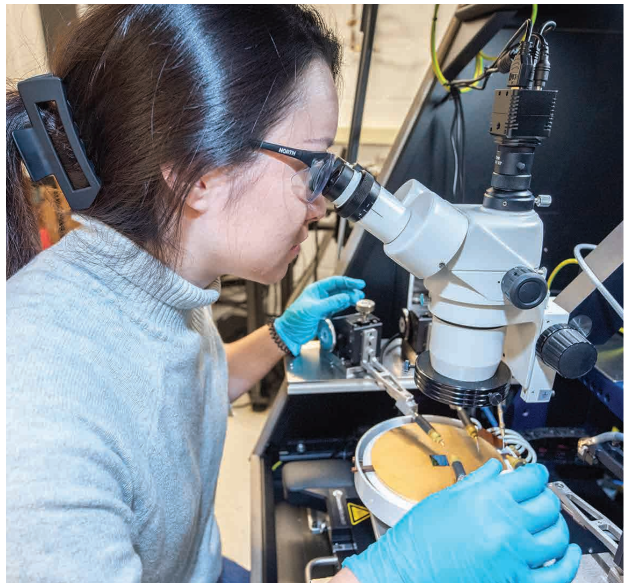
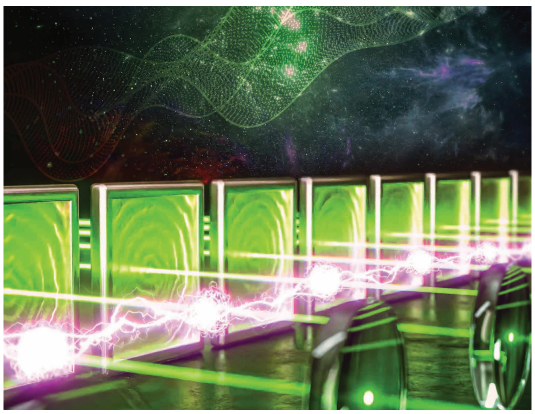
inside ECE

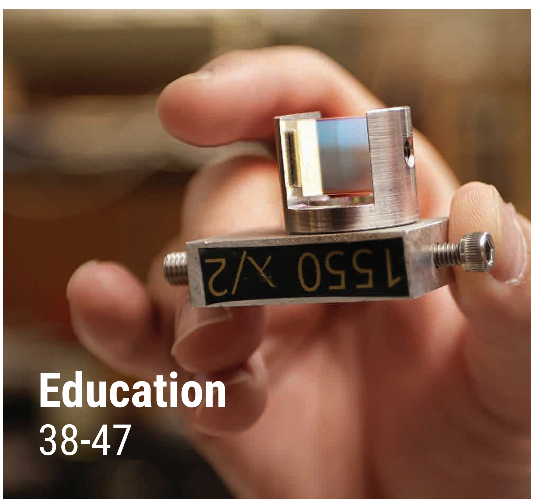
2023 Year in Review

ECE ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY OF MICHIGAN

INSIDE THIS **ISSUE**







ELECTRICAL AND COMPUTER ENGINEERING
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We would like to thank the many additional contributors to the magazine, especially members of the College of Engineering Communications team.

COVER PHOTO: Students participating in the M-SHORE program get ready to enter the Lurie Nanofabrication Facility. Read more on page 43.

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DEAR ECE COMMUNITY,

It's been nearly five months since I've taken on the role of Interim Chair for Electrical and Computer Engineering, and it's been enlightening, rewarding, and a challenge – like all worthy endeavors.

Our former Chair, Mingyan Liu, is now our Associate Dean for Academic Affairs at the College of Engineering. In this role the entire College is now benefiting from her clear vision and ambitious goals.

Part of her legacy here in ECE is the hiring of seven new faculty starting in the 2023-24 academic year. They will deepen and expand our strength in computer networks, sustainable energy systems, optoelectronics, biomedical AI, control of biological systems, machine learning, and more.

