CHICAGO QUANTUM EXCHANGE

An intellectual hub for advancing the science and engineering of quantum information among the CQE community, across the Midwest, and around the globe.

ANNUAL REPORT 2023

The Chicago Quantum Exchange (CQE) connects leading academic talent, top scientific facilities, and prominent corporate and nonprofit partners to advance the science and engineering of quantum information, train the quantum workforce of tomorrow, and drive the local and national quantum economy.

CHICAGO QUANTUM EXCHANGE MEMBERS

THE UNIVERSITY OF CHICAGO

Argonne NATIONAL LABORATORY

Fermilab

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

Northwestern University

CHICAGO QUANTUM EXCHANGE STEERING COMMITTEE

David Awschalom
Liew Family Professor of Molecular Engineering and Physics, UChicago; Senior Scientist, Argonne; Director of the Chicago Quantum Exchange; Director of Q-NEXT, a Department of Energy Quantum Information Science Center

Bonnie Fleming
Deputy Director and Chief Research Officer, Fermi National Accelerator Laboratory; Professor of Physics, UChicago

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

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

OUR WORK

With world-class researchers, acclaimed science and engineering programs, uniquely capable research facilities, and leading industry, nonprofit, and international partners, the CQE is one of the largest collaborative teams working on quantum information science in the world.

BRIDGING ACADEMIA, INDUSTRY, AND GOVERNMENT

The CQE facilitates collaboration, joint projects, and information exchange among private and public universities, national laboratories, and corporate and nonprofit partners.

ADVANCING RESEARCH, DISCOVERY, AND IMPACT

The CQE's research — focused on quantum communications, computing, and sensing — is shaping the future of quantum science and engineering and its impact on the world.

TRAINING QUANTUM SCIENTISTS AND ENGINEERS

The CQE is developing the next generation of the quantum workforce and equipping those already working in science and engineering to transition to quantum careers.

DRIVING THE LOCAL AND NATIONAL QUANTUM ECONOMY

As a hub for cross-sector collaboration, research, and workforce development, the CQE drives quantum jobs and supports companies and technologies across the region and the U.S.

2022 SPOTLIGHTS

In 2022, Chicago Quantum Exchange member institutions expanded regional research infrastructure, published leading-edge science, trained the workforce of the future, and developed partnerships with companies and nonprofits. The region launched new companies, attracted others, and brought the international community together.

40

CORPORATE PARTNERS, including **11 added** in 2022

124

MILES
Length of expanded Chicago-region quantum network announced by CQE in June

500

CHICAGO QUANTUM SUMMIT ATTENDEES
in-person and virtual, from **19 countries**

3 international partners + **3** nonprofit partners + **1** regional academic partner

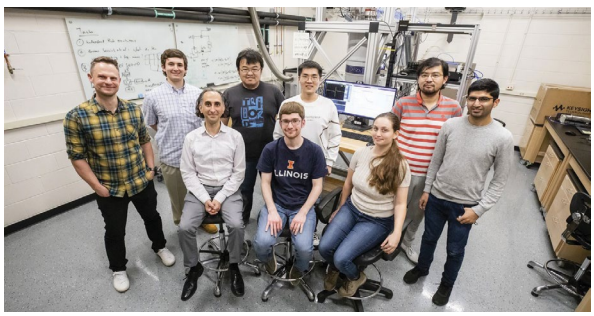
Chicago activates quantum network, moving toward secure quantum internet

Scientists with the CQE at the University of Chicago Pritzker School of Molecular Engineering connected the city of Chicago and suburban labs with a quantum network — nearly doubling the length of what was already one of the longest in the country. The network is now actively running quantum security protocols using technology provided by Toshiba, distributing quantum keys over optic cable at a speed of over 80,000 quantum bits per second between Chicago and the western suburbs. > READ MORE

High schoolers first to use ultra secure quantum technology in mock vote

More than 50 students from Chicago's Kenwood Academy High School became the first members of the U.S. public to use quantum key distribution to vote on a modern hot topic: should social media companies be allowed to censor information and misinformation? Former President Barack Obama surprised the students at the event and shared a few words about the dangers of disinformation online in an era where their attention is a prized commodity for businesses.

