CHICAGO QUANTUM EXCHANGE

A growing intellectual hub for the science and engineering of quantum information

2020

THE FULL IMPACT OF QUANTUM TECHNOLOGY IS BEYOND OUR IMAGINATION.

IT'S ALSO WITHIN OUR REACH.

CHICAGO QUANTUM EXCHANGE MEMBERS

THE UNIVERSITY OF CHICAGO

Argonne NATIONAL LABORATORY

Fermilab

ILLINOIS

WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

Northwestern University

CHICAGO QUANTUM EXCHANGE STEERING COMMITTEE

David Awschalom
Liew Family Professor of Molecular Engineering, UChicago; Senior Scientist, Argonne; Director of the Chicago Quantum Exchange

Supratik Guha
Senior Scientist/Senior Advisor to Physical Sciences & Engineering, Argonne; Professor of Molecular Engineering, UChicago

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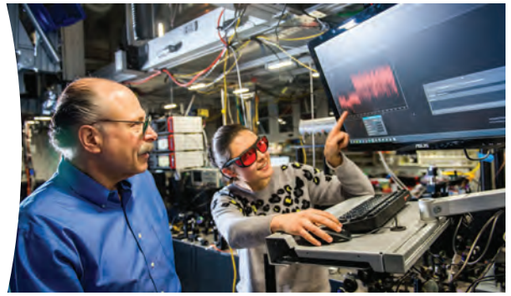
Fermilab Deputy Director and Chief Research Officer

Dale Van Harlingen
Donald Biggar Willett Professor, College of Engineering, University of Illinois at Urbana-Champaign

CHICAGO QUANTUM EXCHANGE

With today's technology, we can now harness quantum physics in a way previously impossible, and the world is racing to unlock quantum's potential. But we still need fundamental and applied research to fully understand and control objects at the very smallest scales—and to drive new discoveries that will have far-reaching applications.

The Chicago Quantum Exchange connects the leading academic talent in quantum research, the top scientific facilities in the region, and the most innovative industry partners in the world around the shared goal of advancing the science and engineering of quantum information. This growing intellectual hub is the nation's leading center for research in quantum information and for training the quantum workforce of tomorrow.



QUANTUM'S HEADQUARTERS

With its world-class universities, researchers, and lab facilities, Chicago is a prime destination to explore and drive the future of quantum information science. The Chicago Quantum Exchange comprises more than 130 researchers across the Midwest, plus international, industry, and non-profit partners, making it one of the largest collaborative teams working on quantum science in the world.

ACCELERATED GROWTH

The Chicago Quantum Exchange began as a partnership between the University of Chicago, Argonne National Laboratory, Fermilab, and the University of Illinois at Urbana-Champaign. Since then, the University of Wisconsin–Madison and Northwestern University joined as partners and in 2019, the CQE welcomed seven industry partners; its first two international partners, QuTech and the Centre of Excellence for Quantum Computation and Communication Technology at UNSW; and two non-profit partners, the Quantum Economic Development Corporation (QED-C) and P33.

P33 QuTech QED·C CENTRE FOR QUANTUM COMPUTATION & COMMUNICATION TECHNOLOGY AUSTRALIAN RESEARCH COUNCIL CENTRE OF EXCELLENCE