Years of effort behind the scenes has led to the new U-M Quantum Research Institute, co-led by Mack Kira. Many other ECE faculty are part of this new Institute, and we are excited for the opportunities this will bring for collaborations across the university and beyond as we explore the potential inherent in this revolutionary technology. We are preparing our students to enter this field through the creation of several new undergraduate courses, which you can read about in our Education section.

In this issue, you'll also read about expanding efforts to support the future microelectronics and semiconductor industry through groundbreaking research, workforce development, and collaborations with other institutions and industry.

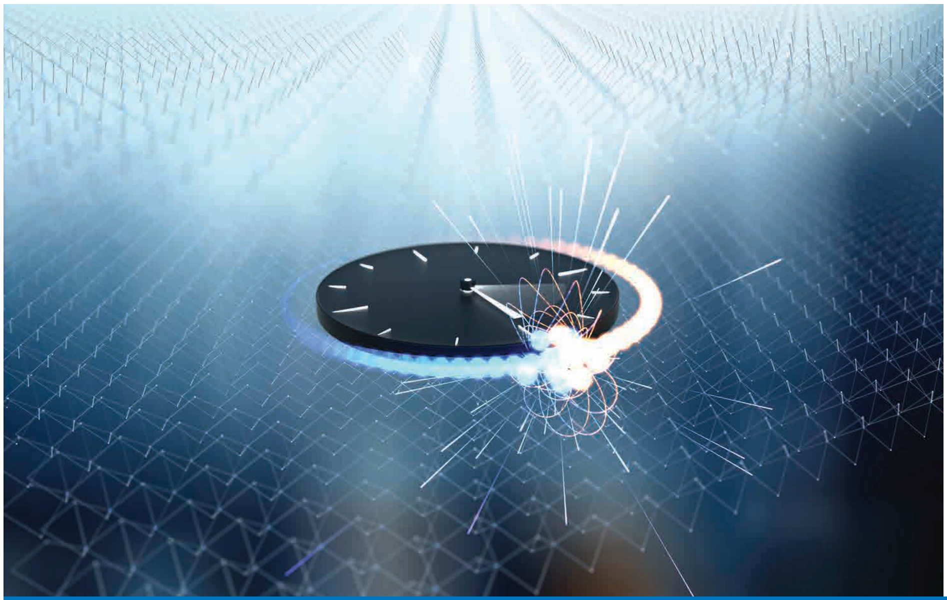
I hope you take the time to read the stories about our remarkable students and alumni, and enjoy the photos taken at some of our events, including Pie a Prof day, and snapshots of our popular summer tech camp called Electrify.

As always, it's an exciting time to be part of Electrical and Computer Engineering!

DENNIS SYLVESTER
Interim Chair, Electrical and Computer Engineering
Edward S. Davidson Collegiate Professor of Electrical and Computer Engineering

Quantum is Here to Stay

ECE's research and education in the area of Quantum Information Science and Technology complements the goals of the newly-established Quantum Research Institute, which is co-directed by ECE faculty. It's an exciting time be working in quantum!



An artist's impression of attosecond clocking.
Credit: Brad Baxley (parttowhole.com)

The New Quantum Research Institute

Earlier this year, U-M announced the official establishment of the Quantum Research Institute, which comes with a $55M investment "to address global quantum challenges and prepare a new generation of researchers to drive groundbreaking discoveries."

The Institute is a formal recognition of the remarkable achievements in quantum science and technology that have been happening across the Michigan campus for decades. And it comes at a time when capitalizing on those accomplishments will take creativity, teamwork, and a convergence of interdisciplinary approaches to achieve their future potential.

"The Institute provides structure where new ideas can quickly evolve," said Mackillo Kira, co-director of the Institute with Steven Cundiff, the Harrison M Randall Collegiate Professor of Physics. "Michigan should be who people think of when it comes to quantum photonic information technology. We have the people, we have the expertise, and now we have the organizational infrastructure with the Quantum Research Institute."

