Northwestern | McCORMICK SCHOOL OF ENGINEERING

SPRING 2020

ELECTRICAL AND COMPUTER ENGINEERING

NORTHWESTERN PART OF NEW US DEPARTMENT OF ENERGY QUANTUM COLLABORATION

Pioneering IEQNET effort aims to connect quantum devices for powerful distributed communications

Northwestern Engineering's **Prem Kumar**, professor of electrical and computer engineering and director of Northwestern University's Center for Photonic Communication and Computing, is one of the researchers working on a new $3.2 million quantum research initiative funded by the US Department of Energy.

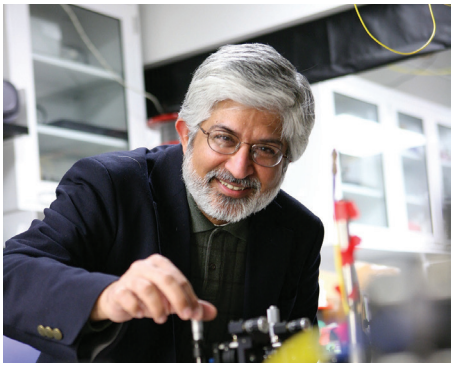
Northwestern will be a partner institution in the effort, which, in conjunction with Fermilab and others, will develop designs for transparent optical quantum networks and demonstrate their operation in the greater Chicago area. These networks promise to lay the foundation for interconnecting quantum computers — which are actively being developed by many companies — much like classical computers are networked today to form the Internet.

"We have leading quantum technology capabilities at our respective institutions. Now we're combining them to create new opportunities for distributed quantum communications," Kumar said.

The proposed Illinois-Express Quantum Network (IEQNET) connects nodes at Fermilab and proposed nodes at Northwestern's Chicago and Evanston campuses. The metropolitan-scale network uses a combination of cutting-edge quantum and classical technologies to transmit quantum information and will be designed to coexist with classical networks. Fermilab is the lead institution for the IEQNET collaboration, which includes Northwestern, the Department of Energy's Argonne National Laboratory, and Caltech.

Scientists have previously demonstrated point-to-point quantum communications over short distances — on the order of 10 miles — in fiber-optic cables. IEQNET's goal is to demonstrate a multinode fiber-optic quantum network that supports multiple users.

The proposed network stretches between the Chicago-area institutions using existing fiber-optic cables. "We want to utilize existing links because we have significant infrastructure that has already been laid for classical communications," said Rajkumar Kettimuthu, an Argonne scientist affiliated with IEQNET. "One of the challenges will be to achieve classical and quantum co-existence in the same fibers."



Prem Kumar

The project also brings together small quantum tech industry partners (NuCrypt, HyperLight) and the Intelligent Quantum Networks and Technologies (INQNET) program, which was developed through a Caltech and AT&T partnership and is a member of the Quantum Economic Development Consortium of the National Institute of Standards and Technology.

By connecting business with academia, IEQNET has the potential to generate new technologies that have wider application in industry, helping elevate the Chicago area as a hot spot for technology transfer in quantum science.

FROM THE CHAIR

Dear friends,

Last year we welcomed a season of significant change and growth in our department, and it is my pleasure to highlight some of the many ways we've evolved.

In response to rapid development and future plans, our department, formerly known as the Department of Electrical Engineering and Computer Science, split into two departments: The Department of Electrical and Computer Engineering, and the Department of Computer Science. The reorganization provides the basis for increased focus, while allowing continued collaboration on research and education with our colleagues in computer science and across the entire fabric of Northwestern.

We are also preparing for the future by advancing our understanding and involvement in quantum science initiatives. Some of the most notable efforts include **Prem Kumar**'s participation in the Illinois-Express Quantum Network (IEQNET), a $3.2 million research initiative funded by the US Department of Energy. Kumar is also actively involved in the Initiative at Northwestern for Quantum Information Research and Engineering (INQUIRE), a new project that aims to integrate and advance our strengths in quantum science. Outcomes from these activities could have far-reaching implications for the future of quantum science, with impacts for new technologies in communications, networking, computing, and beyond.