$65M+
FEDERAL FUNDING TO CQE MEMBER INSTITUTIONS IN 2019

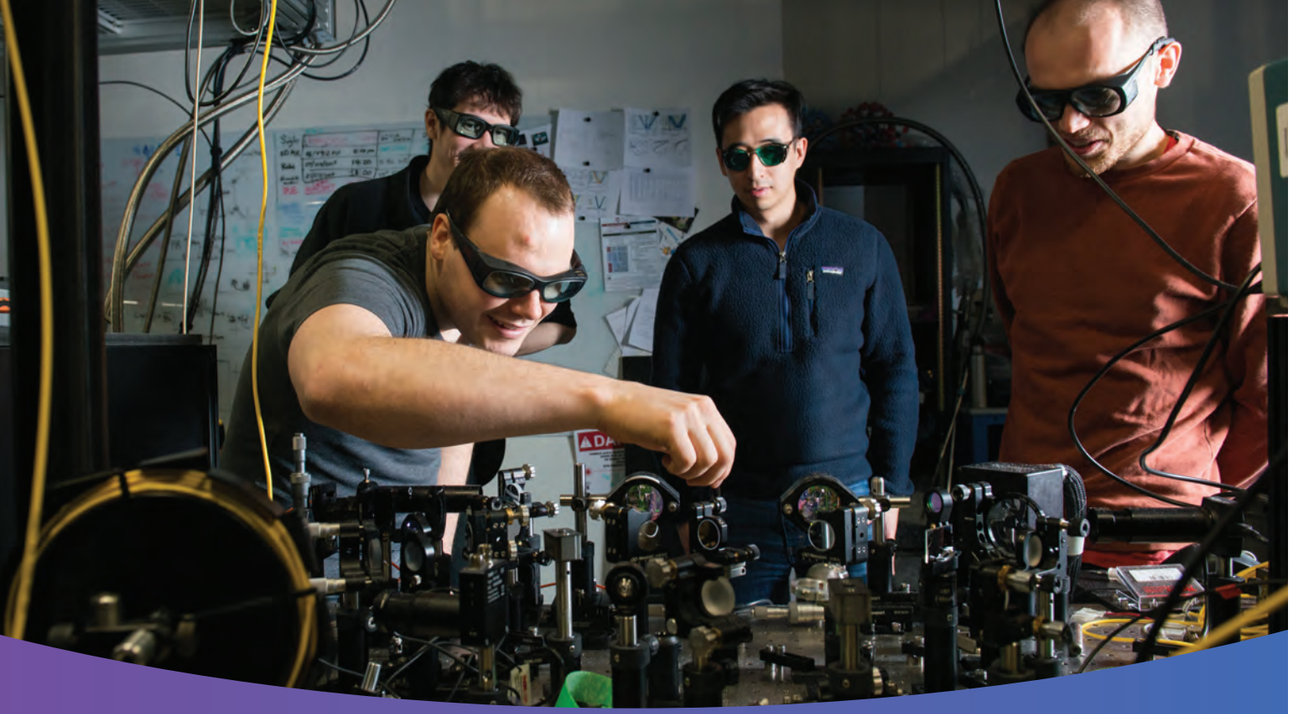
130+
RESEARCHERS

6
MEMBER INSTITUTIONS ACROSS THE CHICAGO AREA

7
INDUSTRY PARTNERS

7
MEMBER AND PARTNER WORKSHOPS IN 2019

53
TOTAL EVENTS IN 2019



BRIDGING ACADEMIA, INDUSTRY, AND GOVERNMENT

Unlocking the potential of quantum information science requires immense intellect, vast resources, and diverse areas of expertise. The Chicago Quantum Exchange answers this need by facilitating collaboration, joint projects, and information exchange among private and public universities, national laboratories, and industry partners.

INDUSTRY ENGAGEMENT

Together, Chicago Quantum Exchange members and industry partners focus on developing new understandings of the rules of quantum mechanics that govern the behavior of particles at the smallest scales, and applying those discoveries to new types of devices, materials, and computing techniques. The CQE and its partners collaborate on research efforts and on creating career pathways for the quantum workforce of tomorrow.

BOEING · rigetti · Quantum Opus · ColdQuanta · HRL LABORATORIES · APPLIED MATERIALS make possible · IBM

PARTNER SPOTLIGHT

Boeing supports collaborative research with CQE member institutions and industry partner HRL. Boeing's Disruptive Computing & Networks organization works on quantum communications and computing, as well as neuromorphic processing and advanced sensing.

EVENTS

Chicago Quantum Exchange events bring together experts from around the world and across disciplines to advance the field.

