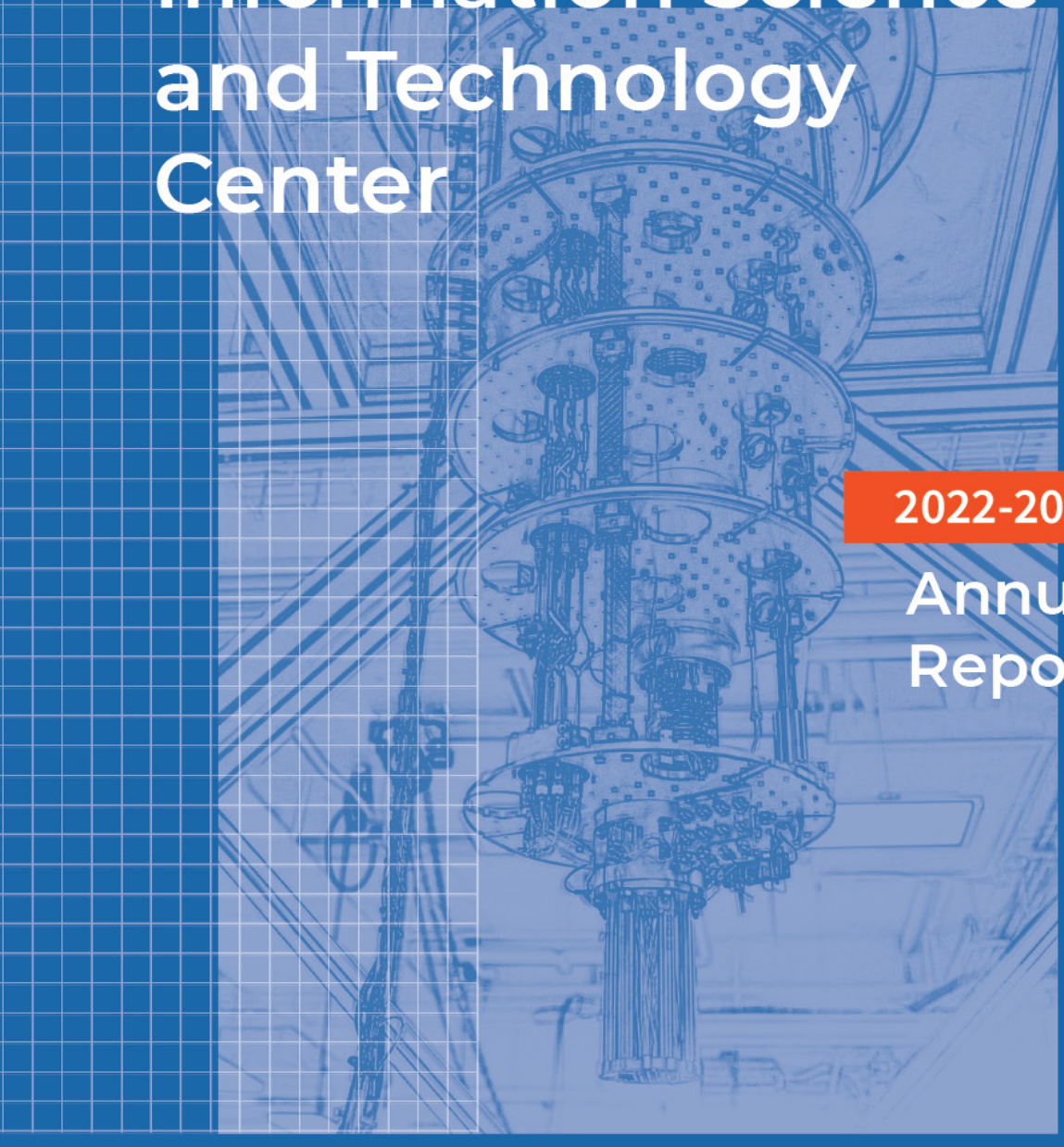
Illinois Quantum Information Science and Technology Center



