OAK RIDGE NATIONAL LABORATORY

Breakthroughs in Quantum Computing, Materials, Networking, and Sensing

Advances in computing, sensing, and networking technologies have defined the last half-century of technological progress. An enhanced understanding of the laws of quantum mechanics is now enabling a quantum revolution that promises to transform a vast range of technologies critical to American competitiveness.

Oak Ridge National Laboratory (ORNL) stands poised to lead the way to the quantum future.

With diverse capabilities to support materials synthesis, fabrication, and characterization, ORNL researchers are exploring new approaches to storing, measuring, and transferring information via four primary capabilities: quantum computing, quantum materials, quantum networking, and quantum sensing.

This effort requires multidisciplinary teams capable of

- synthesizing, characterizing, and measuring properties of quantum materials;
- developing sensing techniques to reduce quantum noise; and
- designing quantum algorithms for use on quantum devices aimed at tackling challenges of importance to the US Department of Energy.

113
Publications in 2022

>30
Full-time staff

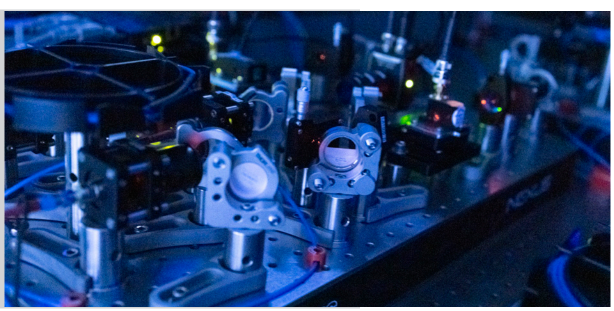
200+
Users in Quantum Computing User Program

20+
Years of programmatic QIS research

Computing

Computing serves an important role in scientific discovery and innovation, and quantum computers are expected to accelerate these capabilities well beyond today's leading systems. The lLaboratory's quantum computing effort is leveraging partnerships with academia, industry, and government to accelerate breakthroughs across the quantum computing spectrum.

Optical tables and ion trap chamber in an ORNL quantum laboratory.



"ORNL's diverse quantum expertise makes it the ideal institution to lead the next quantum revolution."

—Quantum Information Science Section Head and Distinguished R&D Staff **Nick Peters**

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By investigating promising quantum hardware architectures and software applications via experiment, theory, and simulation, ORNL researchers are enabling new paradigms of information processing. This effort requires multidisciplinary teams of computer scientists, physicists, and engineers working in concert to advance the field. In partnership with the Oak Ridge Leadership Computing Facility, the Laboratory's Quantum Computing Institute hosts the Quantum Computing User Program to provide early access to existing commercial quantum computing systems while supporting the development of future quantum programmers through educational outreach and internship programs.

Materials

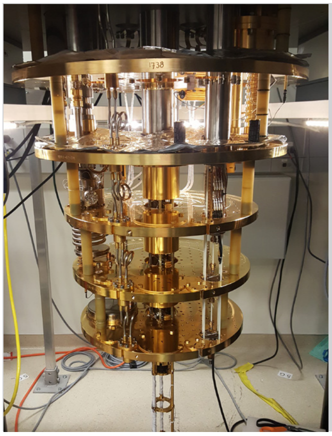
Materials have always dictated the progression of technology, and a new generation of quantum materials may well usher in the next great era of innovation. To accelerate discovery and predictive understanding of these materials, researchers leverage Laboratory leadership in high-performance computing, neutron scattering, condensed matter sciences, and data analytics. These capabilities, along with specialized facilities, strategic internal investments, and decades of experience exploring quantum materials, are enabling lab staff to explore a range of candidates, from graphene to quantum spin liquids, across a range of applications.

Networking

Quantum networks are capable of connecting resources across distance scales, from nearest-neighbor interactions between microscopic qubits to far-off satellite transmissions. The Laboratory's scientists and engineers are leaders in the development of quantum networking technologies, including quantum communication, quantum key distribution, and quantum repeaters.

Through ORNL's quantum-based cybersecurity research, Laboratory's staff have established a robust portfolio of more than a dozen quantum networking–related inventions that are available for either research or commercial license. In particular, ORNL has state-of-the-art laboratories with the following resources:

- Entangled photon sources
- Quantum key distribution
- Superconducting single-photon detectors
- Homodyne single-photon detectors
- Telecom quantum frequency processing and conversion
- Local dark-fiber network test bed for quantum communications experiments
- Quantum random number generators



A dilution refrigerator run by the Quantum Information Science group. This refrigerator operates at a base temperature of roughly 10 mK and includes optical and scanning probe microscope heads for material and device characterization at low temperatures.

Sensing

Characterizing quantum technologies requires exquisite control and advanced sensing techniques. ORNL researchers are using their expertise in quantum information and sensing to gain improvements over classical sensors and optimize a new class of quantum sensors. The Laboratory has dedicated research staff tasked with reducing quantum noise and controlling and correcting errors inherent in quantum systems, both of which are critical to advancing a range of quantum technologies, from computing to information transfer to imaging.

Sensing techniques developed in ORNL's state-of-the-art quantum optics labs have found applications in improving measurements in ORNL's other facilities, including the Institute for Functional Imaging of Materials and the Center for Nanophase Materials Sciences.

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