Bridging engineering and diverse disciplines is one of our many strengths, and last year was no different. Professor **Aggelos Katsaggelos** helped us to deepen our relationship with colleagues in the Feinberg School of Medicine through a productive Workshop on AI and Radiology, which drew more than 150 radiologists, engineers, and computer scientists to collaborate and discuss the intersection of technology and medicine. Katsaggelos is also part of a team that was granted seed money last year through the Collaborative Research Catalyst Awards to apply a novel brain imaging analysis method to study Alzheimer's disease.

Our faculty are widely recognized for their research, and we are honored to celebrate their many accomplishments. In particular, **John Rogers** was elected to the National Academy of Medicine—becoming one of only 25 people ever to be named to all three National Academies. We congratulate Rogers on this tremendous achievement.

I want to also acknowledge some of our talented junior faculty who received well-deserved honors, including **Jie Gu**, who was awarded the prestigious Faculty Early Career Development (CAREER) award from NSF for his work on hardware design for time-domain computing, and **Josiah Hester**, who received a CRII NSF award to research the next generation of energy-harvesting computers. These are accomplishments made by faculty who are supported by the vibrant academic community at Northwestern and beyond, and I look forward to keeping in touch with you about the many activities to come, and welcome hearing from you about ways we can work together toward a better future.

Randy Berry
Department Chair

Jie Gu Receives Prestigious NSF CAREER Award

Grant recognizes 'individuals who exemplify the role of teacher-scholar'

Northwestern Engineering's **Jie Gu** received the prestigious Faculty Early Career Development (CAREER) Award from the National Science Foundation (NSF), the foundation's most prestigious honor for junior faculty members.

The CAREER Award is designed to support promising young faculty members who exemplify the role of teacher-scholar through the combination of outstanding research and education.

Gu is an assistant professor of electrical engineering and computer science in the McCormick School of Engineering. He will receive $566,880 over five years from NSF's Division of Computing and Communication Foundations to develop a systematic design approach for time-domain computing.

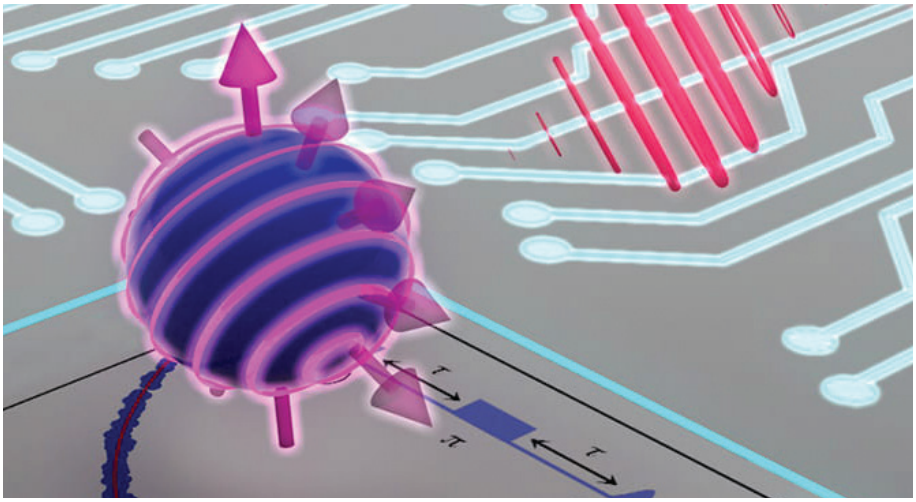
Gu's research group develops novel computing methods that combine digital and mixed-signal circuit technology to enable ultra-low power, ultra-efficient computing. His technologies have potential applications in real-time machine learning, artificial intelligence, or Internet-of-things devices.

Jie Gu

Before joining Northwestern in 2015, Gu was a researcher and developer at Texas Instruments.

INTERDISCIPLINARY INITIATIVE IN QUANTUM SCIENCE LAUNCHED

Project bridges disciplines, connects dozens of faculty thought leaders to pursue fundamental breakthroughs



Learn more about INQUIRE at quantum.northwestern.edu.