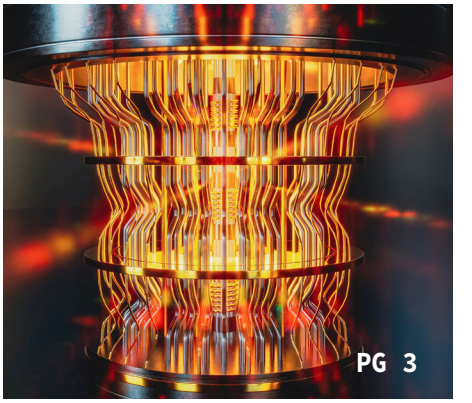
2022-2023

Annual Report

The Grainger College of Engineering

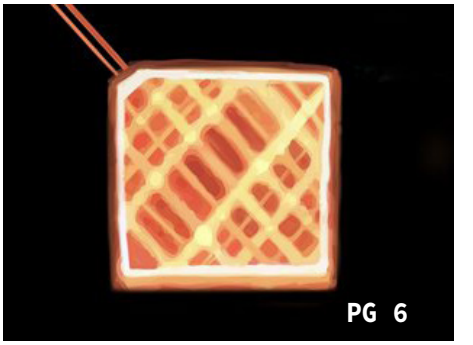
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Table of Contents



QSQM

PG 4



Director's Note

Brian DeMarco

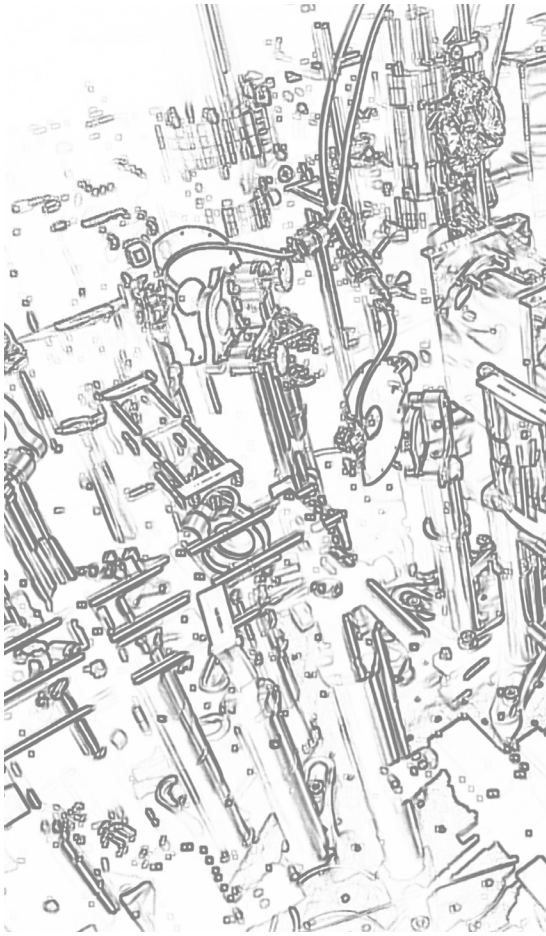
Quantum information science and engineering promises to transform the computing and networking technology that forms the backbone of modern society and to unveil secrets of nature and the universe. There is growing anticipation about this opportunity across the US and around the world. The US has invested $3.8B through the 2018 National Quantum Initiative Act, the 2022 CHIPS and Science Act, and other initiatives. The total global investment by governments is now over $35B. The private sector is engaged too, with $2.4B invested in 2022 alone.

I am excited by how Illinois is taking a leading role in this revolution. Our faculty lead two national-scale centers and have a significant footprint in two Department of Energy centers based in the state. The research programs on our campus address frontier challenges in quantum materials and devices, using quantum computers to solve scientific problems, building quantum networking and processor technologies, devising new algorithms and applications, and tackling fundamental science. We also excel at partnerships. The IBM-Illinois Discovery Accelerator Institute is an exciting example of how we can work with industry to advance the field. The Q2Work program and National Q-12 Education Partnership create resources for early learners and bring together ideas from academia, industry, and government to grow the workforce.

The new faculty (including Simeon Bogdanov, Jacob Covey, Elizabeth Goldschmidt, Dakshita Khurana, Kohei Kishida, Angela Kou, Felix Leditzky, Wolfgang Pfaff) and staff (Angela Graham, Patrick Snyder, Hannah Stites) we have recently hired have energized the research and education enterprise at UIUC. I am thrilled that Chris Anderson, Makrand Sinha, and Amanda Young are joining as new faculty in Materials Science and Engineering, Computer Science, and Mathematics.