> READ MORE



IQUIST testbed stands up quantum computing processors

Researchers at the Grainger College of Engineering at the University of Illinois Urbana-Champaign are assembling quantum processors based on today's leading qubit technologies — superconducting circuits and trapped atomic ions. The state-of-the-art Illinois Quantum Information Science and Technology Center (IQUIST) quantum testbed will explore novel ways to hybridize quantum hardware and scale it to high-performance systems. The testbed provides a venue for quantum experts to address problems collaboratively and to work with industry partners.

> READ MORE

Leaders discuss past, present, future of quantum tech at Chicago Quantum Summit

The fifth annual Chicago Quantum Summit brought together over 220 members of the quantum information science and technology community in person from across the nation and around the world. Industry leaders, U.S. government officials, university presidents, and national laboratory directors gathered to discuss quantum education, cutting-edge quantum research, and what comes next for the rapidly growing field. The summit also featured the Quantum Creators Prize Symposium, where early-career researchers working in exciting new directions of quantum science shared their work. > READ MORE

RESEARCH & DISCOVERY

Members of the Chicago Quantum Exchange are advancing fundamental and applied research. Their efforts are the gateway to fully understanding and controlling objects at the smallest scales, driving discoveries with far-reaching applications.

150+

RESEARCHERS across member institutions

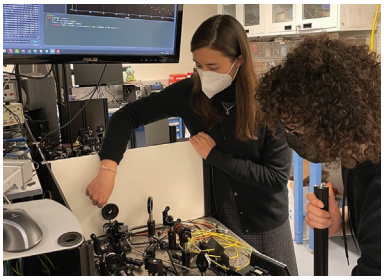
24

HONORS to CQE researchers in 2022

10

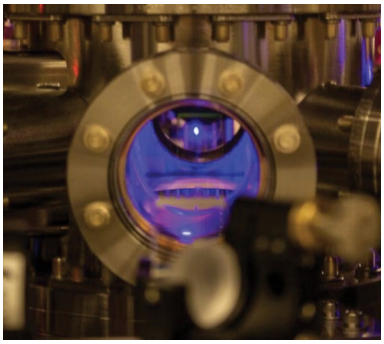
WORKSHOPS on emerging research topics

> *"I believe that the future of quantum computing is going to run squarely through the universities and laboratories you see partnered here, and it's going to run squarely through the state of Illinois and the city of Chicago."*
>
> **ROBERT JONES, Chancellor of the University of Illinois Urbana-Champaign,** at the Chicago Quantum Summit



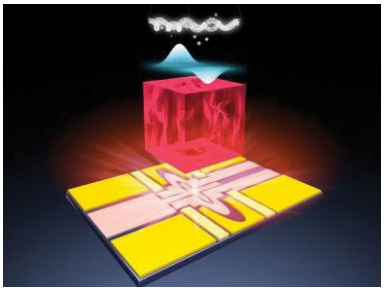
Researchers preserve quantum states for more than five seconds, setting record

A team of researchers at the University of Chicago achieved two major breakthroughs to overcome common challenges for quantum systems: They were able to read out their qubit on demand, then keep the quantum state intact for more than five seconds — a new record for silicon carbide devices. The findings were published in the journal *Science Advances*. > READ MORE



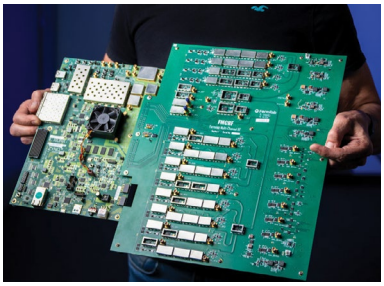
Ultraprecise atomic clock poised for new physics discoveries

University of Wisconsin–Madison physicists made one of the highest-performance atomic clocks ever, as announced in the journal *Nature*. Their instrument, an optical lattice atomic clock, can measure differences in time to a precision equivalent to losing just one second every 300 billion years. It is the first example of a "multiplexed" optical clock, in which six separate clocks can exist in the same environment. Its design allows the team to test ways to search for gravitational waves, attempt to detect dark matter, and discover new physics with clocks. > READ MORE



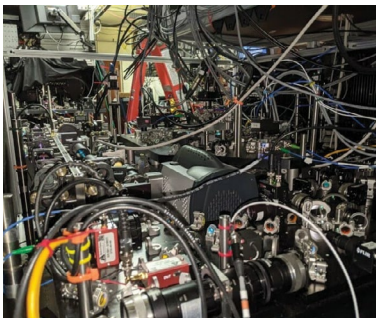
Advancement in quest for ideal quantum bit