CHICAGO QUANTUM SUMMIT

For the second year, the Chicago Quantum Exchange gathered more than 120 scientists, engineers, and members of industry from around the world to discuss the latest research and promising paths forward for the field. Attendees included CQE members and partners as well as leaders from Congress and companies including Intel and Toshiba.

WORKSHOP ON ETHICS OF QUANTUM AND AI

The Chicago Quantum Exchange held a workshop about the ethical and societal impacts of artificial intelligence and quantum computing technologies. Participants from physicists to sociologists discussed the implications of technology on society and vice versa and identified critical steps for developing and implementing technology in an ethical and responsible way.

QUANTUM COMPUTING SUMMER SCHOOL

The Chicago Quantum Exchange co-sponsored the 2019 Illinois Quantum Computing Summer School with the Discovery Partners Institute and IQUIST at the University of Illinois at Urbana-Champaign. The program offered theoreticians who have some background in classical computing an immersive educational experience for learning the basic principles and current applications of quantum computing.

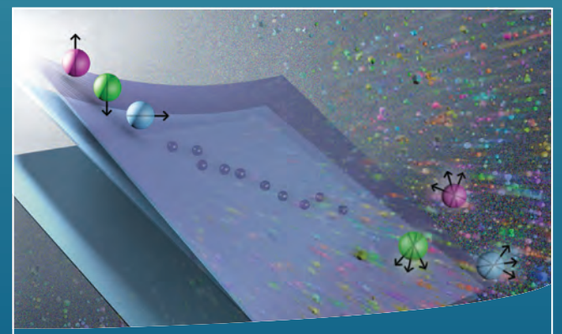
CONNECTING THE WORLD'S INTELLECTUAL TALENT

The Chicago Quantum Exchange builds connections and collaborations with top experts around the world. In 2019, two organizations, Europe's QuTech and the Centre of Excellence for Quantum Computation and Communication Technology at the University of New South Wales in Australia, joined the CQE as its first international members. This expansion further establishes the CQE's position as one of the largest collaborative teams working on quantum science in the world. QuTech is a partnership between the Delft University of Technology and the Netherlands Organisation for Applied Scientific Research. The new partnerships significantly increase the resources and talent available to CQE members in pursuit of advancing quantum computing, communication, and sensing.

For upcoming CQE events, visit **chicagoquantum.org/events**. To learn more about our partners program, email **quantum@uchicago.edu**.

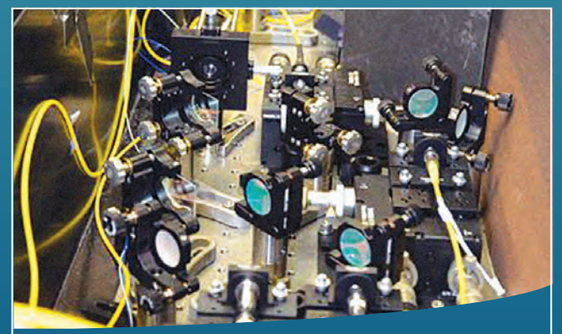
ADVANCING RESEARCH, DISCOVERY, AND IMPACT

Quantum information science will enable computers to solve problems in seconds rather than centuries, doctors to detect cancer in a single cell, and sensors to recognize earthquakes before they begin. The future impact of quantum science and engineering relies on the research and discoveries happening at institutions today, including these by members of the Chicago Quantum Exchange.



ARGONNE RESEARCHERS DEVELOP NEW METHOD TO REDUCE QUANTUM NOISE

Researchers at Argonne National Laboratory reported a new method for alleviating the effects of "noise" in quantum information systems. A research group led by Matthew Otten and Stephen Gray developed a technique that recovers information lost due to "decoherence"—a loss of information on quantum hardware, like computers—by repeating the quantum process many times with different noise characteristics and analyzing the results, which can be applied to reduce quantum noise. The new method has implications for the future of quantum information science, including quantum computing and quantum sensing.