Michigan's strengths and advancements in quantum science over the past several decades are based on a unique research loop that connects many-body quantum theory, quantum material synthesis, and quantum experiments in the area of quantum-light information technology.

But we're still in the infancy of quantum research.

"If we compare quantum to the development of computing, we're still in the vacuum tube era," said Kira. "The next big thing will be to convert these vacuum tubes into real technology."

And much of that will have to do with the integration of classical and quantum components in what Kira calls "quantum plug and play."

> **"Michigan should be who people think of when it comes to quantum photonic information technology."**
> —Mackillo Kira

"If you have artificial-intelligence tasks computed in an ordinary cloud computer, it might consume a huge amount of energy," explained Kira. "But if you apply a quantum component to the most critical parts, it might be able to reduce the energy load and also speed up the processing. But first you have to figure out how to combine a quantum component with a classical component. And for that, you need expertise in materials, light, and sensing. We have a very strong team on these topics."

Industry, from startup companies to multinational corporations, will be key members of the Quantum Research Institute. Locally that includes the semiconductor, automotive, and chemical industries, as well as several local companies specializing in light and spectroscopy.

"That way," said Kira, "we'll have a network of industrial partners that can quickly benefit from the new discoveries that will come out of the Quantum Research Institute."

ECE faculty have already been creating new courses at the undergraduate level to prepare students for the so-called second quantum revolution.

"We have to train the new generation of engineers to speak the language of quantum technologies, and then how to utilize that technology in systems that they're trying to build themselves," said Alex Burgers, who recently developed one of these new undergraduate courses (read more on pages 38-40).

A Grand Vision for Quantum Light Information Technology

> **"What we've needed, in order to push performance forward, are snapshots of that electron movement that are a billion times faster. And now we have it."**
> —Mackillo Kira

Imagine electronics that operate a million times faster - realizing quantum computing speeds - and sensors that are so accurate they can track objects that are smaller than a single molecule.

In a recent review published in *Nature Reviews Materials,* Prof. Mack Kira and his team shared their grand vision for how these possibilities can become reality with lightwave electronics.

"With lightwave electronics, we'll be able to access a completely new world of quantum phenomena," said Kira. "We could even visualize what's happening inside quantum materials, which is extremely important to develop quantum technology further."

The article was published just three weeks before the world heard that the 2023 Nobel Prize in Physics went to three independent individuals "for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter."

Lightwave electronics is one of the promising applications that have become possible with the ability to generate attosecond pulses of light. With lightwave electronics, electrons can be guided by ultrafast laser pulses.

"Your current computer's processor operates in gigahertz, that's one billionth of a second per operation," said Kira. "In quantum computing, that's extremely slow because electrons within a computer chip collide trillions of times a second and each collision terminates the quantum computing cycle."

"What we've needed, in order to push performance forward, are

Mackillo Kira (L) and Markus Borsch work together in Kira's office going over some of the fundamental light emission properties for semiconductors. Photo: Brenda Ahearn.

snapshots of that electron movement that are a billion times faster. And now we have it," added Kira, thanks to the experimental results of his team members at the University of Regensburg.

But that's not all.

The result's potential impact in the field of many-body physics could surpass its computing impact, according to Rupert Huber, professor of physics at the University of Regensburg and long time collaborator with Kira. Huber's team performed the experiments, while Kira's team focused on the theory.

"Many-body interactions are the microscopic driving forces behind the most coveted properties of solids—ranging from optical and electronic feats to intriguing phase transitions—but they have been notoriously difficult to access," said Huber. "Our solid-state attoclock could become a real game changer, allowing us to design novel quantum materials with more precisely tailored properties and help develop new materials platforms for future quantum information technology."