A team led by Argonne National Laboratory created a new qubit platform formed by freezing neon gas into a solid at very low temperatures, spraying electrons from a light bulb's filament onto the solid, and trapping a single electron there. A key component in the team's qubit platform, announced in the journal *Nature*, is a chip-scale microwave resonator made from a superconductor. This system shows great promise to be developed into ideal building blocks for future quantum computers. > READ MORE



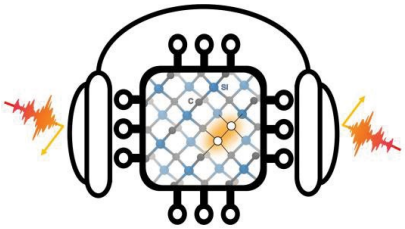
New control electronics for quantum computers improve performance, cut costs

Engineers at Fermi National Accelerator Laboratory have developed a new system of control and readout electronics known as Quantum Instrumentation Control Kit (QICK), which they described in the AIP *Review of Scientific Instruments*. The system has drastically improved quantum computer performance while cutting the cost of control equipment. QICK is specialized, yet it is versatile enough to be compatible with many designs of superconducting qubits. > READ MORE



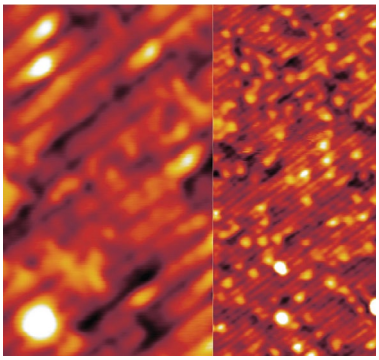
Quantum algorithm runs on neutral atom quantum computer

A university-industry collaboration successfully ran a quantum algorithm on a cold atom quantum computer for the first time. The achievement, published in *Nature* by scientists from the University of Wisconsin–Madison, ColdQuanta, and Riverlane, brings quantum computing one step closer to being used in real-world applications. Running a quantum algorithm on the cold atom style of computer is a proof of concept that this approach could work. > READ MORE



Scientists use quantum computers to simulate quantum materials

Researchers from Argonne and UChicago performed quantum simulations of spin defects, which are specific impurities in materials that could offer a promising basis for new quantum technologies. The study, published in *Physical Review X Quantum*, improved the accuracy of calculations on quantum computers by correcting for noise introduced by quantum hardware. Looking at spin defects offers a real-world system to validate the capabilities of quantum computers. > READ MORE



A nanowire with exotic currents probes for magnetism

A team of researchers at the University of Illinois Urbana-Champaign added a twist to their scanning tunneling microscope technique by replacing the tip with a nanowire made from the material samarium hexaboride (SmB6). They used the nanowire to image magnetic features in an approach that has potential advantages compared to other methods. As published in *Science*, their combined measurements and calculations showed evidence of the unusual nature of the nanowire itself. > READ MORE

CHICAGO QUANTUM PROFILE

Jens Koch
Northwestern University

Jens Koch did not expect to join the field of quantum information science. His PhD was focused on something much different: the idea of using single molecules as transistors. Now Koch has been conducting theoretical research on superconducting qubits as a professor at Northwestern University for 12 years. > READ MORE

TRAINING & EDUCATION

Chicago Quantum Exchange members and partners educate and train the next generation of the quantum workforce and equip those already working in science and engineering to transition to quantum science careers. As our understanding of quantum information science grows, these efforts will ensure that there is a workforce able to apply discoveries to industries such as computing, health care, energy, and finance.

12

STUDENTS
in the Open Quantum Initiative Undergraduate Fellowship

15

CQE PARTNERS AND MEMBERS providing internships

12

QUANTUM CREATORS
awarded at the 2022 Chicago Quantum Summit

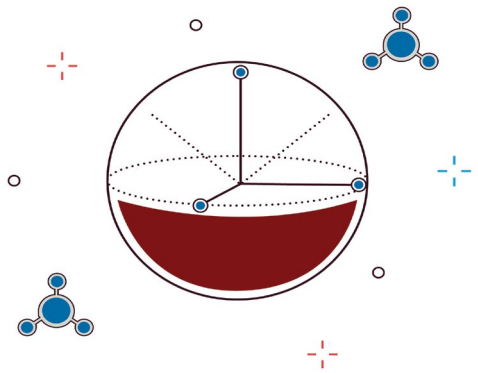
> *"I really feel strongly we are at the cusp of a revolution here. And I am very excited for us to lead this revolution, together with our regional partners that all are represented here, and many more in the audience. I feel strongly we need to come together and make Chicagoland one of these centers in the U.S. and around the world in quantum information science and technology."*
>
> **LIA MERMINGA, Director of Fermi National Accelerator Laboratory,** at the Chicago Quantum Summit