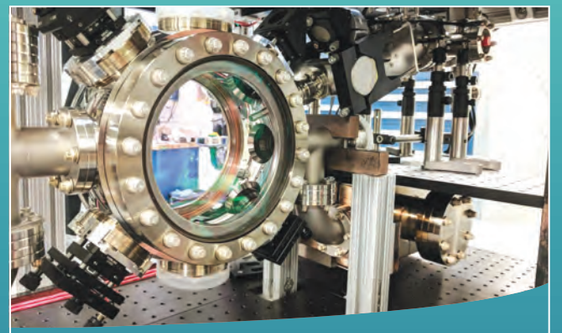


RECORD SET FOR SINGLE-PHOTON PRODUCTION EFFICIENCY

The research group led by physicist Paul Kwiat at the University of Illinois at Urbana-Champaign built an apparatus that can produce single photons about 500,000 times faster than the world's best competing experiment to date, cutting the time from about two minutes to two microseconds. With planned upgrades, the apparatus could generate 30 photons at unprecedented efficiencies. Developing a source that can efficiently and reliably produce single photons is key to advancing research in quantum information science, as single photons make an excellent resource for applications in quantum computing and communication.

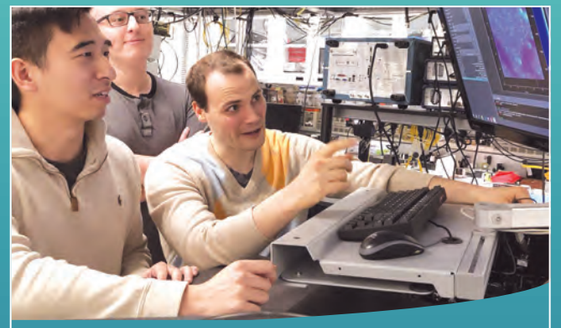
THE FIRST QUANTUM TELEPORTATION VIA CHEMICAL REACTION

Northwestern University researchers led by chemist Michael R. Wasielewski discovered how to move quantum information on the nanoscale through quantum teleportation, the transfer of quantum information from one location to another. The group was able to teleport information across a molecule using an electron transfer mechanism, which has never been achieved before. This discovery demonstrates the role chemistry can play in quantum information science and has implications for computing and communication as well as sensing, such as refining the scale on which a magnetic field can be sensed.



INCREASING THE QUANTUM STATE OF ATOMS

Fermilab's new 100-meter Matter-wave Atomic Gradiometer Interferometric Sensor, or MAGIS-100, will be the world's largest atom interferometer and push the boundaries of how far an atom can be driven apart from itself, and for how long. The team anticipates they can at least triple the current record of 54 centimeters in length and increase the time from around two seconds to between five and ten. In the experiment, scientists will drop groups of atoms down a vacuum tube, followed by laser light, aiming to reveal the presence of ultralight dark matter particles. This will set the groundwork for a larger experiment that could detect gravitational waves at a lower frequency, giving us more advance notice of a black hole merger.

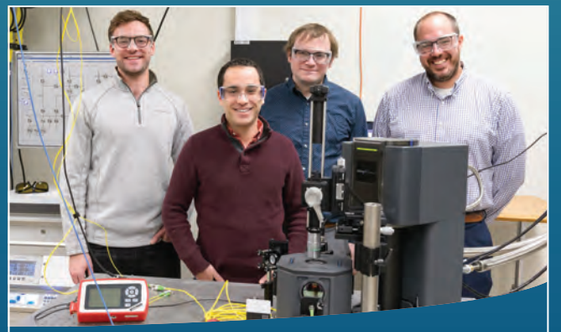


SCIENTISTS CREATE QUANTUM STATES IN EVERYDAY ELECTRONICS

University of Chicago scientists led by David Awschalom discovered a way to integrate and control quantum states in common electronic devices made from silicon carbide. The breakthrough could offer a means to more easily design and build quantum electronics. The ability to integrate quantum mechanics with well-developed classical semiconductor technology is a milestone toward creating systems capable of storing and distributing quantum information across the world's fiber-optic networks, which could allow for the creation of unhackable communication channels, the teleportation of single electron states and the realization of a quantum internet.