I am thankful for the opportunity to serve as IQUIST Director. Moving forward, I plan to build coalitions across campus and with industry focused on devices, information science, and computing. Another priority of mine is to build programs to expand our leadership, support the State of Illinois quantum ecosystem, and to grow opportunities to educate the next generation of pioneers.

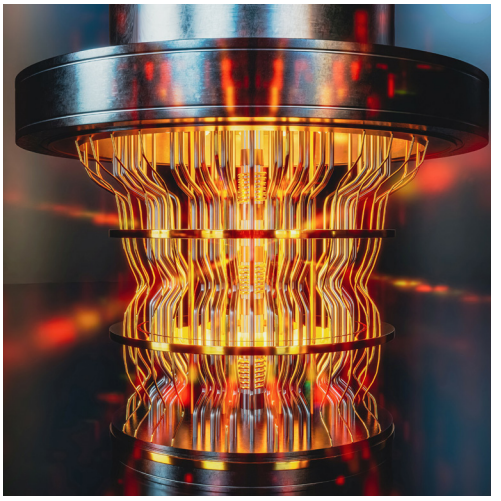
"We plan to build coalitions across campus and with industry focused on devices, information science, and computing."



Founded in 2018, the Illinois Quantum Information Science and Technology Center (IQUIST) is a collaboration of computer scientists, electrical and computer engineers, materials scientists, mathematicians, physicists, entrepreneurs, and others. The IQUIST team encompasses expertise in quantum computing, simulation, networking, and sensing, from the exploration of fundamental science to the implementation of novel quantum algorithms and state-of-the-art equipment for the fabrication of quantum materials and devices. The Urbana-Champaign campus will play a principal role in the coming quantum information revolution as IQUIST develops QISE-focused educational programs for the next-generation quantum workforce.

The IQUIST team is continuing UIUC's legacy of groundbreaking contributions to the development of technologies that have shaped society over the past century, including the quantum-well laser that is at the heart of fiber-optic communications, the first supercomputer at an academic institution, and the first modern web browser. IQUIST collaborators are pursuing promising lines of fundamental research and engineering, including work on a multi-node quantum testbed that enables researchers to explore and implement new ideas for distributed quantum processing and quantum networks.

IQUIST is a core partner in the Chicago Quantum Exchange, alongside the University of Chicago, Argonne National Lab, Fermilab, the University of Wisconsin–Madison, and Northwestern University. We strive to continue building valuable partnerships with research institutions and the tech industry to advance the field of quantum information science.



Our mission

To advance quantum science and technology and to train a quantum-ready workforce through collaborative, cross-disciplinary research programs.

NSF QLCI Hybrid Quantum Architectures and Networks

The National Science Foundation Quantum Leap Challenge Institute for Hybrid Quantum Architectures and Networks (HQAN) is one of the five NSF centers created by the 2018 National Quantum Initiative Act. Led by UIUC, HQAN integrates multidisciplinary expertise to develop hybrid, distributed quantum computing as a new paradigm. Its workforce development initiatives are inspiring and training students who will contribute to the future quantum technology and innovation ecosystem.

QuSTEAM

QuSTEAM facilitates the national scale-up of equitable and effective undergraduate quantum education by supporting a collaborative network of academic institutions, private-sector employers, and a community of instructors to enable a diverse and capable quantum workforce. QuSTEAM helps the quantum education community research, curate, disseminate, and deliver instructional content using methods that engage students and promote equity by re-envisioning how QISE is taught.

Q-NEXT

Q-NEXT brings together national labs, universities, and technology companies to solve cutting-edge challenges in quantum information science. Led by the U.S. Department of Energy's Argonne National Lab, Q-NEXT focuses on how to reliably control, store, and transmit quantum information at distances that could be as small as the width of a computer chip, or as large as the distance between Chicago and San Francisco.