UNDERGRADUATE TRAINING

Undergrads conduct summer quantum research through new initiative

A dozen college students from backgrounds under-represented in science spent the summer conducting quantum information science and engineering research in labs across the Midwest. The Open Quantum Initiative Undergraduate Fellowship is a new program that seeks to make the burgeoning quantum workforce a more diverse and inclusive community from the start. > READ MORE

CERTIFICATE PROGRAM



New certificate helps build quantum workforce of tomorrow

A newly launched certificate in Quantum Science, Networking, and Communications is preparing workers to join the quantum industry. The online course, taught by leading quantum researchers from the University of Chicago and the University of Illinois Urbana-Champaign, is designed to enlist early-career computer scientists, engineers, and other tech workers in the quantum field. This new course builds upon a successful quantum certificate program launched in 2020 to help develop a broad and diverse workforce. > READ MORE

NATIONAL EVENTS

Community celebrates World Quantum Day

World Quantum Day
#MidwestQuantum

CQE member institutions celebrated the first-ever World Quantum Day on April 14. This international, community-driven event aims to promote public awareness of the positive impact quantum science has had and will have on society. The date is taken from Planck's constant, 4.14 * 10-15 eV · s, a value that is used in many quantum mechanics equations.

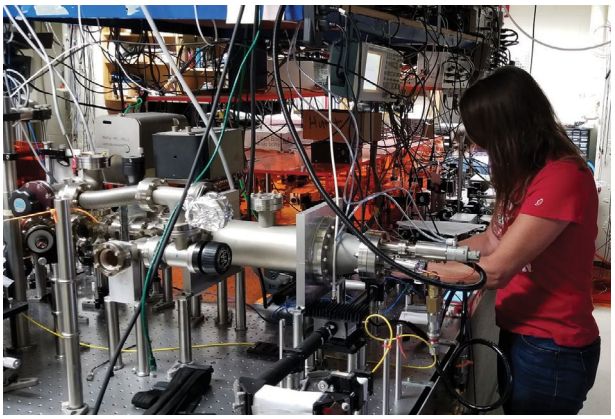
> READ MORE

Leaders discuss building quantum workforce at national workshop

Leaders in quantum information science, including several from the CQE, came together to discuss the future of quantum education in the U.S. at a workshop called "Quantum Workforce: Q-12 Actions for Community Growth." A corresponding National Strategic Plan for Quantum Information Science and Technology Workforce Development also featured several CQE members and educational initiatives.

> READ MORE

OUTREACH TO K-12 AND BEYOND



High school teachers immersed in quantum research labs

TeachQuantum is a multi-year program that consists of an annual six-week summer research experience for high school teachers. The teachers are immersed in real-world quantum research environments, preparing them to teach quantum-focused STEM concepts in their classrooms. The selected teachers develop new quantum-inspired activities to implement with their students and share their outcomes and best practices in meetings throughout the school year.

> READ MORE

Quantum Casino helps explain physics' most complex laws

The STAGE Lab within UChicago's Pritzker School of Molecular Engineering worked with undergraduate and graduate students to develop Quantum Casino, a suite of games designed to impart the core principles of quantum mechanics in a way that's engaging and easy to understand. It consists of three digital games and three custom-deck analog card games, all demonstrating elements of quantum mechanics. > READ MORE

CHICAGO QUANTUM PROFILE

Silvia Zorzetti

Fermi National Accelerator Laboratory

When Silvia Zorzetti was a student, she worked at Fermilab on particle detectors. Now, Zorzetti is back at Fermilab with a senior position at the Superconducting Quantum Materials and Systems (SQMS) Center, applying her skill with complex hardware to quantum computing. "Be curious," she says as advice for future quantum scientists, "and don't be scared to ask questions."

> READ MORE

BUILDING THE QUANTUM ECONOMY

The Chicago Quantum Exchange is unlocking the region's potential to be the center of the quantum economy, convening leading academic researchers, top scientific facilities, and innovative industry partners. These partners are fueling world-changing discoveries, empowering a robust quantum workforce, and creating quantum jobs across the country.