Quantum materials could possess robust magnetic, superconductive or superfluid phases, and quantum computing represents the potential for solving problems that would take too long on classical computers. Pushing such quantum capabilities will eventually create solutions to problems that are currently out of our reach. That starts with basic observational science.

"No one has been able to build a scalable and fault-tolerant quantum computer so far and we don't even know what that would look like," said Markus Borsch, ECE doctoral student. "But basic research, like studying how electronic motion in solids works on the most fundamental levels, might give us an idea that leads us in the right direction."

Lightwave electronics use the oscillating electric field of light to move charge carriers faster than a single cycle of light. This could seamlessly convert quantum states between light and matter, resulting in quantum chips that are faster, more efficient, and longer lasting. By enabling an electronics-optics interface, semiconductor-compatible technology could be a million times faster than existing electronics.

Another application is quantum sensors. "You could study extremely tiny objects, like smaller than a single molecule," said Kira. "You could monitor the environment by tracking and quantifying even trace amounts of chemicals. You could put them on the satellites to track weather patterns and climate change."

Researchers are also exploring how this quantum technology can be integrated with current electronics, rather than completely replace it.

At Michigan, Prof. Alex Burgers researches the quantum control of single atoms to advance understanding of quantum systems and impact applications of quantum information science, including quantum sensors. Prof. Zetian Mi is looking to discover materials that can both apply lightwave electronics and also support artificial photosynthesis, which could revolutionize clean energy. Prof. Parag Deotare is developing excitonic systems that will advance quantum metrology as well as efficient exchange of quantum information. And as you can read in the next story, Prof. Zheshen Zhang is pushing the frontiers of quantum sensing beyond classical limitations.

A lightwave travels in one attosecond a distance corresponding to the size of an atom.

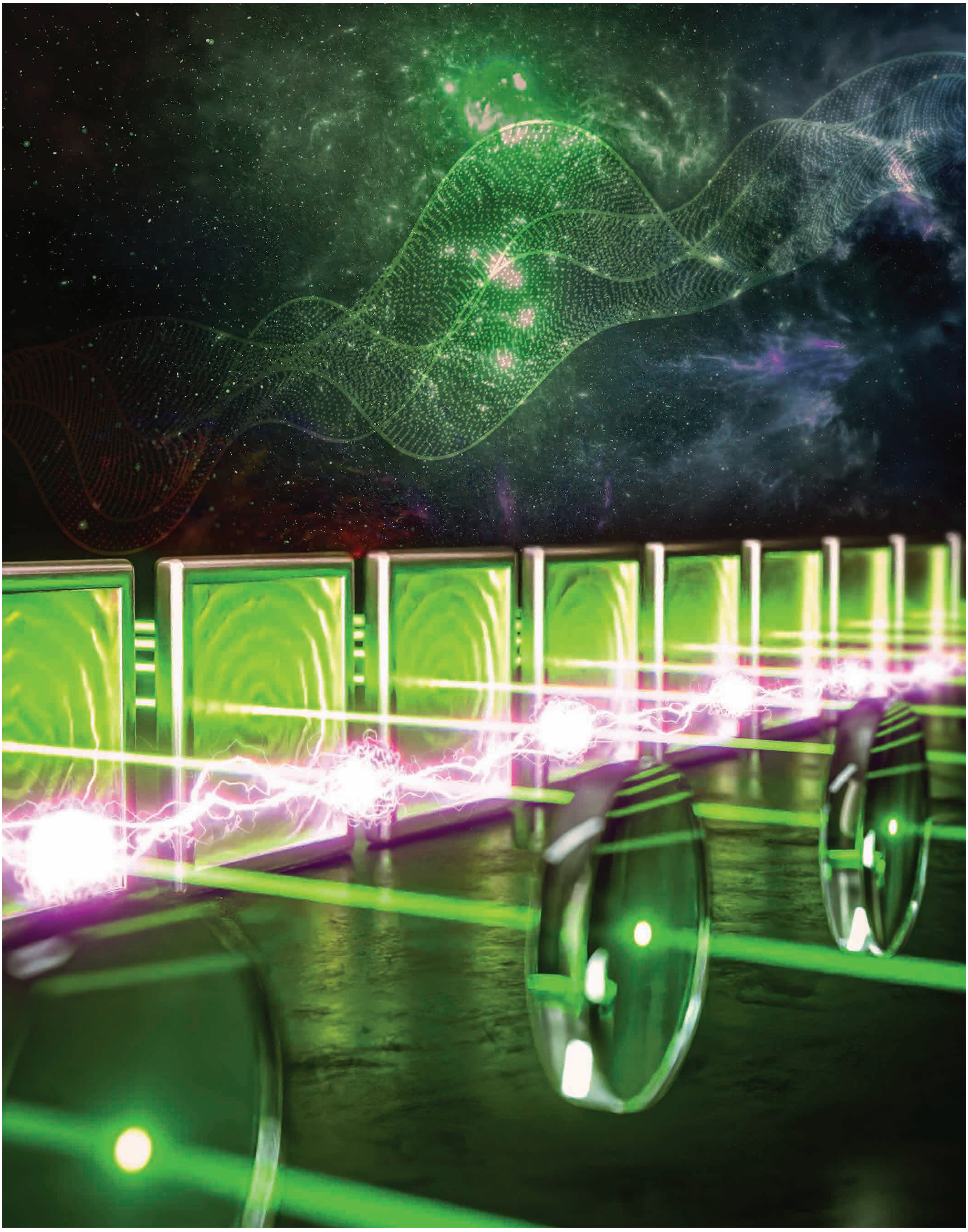
How fast is an
Attosecond?