An interdisciplinary group of faculty members including Professor **Prem Kumar** are leading a new initiative to integrate and advance its strengths in quantum science, a field that promises to transform communications, security, metrology, sensing, and computing.

The Initiative at Northwestern for Quantum Information Research and Engineering (INQUIRE) is designed to bridge multiple academic domains, bringing together faculty from the University's top-ranked departments, including chemistry and materials science and engineering, as well as physics and astronomy, electrical and computer engineering, and computer science. Additional efforts anchored in some of Northwestern's research institutes, centers, and cross-disciplinary knowledge hubs are an integral part of the initiative.

Northwestern also has joined the Chicago Quantum Exchange, a robust and growing collaboration of academic and government partners whose efforts aim at advancing transformative quantum science.

By combining research strengths across multiple disciplines, INQUIRE will focus on fundamental scientific hurdles. Solving those challenges is vital for national security and the US economy and will help drive the next generation of quantum technologies for communications, networking, computing, sensing applications, and more.

Because of this array of potential impacts, quantum science and engineering has emerged as a rich interdisciplinary field, one that has attracted increased interest and funding from the federal government. In December 2018, President Trump signed into law the National Quantum Initiative Act, a 10-year program that authorizes more than $1 billion for quantum information science through the Department of Energy, the National Science Foundation, and the National Institute of Standards and Technology.

INQUIRE's investigations include creating the materials and methods to propel the future of quantum science. Other highlights include:

By using bottom-up molecular and nanoscale synthetic approaches, researchers at Northwestern are producing the next-generation of quantum materials to make large-area qubit arrays with potential operation up to room temperature, breakthroughs that could transform quantum computing and information processing.

Northwestern materials informatics and data science researchers have demonstrated a design methodology that can create new quantum materials much faster and with less cost.

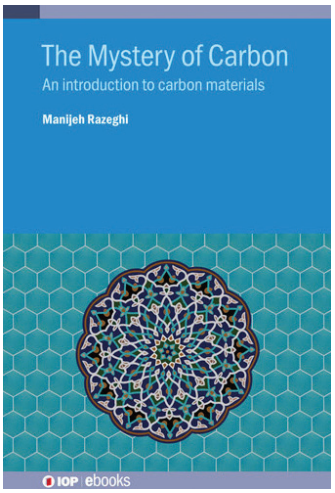
Northwestern has made groundbreaking advances in secure quantum communications, including patented sources of entangled photons used in encrypting fiber-optic quantum networking.

The University's scientists have developed world-class characterization tools to observe and control quantum phenomena — including suspending a single electron for months while measuring it to an unprecedented precision of three parts in 10 trillion.

QUANTUM SCIENCE AND ENGINEERING HAS EMERGED AS A RICH INTERDISCIPLINARY FIELD, ONE THAT HAS ATTRACTED INCREASED INTEREST AND FUNDING FROM THE FEDERAL GOVERNMENT.

NEW TEXTBOOK DEMYSTIFIES CARBON MATERIALS

The focused, concise book aims to be an essential and accessible text for solid-state and electricalengineering students



Carbon is a primary building block of life and forms millions of organic compounds with hydrogen, making it essential to the universe. It is also found in nearly every part of the human body.

Northwestern Engineering's **Manijeh Razeghi**, Walter P. Murphy Professor of Electrical and Computer Engineering wrote a new textbook offering a fundamental understanding of carbon, its science, applications, and recent discoveries made in the field of carbon materials.

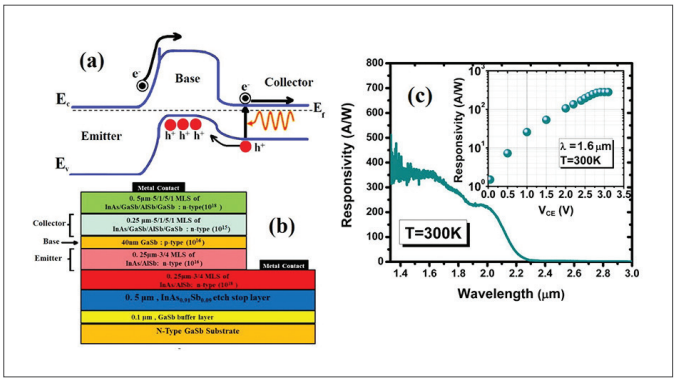
The Mystery of Carbon: An Introduction to Carbon Materials (IOP Publishing Ltd, 2019) presents a vision of carbon as an element essential to all human endeavors, from life itself to many technologies that may emerge over the next decades. It is designed to give science and engineering graduate students a succinct overview of carbon materials and their impact on emerging concepts in science and technology.