11

COMPANIES accelerated through the first two years of Duality

5

QISE COMPANIES moved to the region

1

ACQUISITION of a home-grown QISE startup

> *"Quantum technologies have the potential to revolutionize every field of science and engineering, as well as our everyday lives. It can enable advanced computing, unhackable communications — imagine that — and many other applications that have yet to be discovered. This is what the future looks like."*
>
> **CHICAGO MAYOR LORI LIGHTFOOT,** at a World Business Chicago and CQE event

Duality quantum accelerator announces second cohort startups

Duality, the nation's first accelerator exclusively for quantum companies, accepted five startups from across the globe into the second cohort of the yearlong accelerator based in Chicago. Duality is led by the CQE and the Polsky Center for Entrepreneurship and Innovation at the University of Chicago, along with founding partners the University of Illinois Urbana-Champaign, Argonne National Laboratory, and P33.

Working out of the offices of the CQE, each startup receives $50,000 in unrestricted funding and mentorship from top quantum experts. They also can explore partnerships and access to some of the region's state-of-the-art equipment and facilities for advanced computing, nanofabrication, atomic-scale measurement, quantum testbeds, and other premier resources. > READ MORE

DUALITY COHORT 2

- **Icosa Computing**, a New York, NY–based startup building quantum computing and physics-enhanced optimizers for financial institutions.
- **memQ**, a Chicago, IL–based startup building technology to enable the quantum internet.
- **Quantescence**, a France- and Chicago, IL–based quantum computing software startup that has created a quantum emulator platform.
- **SCALINQ**, a Sweden-based startup developing unique packaging solutions for superconducting quantum chips.
- **Wave Photonics**, a UK-based startup using computational techniques to accelerate integrated photonics design.

DUALITY COHORT 1

Completed in summer 2022

- **Axion Technologies**, a Tallahassee, FL–based startup developing a quantum random number generator for high-performance computing systems.
- **Great Lakes Crystal Technologies**, an East Lansing, MI–based startup developing a commercial manufacturing process for semiconductor-grade diamond materials for photonics, electronics, and quantum technology applications.
- **qBraid**, a Chicago, IL–based startup developing a cloud-based platform for managed access to other quantum computing software and hardware.
- **QuantCAD**, an Iowa City, IA–based startup developing simulation software for modeling noise and current in quantum devices such as high-resolution quantum sensors.
- **Quantopticon**, a UK-based startup developing simulation software for designing and optimizing quantum optical devices.
- **Super.tech**, a Chicago, IL–based startup developing software that accelerates quantum computing applications by optimizing across the system stack from algorithms to control pulses. Super.tech was acquired by CQE partner ColdQuanta, now Infleqtion, in May 2022.

CHICAGO QUANTUM PROFILE

Alex High

The University of Chicago

When Alex High, assistant professor of molecular engineering at UChicago's Pritzker School of Molecular Engineering, was growing up in rural West Virginia, he and his father would often go outside to look at the stars, discussing physics theories like quantum mechanics and relativity. It seems fitting that his career led him to a subject in which those theories elegantly intersect: light. > READ MORE

Celebrating quantum innovation in Chicago

In September 2022, World Business Chicago and the CQE hosted leading innovators in celebration of Chicago's quantum and deep tech ecosystem. The event doubled as a ribbon-cutting ceremony for quantum hardware company EeroQ's new lab headquarters at the Terminal in Chicago's Humboldt Park neighborhood. The event drew representatives from such companies as IBM, JPMorgan Chase, Protiviti, IonQ, Quantum Design, and Quantum Machines, as well as research institutions including UChicago's Pritzker School of Molecular Engineering, Northwestern University, Argonne National Laboratory, and Fermi National Accelerator Laboratory. Chicago Mayor Lori Lightfoot also spoke at the event. > READ MORE

> *"EeroQ conducted a national search for our headquarters, with a focus on finding a robust local ecosystem. We chose Chicago because it checks every box for building a quantum hardware company, and the resources provided by the Chicago Quantum Exchange have been helpful for our company at every turn."*
>
> **NICK FARINA, Chief Executive Officer of EeroQ,** in a CQE partners announcement

