Detailed treatment on four leading qubit modalities -- trapped-ion, superconducting transmons, topological qubits, and quantum dots -- teaches how qubits work so that readers can understand how quantum computers work under the hood and devise efficient algorithms and error correction codes. Also introduces protected qubits - 0-π qubits, fluxon parity protected qubits, and charge-parity protected qubits.

o Principles of quantum computing such as quantum entanglement, no-cloning theorem, quantum teleportation, quantum interference, superdense coding, quantum parallelism, and adiabatic quantum computing."

This book is written as a text to introduce quantum computing. To begin the basics of quantum concepts are covered. These are needed to understand quantum computing, later, but the first chapters seem muddled and unclear. More of a hodgepodge of concepts as opposed to a clear and clean statement of quantum facts. Fortunately, the rest of the text doesn't follow this example.

The mathematics of quantum comes next and these chapters are very clear and well written. Vector and matrix algebras as well as the concepts of operators are covered quite well here.

Construction of operators into gates and gates into the flow of an algorithm is also well described in the text. However, many of the standard algorithms are described in various quantum computing schemes/languages. It is truly unfortunate that Qiskit was not used since it is among the most natural quantum computing schemes for the beginner. Qiskit and its fantastic support resources online is the natural programming language to teach beginners. This seems to be an indication that the author here is a computer scientist, not a physicist.

Some attempt is also made at description of hardware and the major approaches to the construction of quantum machines. Again, the details here are quite weak. It is true that registers are described for a number of qubit types, but little is said about the quality factors of the systems, how they are programed, and how they create superposition and entanglement. This is clearly not an experimentalist writing the text.

Finally, the author does a very good job of detailing error and error codes.

Overall, this text is an acceptable textbook and a good attempt by a computer scientist to describe the way quantum information theory works in the lab. Its short comings stem from too little contact with the physics and a lack of detail of how the device might actually work, something that most readers find fascinating.

4/5 Stars

Breaking News

KF-99 room temperature superconductors are back…

https://arxiv.org/pdf/2401.00999.pdf

If you have been keeping up with this story you will know that the announcement last year of a room temperature superconductor by a Korean research group met with controversy. Following this a distinct failure to replicate the work fully added significant doubts to the claims.

But now:

A team of researchers report replication experiments that suggest a copper-substituted lead apatite (CSLA) could serve as a candidate for room-temperature superconductivity.

These results are intriguing, but a lot more work is needed for this extraordinary claim.

And we remember that this entire conversation is taking place through Arxiv and on You tube. So, let's not get too excited just yet.