Carbon has always fascinated Razeghi. "Everything you can see in the world is made from carbon, including humans," Razeghi said. "From energy to electronic properties to new technologies, there are so many reasons why carbon is important".

"Professor Razeghi has done a challenging task in this book by integrating the fundamental science of carbon with current research topics to stimulate interest of her readers at the senior and graduate level," said **Robert Chang**, professor of materials science and engineering. "This short and concise book takes only one sitting to read, but one walks away with a global perspective on the subject." important."

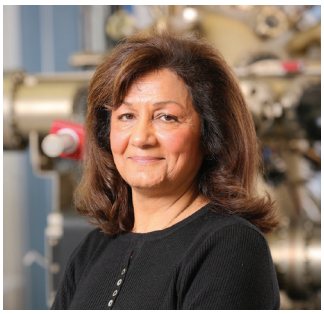
"FROM ENERGY TO ELECTRONIC PROPERTIES TO NEW TECHNOLOGIES, THERE ARE SO MANY REASONS WHY CARBON IS IMPORTANT."

MANIJEH RAZEGHI



(a) Energy-band diagram of e-SWIR HPT (b) Schematic of T2Sl based HPT design (c) T2Ls device optical performance

NOVEL TYPE-II SUPERLATTICE EXPLOITS PHOTOTRANSISTORS



Manijeh Razeghi

Manijeh Razeghi has developed a novel type-II superlattice (T2SL) based heterojunction phototransistor (HPT) device as a possible solution to the urgent demand for sensitive photodetectors for free-space optical communication as well as high-speed sensitive imagers.

As a pioneer research group in growth and implementing T2SL based devices, Razeghi and her team at the Center for Quantum Devices (CQD) demonstrated a newly developed InAs/AlSb/GaSb T2SLs-based HPT, which can take advantage of the extreme bandstructure tunability of T2SL material system to deliver low noise and large optical conversion gain for the HPT device.

Supported by the Defense Advanced Research Projects Agency (DARPA), the Army Research Laboratory, and NASA, the team's paper, "Extended Short Wavelength Infrared Heterojunction Phototransistors Based on Type II Superlattices" was published in *Applied Physics Letters*.

"For the first time, by using a well-designed band structure-engineering approach, we showed capability of T2SL based device to cover e-SWIR region for HPT devices," said Razeghi, director of CQD.

Extended short-wavelength infrared (e-SWIR) photodetectors are of great interest for many applications such as medical imaging, astronomy, light detection and ranging (LiDAR), quantum computing, and single photon detection. By extending short wavelength infrared toward longer wavelength cutoff to cover up to 2.5 μm (e-SWIR), it allows superior transmission through common atmospheric obscurants such as fog, clouds, dust, and smoke.

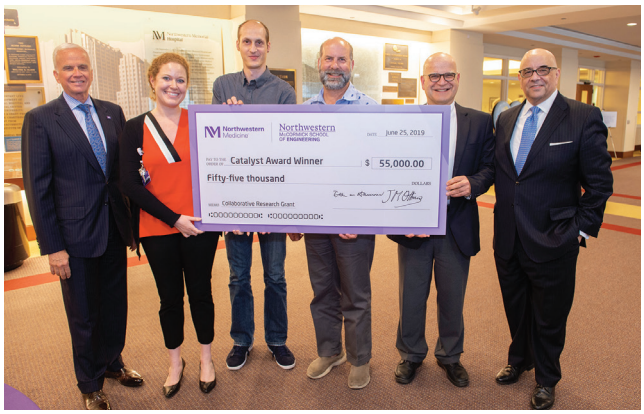
Northwestern Medicine Collaborations Receive Inaugural Catalyst Award

Faculty teams receive $55,000 in seed money

Aggelos K. Katsaggelos is one of three Northwestern Engineering faculty members on teams that were granted $55,000 in seed money through the Collaborative Research Catalyst Awards.