ACHIEVEMENTS IN QUBIT SCIENCE

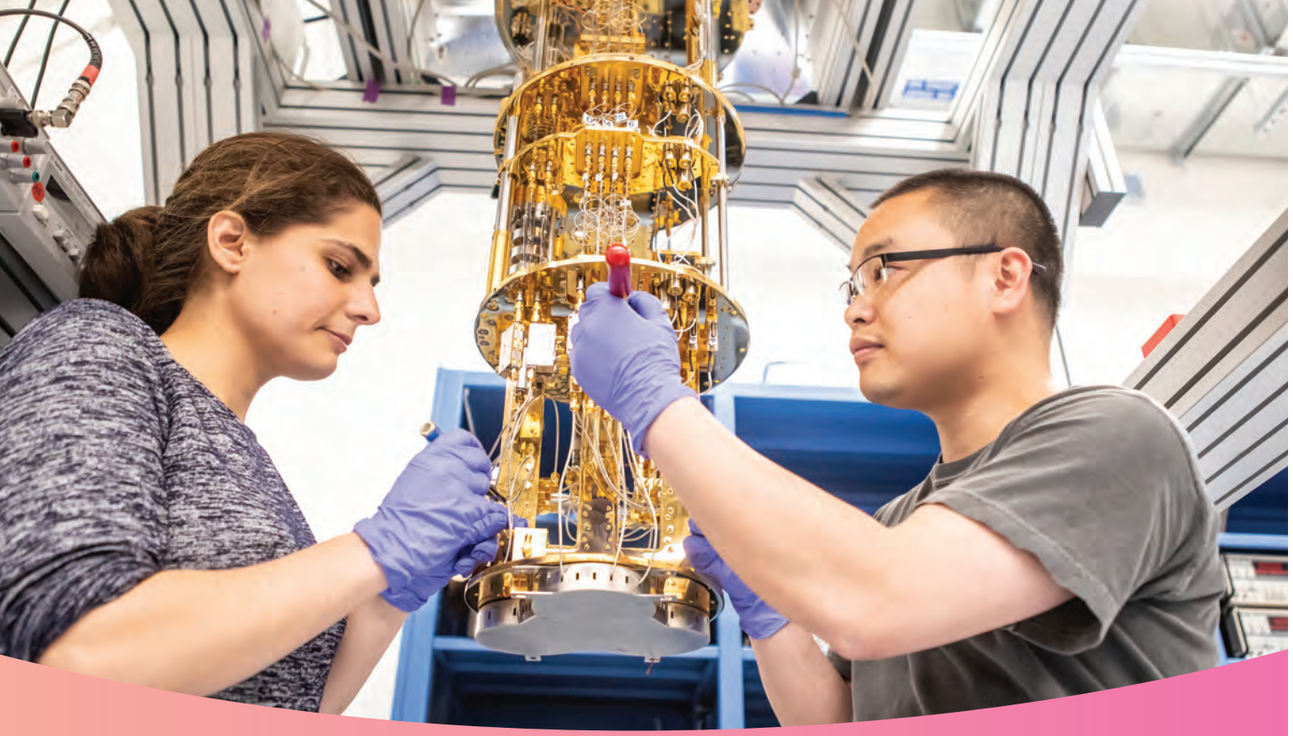
Researchers at the University of Wisconsin–Madison and QuTech at TU Delft have advanced the science of qubits by characterizing the fidelity of a two-qubit gate with silicon quantum dot qubits using randomized benchmarking. The fidelity, or distance between two quantum states, measured at 92 percent, which positions quantum dot technology as a strong contender for quantum computing applications. In another paper, researchers at UW–Madison demonstrated high fidelity two-qubit entanglement with fidelity 89 percent in a large 2D array of 121 neutral atom qubit sites.