CQE PARTNERS

Industry

Ally
Applied Materials
Atom Computing
Boeing
Classiq
Corning
Discover
EeroQ
Great Lakes Crystal Technologies
HRL Laboratories
IBM
Infleqtion
Intel
JPMorgan Chase
Lake Shore Cryotronics
Microsoft
Oxford Instruments
Protiviti
PsiQuantum
qBraid
QuantCAD
Quantinuum
Quantopticon
Quantum Design
Quantum Machines
Quantum Opus
Qubitekk
QuEra
Rigetti Computing
State Farm
TOPTICA Photonics
Toshiba
Verizon
Zurich Instruments

Duality Startups

Icosa Computing
memQ
Quantescence
SCALINQ
Wave Photonics

International

CQC²T
QuTech
Weizmann Institute of Science

Nonprofit

Le Lab Quantique
P33
Quantum Economic Development Corporation (QED-C)

Regional

The Ohio State University

IN THE NEWS

The Chicago Quantum Exchange is building the reputation of the Midwest as an epicenter for quantum research and helping to educate the public on the significance of quantum information science and engineering. Here are highlights of CQE researchers and institutions in the media.

Chicago scientists are testing an unhackable quantum internet in their basement closet
Washington Post
> READ MORE

Chicago bets on quantum tech as 'next big thing' for its future
Bloomberg
> READ MORE

Chicago Quantum Exchange takes first steps toward a future that could revolutionize computing, medicine and cybersecurity
Chicago Tribune
> READ MORE

Chicago now has a 124-mile quantum network. This is what it's for.
Popular Science
> READ MORE

Undergraduate fellowship works to diversify quantum science
Diverse: Issues in Higher Education
> READ MORE

SELECT CQE PATENTS

The following technologies from CQE-affiliated faculty members are available for licensing.

Title: Dynamically Reconfigurable Devices Based on Ferroelectric Materials

Owner: University of Illinois Urbana-Champaign

Inventors: Wenjuan Zhu, Kai Xu, Jialun Liu, Zijing Zhao

US Patent 11,527,648

Publication link/doi: https://aip.scitation.org/doi/full/10.1063/5.0019555

Contact: Michelle Chitambar, mchitamb@illinois.edu

Title: Volumentric Optical Integrated Circuit Elements (VOICE)

Owner: University of Illinois Urbana-Champaign

Inventors: Paul Braun, Lynford Goddard, Kimani Toussaint, Jinlong Zhu, Daniel Bacon-Brown, Christian Ocier, Qing Ding, Corey Richards

US Patent 11,237,343

Publication link/doi: https://www.scopus.com/record/display.uri?eid=2-s2.0-85116487953&origin=inward&txGid=6915269ece4a94889519f83b65ddfe0b

Contact: Michelle Chitambar, mchitamb@illinois.edu

Title: Practical Architectures and Algorithms for Quantum Source Coding

Owner: The University of Chicago

Inventors: Liang Jiang, Connor Hann, Senrui Chen, Isaac Chuang

US or International Patent App. No.: Patent unpublished

Contact: Mike Hinton, mhinton@uchicago.edu

Title: Model-Free Interferometry Enabled by Machine Learning

Owner: The University of Chicago

Inventors: Liang Jiang, Seyed Alireza Seif Tabrizi

US or International Patent App. No.: Patent unpublished

Contact: Mike Hinton, mhinton@uchicago.edu

Title: Electrically Tunable Quantum Platform Using Spin Defects in SiC Heterostructures

Owner: The University of Chicago

Inventors: David Awschalom, Christopher Anderson, Alexandre Bourassa

US or International Patent App. No.: 17/438,600

Contact: Mike Hinton, mhinton@uchicago.edu

Title: A Strategy to Perform Magnetization Reversals in Ferromagnets

Owner: Northwestern University

Inventors: Anupam Garg, John B. Ketterson, Jinho Lim, Zhaohui Zhang

US or International Patent App. No.: 63/082,266, 17/483,405

Publication link/doi: https://doi.org/10.1109/TMAG.2020.3039468

Contact: Arjan Quist, arjan.quist@northwestern.edu

Title: Magnetic Memory Devices Having a Low Switching Voltage

Owner: Northwestern University

Inventor: Pedram Khalili Amiri

US or International Patent App. No.: 63/293,363, 18/068,173

Publication link/doi: https://doi.org/10.1038/s43246-022-00310-x

Contact: Min Choi, min.choi@northwestern.edu

Title: Electrical Write/Read of High-Information-Density Magnetic Thin Film

Owner: Northwestern University

Inventors: Sevde Nur Arpaci, Matthew Grayson, Pedram Khalili Amiri, Victor Lopez Dominguez, Claire Cecelia Onsager, Chulin Wang