The new grants for this research collaboration opportunity require one principal investigator be an employed physician with Northwestern Medicine and another to be a faculty member of the McCormick School of Engineering.

Katsaggelos, Joseph Cummings Professor of Electrical and Computer Engineering, and Todd Parrish, professor of radiology at Northwestern's Feinberg School of Medicine and of biomedical engineering at Northwestern Engineering, will work with S. Kathleen Bandt, a Northwestern Medicine neurosurgeon, and Pierre Besson, a postdoctoral fellow in the department of radiology. The group will apply a novel approach to brain imaging analysis, known as surface-based deep learning, to study Alzheimer's disease.



Left to right: Dean Harrison, S. Kathleen Bandt, Pierre Besson, Todd Parrish, Aggelos K. Katsaggelos and Dean Julio Ottino.

Currently, tools are limited to identify Alzheimer's early in the disease when patients suffer from mild cognitive impairment. The group aims to create new tools for diagnosis at the early stage and predict the clinical progression of the disease within six months of diagnosis.

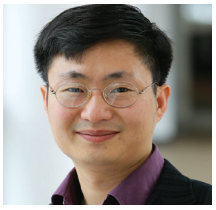
New Institute Aims to Explore Theoretical Foundations of Data Science

The multidisciplinary institute unites Northwestern University, Toyota Technological Institute at Chicago, and University of Chicago

Randall Berry and **Dongning Guo** are two of 14 coprincipal investigators working together in a new collaborative institute: the Institute for Data, Econometrics, Algorithms, and Learning (IDEAL).

IDEAL is a multi-discipline (computer science, statistics, economics, electrical engineering, and operations research) and multi-institution (Northwestern University, Toyota Technological Institute at Chicago, and University of Chicago) institute focused on understanding key aspects of data science theory. Supported by the National Science Foundation HDR TRIPODS program, IDEAL aims to develop the foundations of data science by combining perspectives from algorithms, econometrics, and machine learning.

Randy Berry



Dongning Guo

A key component for the institute is the incorporation of econometrics in the academic dialog around data science. "Northwestern has a strong connection between computer science and economics. It's an incredibly underexplored area and potential opportunity for this institute," said Jason Hartline, professor of computer science at Northwestern Engineering and codirector of IDEAL.

Through academic special quarters, workshops, and external visitors, IDEAL aims to foster interdisciplinary, inter-institute collaborative research. The institute will support the study of three broad research themes: high dimensional data analysis, data science in strategic environments, and machine learning and optimization. IDEAL's first special quarter, "Inference and Data Science on Networks," starts this spring.

John Rogers Elected to the National Academy of Medicine

Rogers becomes one of only 25 people ever to be named to all three National Academies

John Rogers

Northwestern Engineering's **John Rogers**, the Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering and Neurological Surgery and professor of electrical and computer engineering (by courtesy), has been honored with election to the National Academy of Medicine (NAM).

NAM, previously known as the Institute of Medicine, is one of three academies that make up the National Academies of Sciences, Engineering, and Medicine in the US, and is one of the highest honors in the fields of health and medicine. NAM serves as a source of expertise by providing independent, evidence-based scientific and policy advice to inspire action across the private and public sectors regarding critical issues in health, medicine and science.

Rogers becomes one of only 25 people ever to be named to the National Academies of Sciences, Engineering, and Medicine.

Since it was founded in 1970, current members of NAM elect no more than 90 regular members and 10 international members annually based on professional achievement and a commitment to service and advancement in the fields.

"We are tremendously proud to see John recognized at the highest level, yet again," said Julio M. Ottino, dean of the McCormick School of Engineering. "It is a truly remarkable and rare accomplishment to be elected to all three branches of the National Academies, and it reflects the impact his pioneering research has made across disciplines and how people like John are blurring the boundaries of disciplines."

FACULTY NEWS

Randall Berry co-chaired a talk on AI for network monitoring at a Networking and Information Technology Research and Development workshop in Rome, New York.