A QUINTILLIONTH OF A SECOND

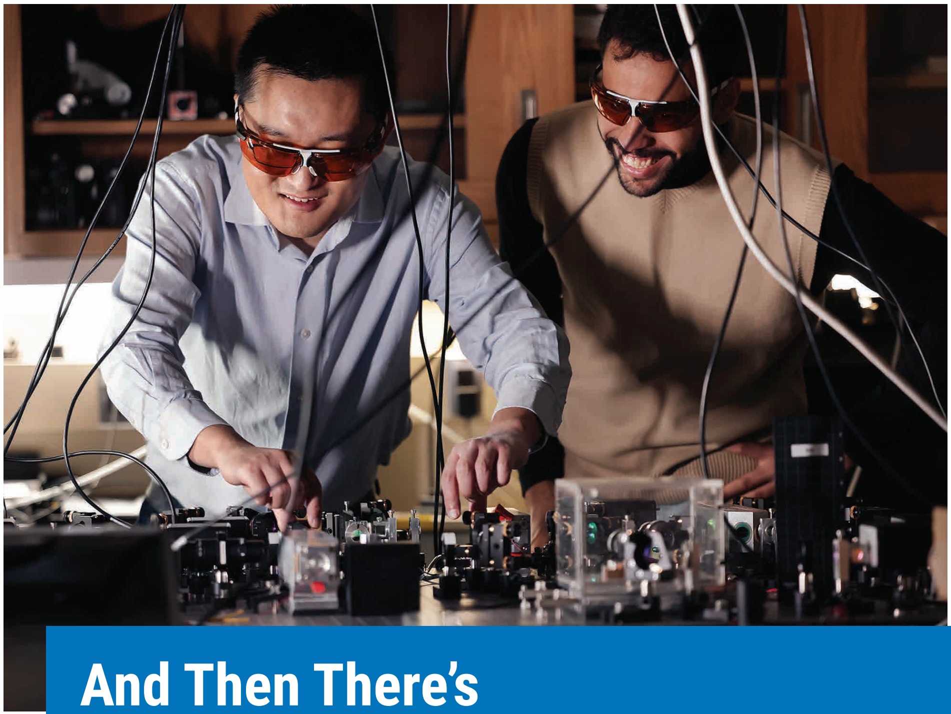
A BILLIONTH OF A BILLIONTH OF A SECOND

10^{-18} SECOND

FASTER THAN *THE FLASH*



An array of membranes, each probed by laser beams that are entangled with one another, could enable miniaturized yet highly accurate devices for measuring acceleration, dark matter and more. Designed by Ehsan Faridi and Ehsan Keshavarzi, Inmywork Studio