Q2Work

Q2Work is a National Science Foundation-funded initiative led by UIUC and the University of Chicago to provide quantum education, programs, tools, and curricula to K-12 students. To achieve a competitive quantum workforce, future workers must gain a robust set of quantum computing skills. Q2Work is designed to accelerate progress across the quantum education community by amplifying its efforts through dissemination and collaboration.

Quantum Sensing and Quantum Materials

Quantum Sensing and Quantum Materials (QSQM) is a collaborative Energy Frontier Research Center (EFRC) spanning three institutions, including UIUC, the University of Illinois Chicago, and the SLAC National Accelerator Laboratory. QSQM draws together experts in quantum information science, physics, and materials science to develop and apply novel quantum sensing methods to unravel the mysteries of three families of quantum materials: exotic superconductors, topological crystalline insulators, and strange metals.

IBM-Illinois Discovery Accelerator Institute

The IBM-Illinois Discovery Accelerator Institute launched in 2021 with a $200 million investment by IBM, the University of Illinois, and the State of Illinois. Its initial ten-year focus is on the rapidly growing areas of hybrid cloud and AI, quantum information science and technology, and accelerated materials discovery and sustainability. Several quantum-technology projects led by IQUIST faculty are underway:

- ***Eric Chitambar*** and ***Felix Leditzky:*** Collaborating with IBM's Srinivasan Arunachalam on enhanced measurement approaches for quantum processors.
- ***Bryan Clark:*** Working with IBM's Kristan Temme, Ewout Van den Berg, and Alireza Seif on a new approach to error mitigation for quantum computers.
- ***Brian DeMarco*** and ***Emily Edwards:*** Collaborating with IBM's Kayla Lee on quantum education and training.
- ***Patrick Draper*** and ***Aida El-Khadra:*** Collaborating with IBM's Nathan Earnest-Noble on adaptive resource allocation algorithms for digital quantum simulation.
- ***Angela Kuo:*** Collaborating with IBM's Matthias Steffen on superconducting devices based on high-kinetic inductances.
- ***Santiago Nunez-Corrales*** and ***Wolfgang Pfaff:*** Working with IBM's Carlos Costa on building digital twins for quantum devices.
- ***Wolfgang Pfaff:*** Collaborating with IBM's Matthias Steffen on modular qubit architectures.
- ***Andre Schleife:*** Collaborating with IBM's Barbara Jones on first-principles defect simulations and quantum embedding for materials simulation.

Duality

Duality, the nation's first quantum accelerator, aims to support next-generation science and technology. Based in Chicago, IL, it hosts startups from across the globe in year-long accelerator cohorts. Duality provides world-class business and entrepreneurship training from its partner institutions and the University of Chicago's Booth School of Business. UIUC, Argonne National Lab, and P33 are the founding partners at Duality, which is led by the Polsky Center for Entrepreneurship and Innovation at the University of Chicago and the Chicago Quantum Exchange (CQE).

Chicago Quantum Exchange (CQE)

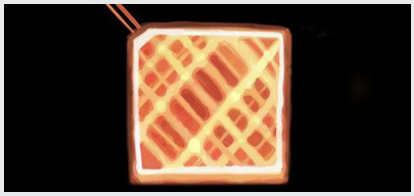
The CQE is an intellectual hub for advancing the science and engineering of quantum information. The CQE is based at the University of Chicago and anchored by the U.S. Department of Energy's Argonne National Lab and Fermilab, the University of Illinois Urbana-Champaign, the University of Wisconsin–Madison, and Northwestern University. CQE connects researchers and institutions at the forefront of theory and experimentation across a broad spectrum of quantum science research areas and provides education and training of quantum scientists and engineers at all stages of their careers.

Collaboration between UIUC and Xanadu reveals quantum technology is more robust than thought

An academia-industry collaboration developed through a fellowship from the NSF-funded QISE-NET and HQAN created a publicly released software suite called qNetVO that showed quantum networks are more robust to noise than previously thought. The fellowship was awarded to Brian Doolittle, a graduate student in Eric Chitambar's group. Working with the Toronto-based company Xanadu to develop computational tools for investigating quantum networks, the researchers used qNetVO simulations to determine that appropriate adjustments to an entire network can make it possible to overcome the effects of bad components and maintain the network's quantum properties.