Alok Choudhary was selected to participate in the US Secretary of Energy Advisory Board working group for artificial intelligence.

Nikos Hardavellas and collaborators were awarded the 2019 Test-of-Time Award by Extended Database Technology (EDBT) during the EDBT/ICDT Joint Conference in Lisbon, Portugal.

Josiah Hester received a $175,000 Computer and Information Science and Engineering Research Initiation Initiative two-year grant from the National Science Foundation.

Prem Kumar took the helm as editor-in-chief of *Optica*, The Optical Society's monthly peer-reviewed journal for optics and photonics content.

Thrasos Pappas was awarded the 2019 Leo L. Beranek Meritorious Service Award by The Signal Processing Society.

Allen Taflove and his team are developing dynamic partial-wave spectroscopic (PWS) micros-copy to detect possible cancers in their early stages.

ECE PROFILES

PhD Candidates Place Second in CSAW '19 Logic Locking Conquest

Amin Rezaei

Yuanqi Shen

PhD candidates **Amin Rezaei** and **Yuanqi Shen** placed second in the 2019 Cyber Security Awareness Week (CSAW) Logic Locking Conquest.

The annual competition challenges participants to attack designs secured with sophisticated logic locking methods, a revolutionary technique for protecting intellectual property and integrated circuits against cyber attacks.

Rezaei and Shen, from the NULogiCS lab under the supervision of Professor **Hai Zhou**, presented their attacks and defenses at the finals held in November at New York University Tandon School of Engineering to a panel of judges from US government agencies, semiconductor companies, and defense contractors. Borrowing the idea from one of their research works, "SAT-based Bit-Flipping Attack on Logic Encryptions," they were able to solve the first half of the keys exactly and the second half approximately, with a low error rate in less than one minute for the largest locked circuit.

Alumni Profile: Catherine Canby

Canby will work for Apple before pursuing a law degree

Every year, the Grace Hopper Celebration brings together women technologists from around the world for a conference centered on empowering women in computing and technology fields through a career fair, speakers, and mentoring circles.

For recent alumna **Catherine Canby** ('19), the conference changed her life.

During the 2018 trip with nearly 50 Northwestern Engineering students, Canby secured her post-graduation job as an engineering project manager with Apple during the conference career fair.

"Attending the conference gave me lots of exposure to different tech companies, and I attribute my position at Apple to going to that conference," Canby said. "That wouldn't have been possible without McCormick."

During her time at Northwestern, Canby, who also earned a managerial analytics certificate from the Kellogg School of Management, pursued opportunities beyond her engineering studies.

Canby participated in the Institute for Student Business Education group, in addition to helping lead Northwestern's Society of Women Engineers chapter, tutoring her peers in the Engineering Analysis 1 course, and serving as the president of the electrical and computer engineering honor society. She also interned at Medtronic and PricewaterhouseCoopers.

> "MY LONG-TERM GOAL IS TO GO TO LAW SCHOOL, AND THE FACULTY WERE REALLY SUPPORTIVE OF ME EVEN THOUGH THAT'S NOT A VERY TRADITIONAL CAREER PATH."
>
> CATHERINE CANBY

Canby felt supported by the ECE department throughout her four years at the McCormick School of Engineering. **Allen Taflove**, professor of electrical and computer engineering, particularly took an interest in her career path since her first quarter on campus.

"I had a really, really great experience in the ECE department," Canby said. "My long-term goal is to go to law school, and the faculty were really supportive of me even though that's not a very traditional career path."

Northwestern | McCORMICK SCHOOL OF ENGINEERING
Electrical and Computer Engineering

Technological Institute
2145 Sheridan Road
Evanston, Illinois 60208-3100

Nonprofit
Organization
U.S. Postage
PAID
Northwestern
University

ECE Facts and Figures

1/3 of faculty have joint appointments with other departments

connections to Chicago

Alumni work at Nokia Bell Labs and Motorola, while students and faculty participate in research collaborations with local national labs including Argonne National Laboratory and Fermilab

7 research centers where faculty actively collaborate

13 faculty members have NSF CAREER awards and other young investigator awards