US or International Patent App. No.: 63/348,246

Publication link/doi: https://doi.org/10.1038/s41467-021-24237-y

Contact: Min Choi, min.choi@northwestern.edu

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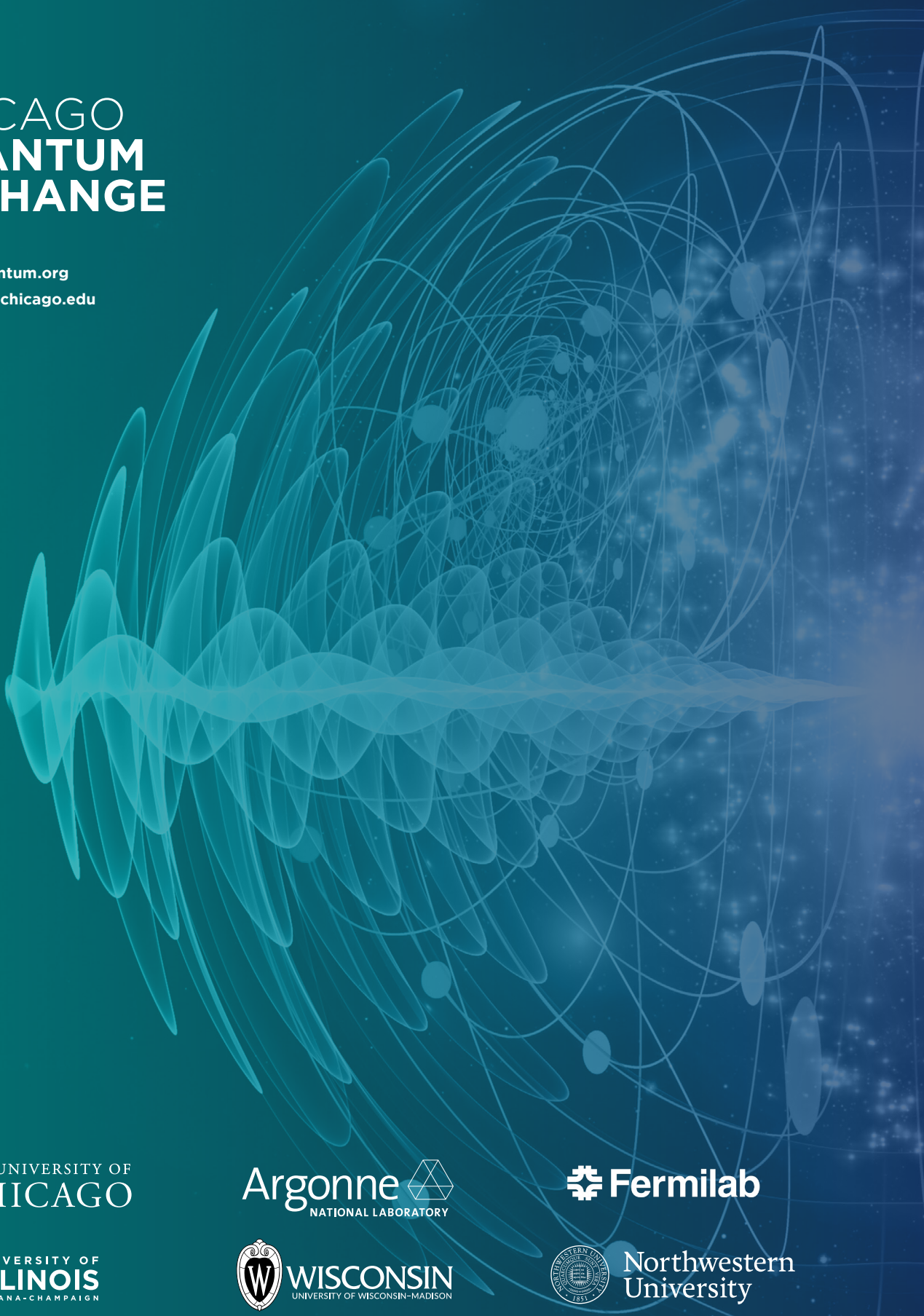

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