Diamond cut precision:

Beck to develop diamond sensors for neutron experiments and quantum information science



Douglas Beck was awarded a grant from the Department of Energy to develop sensors based on nitrogen vacancies in diamond, a material whose quantum properties at low temperatures make it unusually sensitive to electric fields. Beck is participating in the Oak Ridge National Lab's nEDM experiment, which will measure the neutrons electric dipole moment, a property that allows neutrons to interact with electric fields despite their neutrality. His group has shown that diamond can be used to measure strong electric fields, and the award will allow the researchers to construct sensors to use in the nEDM experiment.

Quantum visualization technique gives insight into photosynthesis

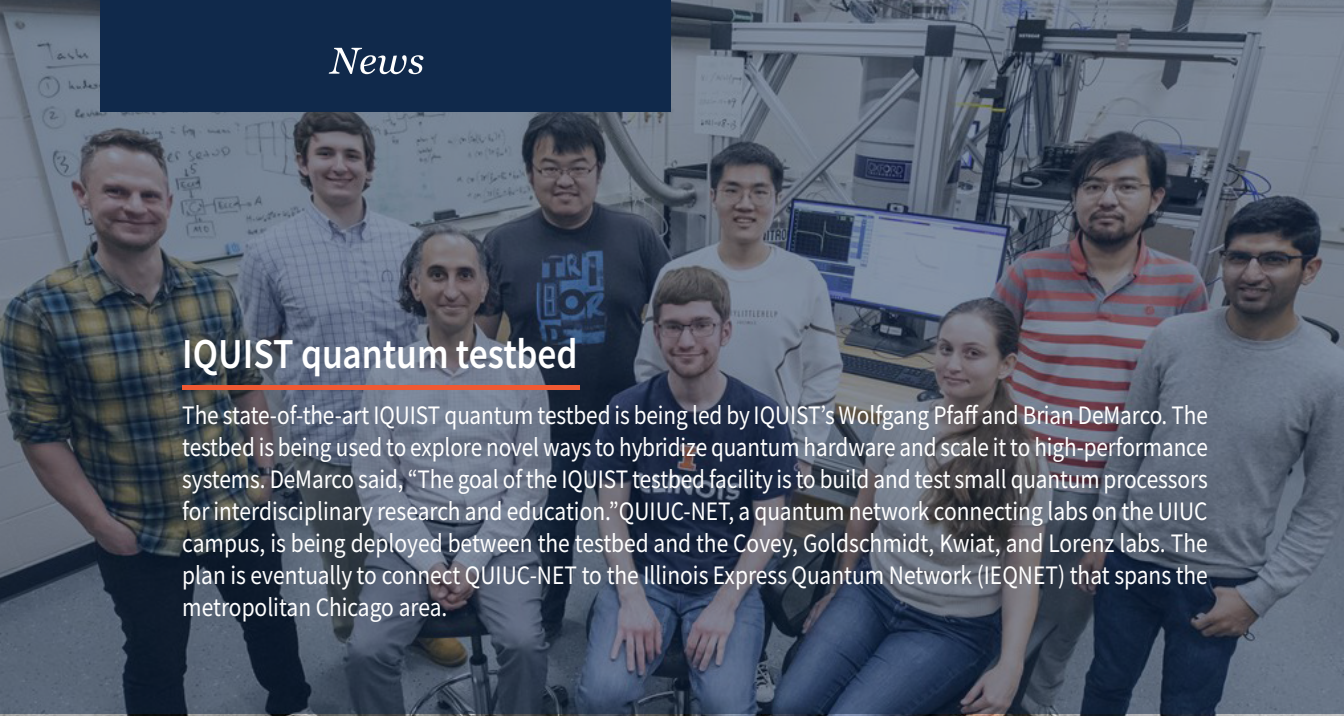
Nancy Makri

The researchers led by Nancy Makri developed a visualization technique that displays quantum features in an easy-to-read diagram called a coherence map. The researchers used these maps to study the quantum mechanisms that underlie photosynthesis. This allowed the researchers to identify the transfer pathways in the bacterial light harvesting complex "very transparently," according to Makri.