Zheshen Zhang (L) and Abdulkarim Hariri, a PhD student in the Quantum Engineering Laboratory. Photo: Brenda Ahearn.

And Then There's Quantum Entanglement

The "spooky action at a distance" that once unnerved Einstein may be on its way to being as pedestrian as the gyroscopes that currently measure acceleration in smartphones. Quantum entanglement could take things much further, such as radically improving the precision of sensors that can be used to navigate without GPS.

"By exploiting entanglement, we improve both measurement sensitivity and how quickly we can make the measurement," said Prof. Zheshen Zhang.

Quantum entanglement could make optomechanical sensors more accurate than today's inertial sensors. It could also enable optomechanical sensors to look for very subtle forces, such as identifying the presence of dark matter. Dark matter is invisible matter believed to account for five times more of the mass in the universe than what we can sense with light. It would tug on the sensor with gravitational force.

> **"By exploiting entanglement, we improve both measurement sensitivity and how quickly we can make the measurement."**
> —Zheshen Zhang

To enable high accuracy in miniaturized optomechanical sensors, Zhang explored quantum entanglement with former colleagues at the University of Arizona, namely Prof. Dalziel Wilson and doctoral students Aman Agrawal and Christian Pluchar, who built the membrane devices.

Rather than splitting the light once so that it bounced off a sensor and a mirror, they split each beam a second time so that the light bounced off two sensors and two mirrors. These membranes, just 100 nanometers—or 0.0001 millimeters—thick, move in response to very small forces.

Doubling the sensors improves the accuracy, as the membranes should be vibrating in sync with each other, but the entanglement adds an extra level of coordination. Zhang's group created the entanglement by "squeezing" the laser light.

In squeezed light, the photons are more closely related to one another. Zhang contrasted what happens when the photons go through a beam splitter with cars coming to a fork in the freeway.

"You have three cars going one way and three cars going the other way. But in quantum superposition, each car goes both ways. Now the cars on the left are entangled with the cars on the right," he said.

Because the fluctuations in the two entangled beams are linked, the uncertainties in their phase measurements are correlated. As a result, with some mathematical wizardry, the team was able to get measurements that are 40% more precise than with two unentangled beams, and they can do it 60% faster. What's more, the precision and speed is expected to rise in proportion to the number of sensors.

"It is envisioned that an array of entanglement-enhanced sensors will offer orders-of-magnitude performance gain over existing sensing technology to enable the detection of particles beyond the present physical model, opening the door to a new world that is yet to be observed," said Zhang.

The team's next steps are to miniaturize the system. Already, they can put a squeezed-light source on a chip that is just half a centimeter to a side. They expect to have a prototype chip with the squeezed-light source, beam splitters, waveguides and inertial sensors within a year or two.

Next Generation Electronics

From batteryless devices to advanced haptic displays to the next generation of solar panels and LED displays, ECE faculty are inventing the tools needed to support the electronics of the future. Their work is improving the sustainability and reliability of the electronic technology that will define the next era.

Ding Wang and Ping Wang prepare the ferroelectric tests on their ScAlN sample. Photo: Brenda Ahearn

The Future is Ferroelectric

Ferroelectric semiconductors are contenders for bridging mainstream computing with next generation architectures, and Prof. Zetian Mi led a team that made them just five nanometers thick, merely a span of 50 or so atoms.