NEW QUANTUM LOOP PROVIDES LONG NATIONAL TESTBED

Scientists from Argonne National Laboratory and the University of Chicago launched a new testbed for quantum communication experiments. The Argonne quantum loop consists of a pair of connected 26-mile fiber-optic cables, among the longest ground-based quantum communication channels in the country. The loop serves as a testbed for researchers to send unhackable information across long distances using the properties of quantum entanglement, a phenomenon that links two (or more) particles in a shared state, so that whatever happens to one immediately affects the other. The loop is a significant step in building a large-scale quantum network and helps lay the foundation for a quantum internet.

Read about CQE's latest research and discoveries at **chicagoquantum.org/news**.



TRAINING QUANTUM SCIENTISTS AND ENGINEERS

As our understanding of quantum information science grows, so does the need for scientists and engineers who can apply these discoveries to everyday areas like computing, health care, energy, and finance. The Chicago Quantum Exchange is training the next generation of scientists and engineers in this field and equipping those already in the workforce to transition to quantum careers.

DEGREE AND POSTDOCTORAL PROGRAMS

As premier research institutions, the University of Chicago, the University of Illinois at Urbana-Champaign, the University of Wisconsin–Madison, and Northwestern University play important roles in the education of future quantum scientists and engineers. All four institutions offer PhD programs in quantum-related fields. Additionally, UChicago offers a quantum track in its undergraduate molecular engineering major, and UW–Madison offers a master's degree in quantum computing. Every Chicago Quantum Exchange member institution, including Fermilab and Argonne, offers postdoctoral fellowships for quantum engineers and scientists.

MS IN PHYSICS–QUANTUM COMPUTING

The University of Wisconsin–Madison offers a master's degree in quantum computing, the first such program in the United States. The program, designed to be completed in one year, is closely affiliated with the Wisconsin Quantum Institute and provides students with a thorough grounding in quantum information and computing. Nine students were admitted to the first class in Fall 2019.

IBM POSTDOCTORAL QUANTUM TRAINEES PROGRAM

Through a unique partnership between IBM and the Chicago Quantum Exchange, five promising postdoctoral scientists will receive support and the freedom to work with different groups across the CQE and IBM. The program is especially geared toward those with research interests in quantum computing, quantum communication, quantum sensing, and quantum algorithms, as well as those of mutual research interest for the CQE and IBM, such as research that leverages IBM Q.

QUANTUM INFORMATION SCIENCE AND ENGINEERING NETWORK (QISE-NET)

The CQE manages QISE-NET, an NSF-supported program that enables approximately 20 graduate students to conduct their doctoral research jointly with industry or a national laboratory. Each student is paired with both an academic advisor and an industry collaborator, and the three address a pressing research question over four years. The nationwide QISE-NET program is led by the University of Chicago and Harvard University.

INTERNSHIPS

The CQE partners with companies, national laboratories, and others to provide students and trainees with internships and collaborative research opportunities that expose them to a broad array of experiences in industrial, academic, and government facilities.

CERTIFICATE PROGRAMS IN QUANTUM ENGINEERING AND TECHNOLOGY

A new four-day intensive certificate program at the University of Chicago will educate scientists and engineers in the key principles of quantum technology and practical applications. Companies in the communications, electronics, optics, and materials industries need to build a quantum-ready workforce, and many early and mid-career scientists and engineers, with minimal retraining, would be prime candidates. The program is offered by the Pritzker School of Molecular Engineering at the University of Chicago and is managed by the Chicago Quantum Exchange.

"One of my primary research interests lies in making quantum computing theory into a reality through the transformation of algorithms into implementations that maximize the capabilities of real quantum machines. I want to help make quantum computing practical and scalable for the scientific community, and as an IBM Postdoctoral Scholar, will be able to work towards this goal."