Modular quantum computing platform

Wolfgang Pfaff

IQUIST's Wolfgang Pfaff is leading a collaboration of UIUC, Rutgers University, and The University of Texas at Austin to develop a new quantum computing architecture. Supported by a $5.8 million, four-year award from the Army Research Office, the researchers will leverage fluxonium, a promising new superconducting qubit, to control and modularly connect superconducting cavities that store quantum information.



IQUIST quantum testbed

The state-of-the-art IQUIST quantum testbed is being led by IQUIST's Wolfgang Pfaff and Brian DeMarco. The testbed is being used to explore novel ways to hybridize quantum hardware and scale it to high-performance systems. DeMarco said, "The goal of the IQUIST testbed facility is to build and test small quantum processors for interdisciplinary research and education."QUIUC-NET, a quantum network connecting labs on the UIUC campus, is being deployed between the testbed and the Covey, Goldschmidt, Kwiat, and Lorenz labs. The plan is eventually to connect QUIUC-NET to the Illinois Express Quantum Network (IEQNET) that spans the metropolitan Chicago area.

Illinois quantum experts participate in White House NQI summit

Mason appointed to presidential advisory committee on quantum science

In December 2022, Nadya Mason, the Director of the Beckman Institute for Advanced Science and Technology and an IQUIST member, was appointed by President Biden to the National Quantum Initiative Advisory Committee. NQIAC is tasked with making recommendations for the President, Congress, and the National Science Technology Council Subcommittee on Quantum Information Science to consider when reviewing and renewing the National Quantum Initiative Act. Also in December, HQAN leaders were invited to the White House Office of Science and Technology Policy for the National Quantum Initiative Centers Summit. HQAN Director Brian DeMarco; Co-Lead for Education, Workforce Development, and Partnerships Emily Edwards; and HQAN co-PI Mark Saffman from the University of Wisconsin participated in discussions and presentations around NQI achievements and challenges.

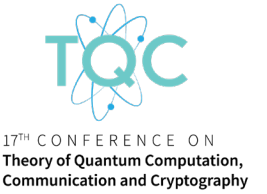
IQUIST-NRIK collaboration to build the first quantum network with open-air links

Paul Kwiat

In August 2022, the National Research Institute of Korea funded a five-year initiative to construct a distributed quantum network connecting nodes separated by 20 kilometers. IQUIST Founding Director Paul Kwiat is playing an integral role in its development. The network will be the first network that connects nodes by using both optical fibers and open-air links to mobile platforms like drones.Kwiat and Hee Su Park of the Korean Research Institute of Standards and Science (KRISS) previously collaborated on a technique that has led to what is now the world's most efficient single-photon source. The network project will extend that research and enable quantum-repeater-enabled networks with unprecedented efficiency.

TQC Conference, July 11–15, 2022

The Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC) is a leading annual international conference on the theoretical aspects of quantum information science. Hosted at UIUC, the 17th TQC brought together the theoretical quantum information science community to present and discuss the latest advances in the field.



IQUIST Seminar Series

IQUIST connected quantum specialists from industry and academia with UIUC students and faculty through its IQUIST Seminar Series. Throughout Fall 2022 and Spring 2023, the seminars gave 27 researchers a platform for sharing their expertise.

Engineering Open House, March 31 & April 1, 2023

IQUIST brought quantum information science activities and events to the public during UIUC's two-day Engineering Open House. Several informational and hands-on exhibits were featured, including a science-based escape room called LabEscape, Wonders of Quantum Physics activities, games that taught quantum principles.

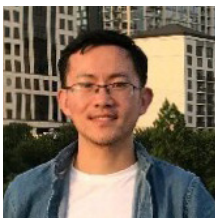
World Quantum Day, April 14, 2023

IQUIST celebrated World Quantum Day with events focused on quantum information science at the Campus Instructional Facility and the Superconductivity Center. Events included an Introduction to Quantum presentation and an "Ask Me Anything" session with IQUIST faculty, staff, and graduate students, as well as a reception, poster session & competition, and laboratory tours.

Ant-Man and the Wasp: Quantumania, February 16–17, 2023 and April 21–22, 2023

IQUIST brought the marvel of quantum to the public with showings of Ant-Man & The Wasp: Quantumania. People were encouraged to ask quantum science questions after the film and enjoy interactive exhibits.