This technology also paves the way for integrating ferroelectric technologies with conventional components used in computers and smartphones, expanding artificial intelligence and sensing capabilities. They could also be used in the batteryless devices that power smart homes, identify problems with industrial systems, and alert people to safety risks, among other things.

“This will allow the realization of ultra-efficient, ultra-low-power, fully integrated devices with mainstream semiconductors,” Mi said. “This will be very important for future AI and IoT-related devices.”

Ferroelectric semiconductors stand out from others because they can sustain an electrical polarization, like the electric version of magnetism. But unlike a fridge magnet, they can switch which end is positive and which is negative. This property can be used in many ways—including sensing light and acoustic vibrations, as well as harvesting them for energy.

“These ferroelectric devices could be self-powered,” Mi said. “They can harvest ambient energy, which is very exciting.”

And they offer a different way of storing and processing both classical and quantum information. For instance, the two electrical polarization states can serve as the one and zero in computing. This way of computing can also emulate the connections between neurons, which enable both memory storage and information processing in the brain. Known as neuromorphic computing, this kind of architecture is ideal for supporting AI algorithms that process information through neural networks.

Storing energy as electrical polarization requires less energy than the capacitors in RAM, which constantly draw power or else lose the data they store, and could even outlast a solid-state drive. This kind of memory could be more densely packed, which increases capacity, and have the ability to withstand harsh environments including extreme temperatures, humidity and radiation.

Mi's team had previously demonstrated ferroelectric behavior in a semiconductor made of aluminum nitride spiked with scandium, a metal sometimes used to fortify aluminum in performance bicycles and fighter jets. However, in order for it to be practical for modern computing devices, they achieved films thinner than 10 nanometers, or about the thickness of 100 atoms.

In addition, the nanoscale manufacturing improved the researchers' ability to study the fundamental properties of the material.

"With this thinness, we can really explore the minuscule physics interactions," said Ping Wang, an ECE Research Scientist. "This will help us to develop future quantum systems and quantum devices."

But Mi's team didn't stop there. They also developed a reconfigurable, ferroelectric high electron mobility transistor (FeHEMT) that is ideal for high frequency and high power applications. Areas of particular interest for this device are reconfigurable RF/microwave applications as well as memory devices in next generation electronics and computing systems.

"By realizing this new type of transistor," Mi said, "it opens up the possibility for integrating multifunctional devices, such as reconfigurable transistors, filters, and resonators, on the same platform – all while operating at very high frequency and high power. That's a game changer for many applications."

The device structure was grown using molecular beam epitaxy (MBE), which allowed the team to control the thickness of the material at an atomic scale. MBE is also one of the preferred methods to manufacture mainstream nitride-based devices.

Support was provided by the Lurie Nanofabrication Facility and the Michigan Center for Materials Characterization.

"This will be very important for future AI and IoT-related devices."
—Zetian Mi

ECE PhD student Minming He and ECE Research Scientist Ding Wang working on the epitaxy and fabrication of high electron mobility transistors (HEMTs) based on a new nitride material, ScAlN. Photo: Brenda Ahearn

Tanya Newsom measures the electrical characteristics of thin film transistors. Photo: Silvia Cardarelli

New Method for Manufacturing TFTs Results in High Performance, Low-voltage Device Operation

Prof. Becky Peterson led a team that has developed a scalable, manufacturable method for developing thin film transistors (TFTs) that operate at the lowest possible voltage. This is particularly important for TFT integration with today's silicon complementary metal-oxide semiconductors (CMOS), which are used in the vast majority of integrated circuits.

"We're essentially developing a less complicated device that operates at lower voltage," said ECE PhD student Tonglin (Tanya) Newsom. "With this steep subthreshold swing device, we could significantly lower the energy dissipation of our circuitry, meaning there's less energy loss. This could help everyone who uses electronic devices."