KAITLIN SMITH, IBM Postdoctoral Scholar, Chicago Quantum Exchange, EPiQC - University of Chicago

Explore the CQE's education programs at **chicagoquantum.org/training-and-education**.

QUANTUM CONVERSATIONS

The Chicago Quantum Exchange plays a critical role in advancing our nation's interests in quantum information science and engineering. CQE members, partners, and advocates are shaping the national dialogue—and the field.

"Even everyday technology, like a smartphone app, affects people in significant ways that they might not realize. If there are concerns about something as familiar as an app, then we need to take more opaque and complicated technology, like AI, very seriously."

Daniel Bowring, Fermilab Scientist

Bowring spoke at the CQE workshop "When Technology Transforms Society: Considering the Societal and Ethical Impacts of Quantum Computing and AI."

"Working in close collaboration with industry and academia, the national labs are ideal places to offer the intellectual and infrastructural breadth that is required to anchor future research in quantum information sciences."

Supratik Guha, Professor of Molecular Engineering, University of Chicago, and Senior Scientist/Senior Advisor to Physical Sciences & Engineering, Argonne

Guha testified before the Senate Committee on Energy and Natural Resources.

"We are now thrilled to be adding the CQE to our global partners. Together, we hope to keep pushing the boundaries of physics in order to create amazing new technologies and to make unprecedented new discoveries in quantum science."

Michelle Simmons, Laureate Fellow and Director of the Centre of Excellence for Quantum Computation and Communication Technology, University of New South Wales

Simmons on the Centre joining the CQE.

"We should be measuring progress in the field by how we're making progress toward solving meaningful problems."

Talia Gershon, Director of Hybrid Cloud Infrastructure Research, IBM

Gershon gave the keynote talk, "Solving Unsolvable Problems: The Future of Quantum Computing," at the second Chicago Quantum Summit.

"We are training students to have a broad base of expertise that will equip them to make a high impact in this developing field of technology."

Mark Eriksson, Vilas Distinguished Achievement Professor of Physics, UW–Madison

When UW–Madison joined the CQE, Eriksson spoke about the benefits of collaborative opportunities that would be available to students.

SELECT CQE PATENTS

Research by CQE members results in discoveries and technologies that advance the field and industry. The following CQE technologies are available for licensing.

Title: Method of making thin films
Owner: UChicago Argonne LLC
Inventors: Tomas Polakovic, Valentyn Novosad
US Patent App. No. U.S. 16/274,202
Relevant publication: APL Materials, 6, 076107 (2018)
Contact: Paulina Rychenkova, prychenkova@anl.gov

Title: C-MOS Compatible SN-Based Resistive Non-Volatile Memory
Owner: UChicago
Inventor: Supratik Guha
International Patent App. No. PCT/US19/27145
Relevant publication: Nanoscale, 10, 9441 (2018)
Contact: Preeti Chalsani, PhD, pchalsani@uchicago.edu

Title: Electrometry by optical charge conversion of defects in solid state materials
Owner: UChicago
Inventor: David Awschalom
International Patent App. No. PCT/US2019/017817
Relevant publications: Proc. Natl. Acad. Sci., 115 (31), 7879–7883 (2018); Appl. Phys. Lett., 115, 043105 (2019)
Contact: Preeti Chalsani, PhD, pchalsani@uchicago.edu

Title: Long-lived 3D multimode microwave cavities
Owner: UChicago
Inventor: David Schuster
US Patent App. No. 16/352,191
Contact: Preeti Chalsani, PhD, pchalsani@uchicago.edu

Title: Non-reciprocal quantum sensor
Owner: UChicago
Inventor: Aashish Clerk
International Patent App. No. PCT/US19/34527
Relevant publication: Nature Communications, 9, 4320 (2018)
Contact: Preeti Chalsani, PhD, pchalsani@uchicago.edu

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