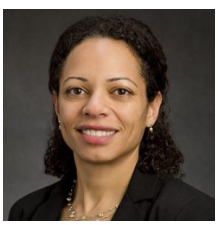












POSTDOCTORAL SCHOLARS PROGRAM

The IQUIST Postdoctoral Scholar Program offers selected scholars an opportunity to engage in an interdisciplinary research fellowship in quantum science. Fellows are appointed annually for up to three years. 2023 awardees include:

- **Yijing Huang**
  Postdoctoral Research Associate
  working with Prof. Fahad Mahmood

- **Zhubing "Gloria" Jia**
  Postdoctoral Research Associate
  working with Prof. Jacob Covey

- **Zhanzhi Jiang**
  Postdoctoral Research Associate
  working with Prof. Angela Kou

OTHER HONORS

- Optica Fellow 2023: **Gaurav Bahl**

- NSF CAREER Awards: **Simeon Bogdanov** and **Dakshita Khurana**

- Elected to the American Academy of Arts and Sciences: **David Cahill** and **Vidya Madhavan**

- 2023 Office of Naval Research Young Investigator Research Program Award: **Jacob Covey**

- American Physical Society Fellows: **Emily Edwards** and **Prashant Jain**

- Elected to the National Academy of Sciences: **Nancy Makri**

- Appointed to the National Quantum Initiative Advisory Committee by President Biden (2022): **Nadya Mason**

IQUIST | BY THE NUMBERS

$100 million+
(in active funding)

49 members

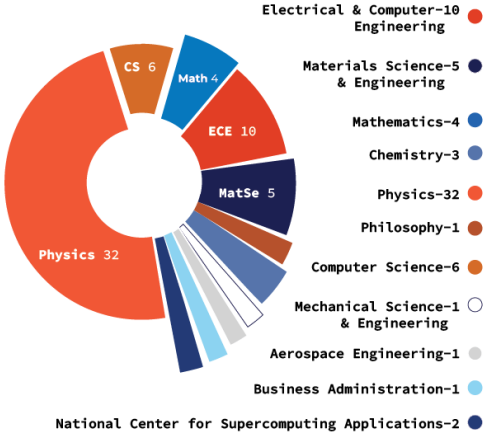
18 affiliates

40+ postdocs

170+ grad students

66

Leading quantum faculty are educating a generation of students in the future of technology and advanced engineering.



Committee Members

EXECUTIVE COMMITTEE

Eric Chitambar,
Associate Professor,
Electrical & Computer Engineering

Brian DeMarco,
Director, IQUIST;
Professor, Physics

Emily Edwards,
Executive Director, IQUIST

Paul Kwiat,
John Bardeen Chair in Electrical Engineering and Physics

Vidya Madhavan,
Professor, Physics

SCIENCE ADVISORY BOARD

Simeon Bogdanov,
Assistant Professor,
Electrical & Computer Engineering

David Cahill,
Professor and Grainger Chair in Engineering,
Materials Science & Engineering

Eric Chitambar,
Associate Professor,
Electrical & Computer Engineering

Bryan Clark,
Associate Professor, Physics

Brian DeMarco,
Director, IQUIST;
Professor, Physics

Emily Edwards,
Executive Director, IQUIST

Dakshita Khurana,
Assistant Professor,
Computer Science

Paul Kwiat,
John Bardeen Chair in Electrical Engineering and Physics

Felix Leditzky,
Assistant Professor, Mathematics

Virginia Lorenz,
Associate Professor, Physics

Vidya Madhavan,
Professor, Physics

Smitha Vishveshwara,
Professor, Physics

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

NONPROFIT
ORGANIZATION
U.S. POSTAGE
PAID
CHAMPAIGN, IL
PERMIT NO. 453

CONTACT

Illinois Quantum Information Science and Technology Center
295 Engineering Sciences Building
1101 W. Springfield Ave.
Urbana, IL 61801

iquist.*illinois.edu* // iquist-info@illinois.edu

Follow IQUIST

Follow on social media: @IllinoisQUANTUM
Facebook, X, Instagram, YouTube and LinkedIn