Peterson's team focused on amorphous oxide semiconductors, which are a category of materials that are commercialized in displays and enable us to individually control pixels. They're important for achieving low power operation, high pixel density screens, touch screens, and haptic displays, which generate tactile effects – such as vibrations – for a variety of applications, including wearables and AR/VR devices.

"I truly hope more people will become interested in doing this kind of fundamental science and engineering," Newsom said "because this work is not just about discovering new possibilities – it's about improving technology to help the world."

> **"This work is not just about discovering new possibilities – it's about improving technology to help the world."**
> —Tonglin Newsom

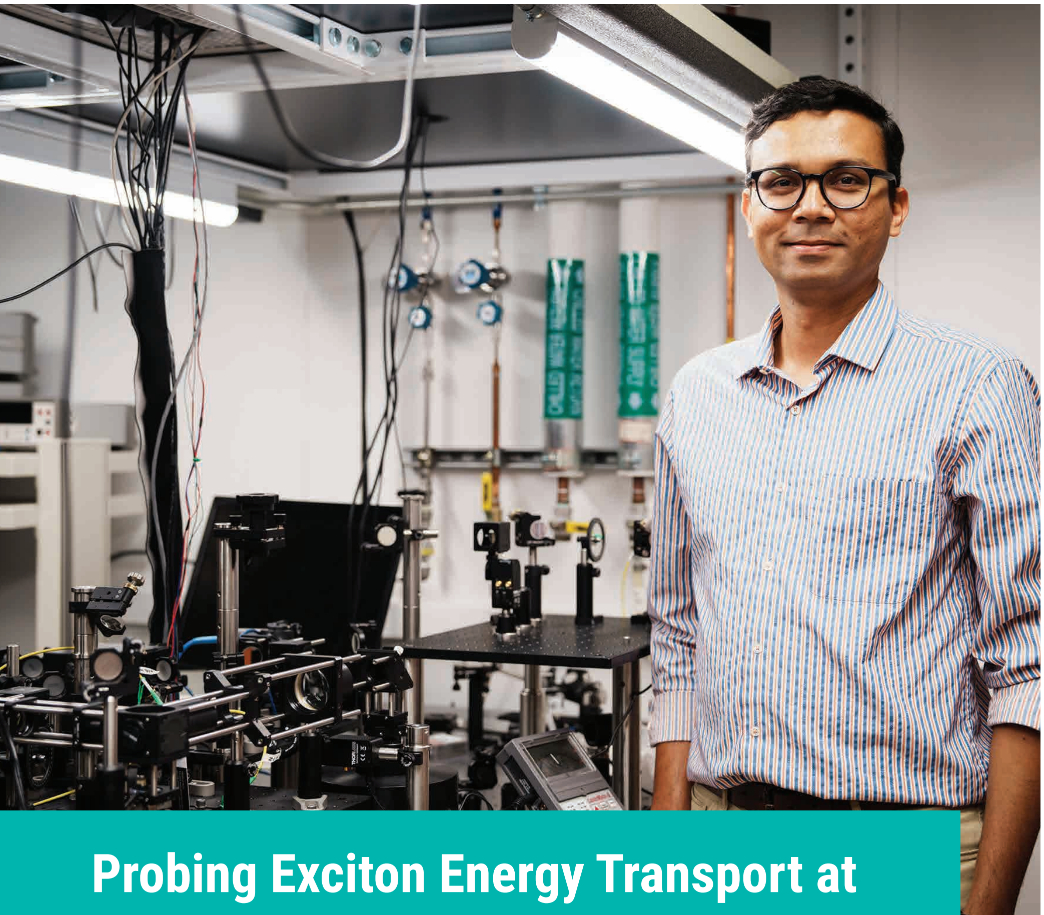
TFTs enable the operation of modern displays, acting as switches that control the light at each individual pixel. Switching efficiently between the on and off states allows for lower voltage operation, and results in a more energy-efficient system.

"The key technology that we were trying to develop is an ultra-clean interface between the semiconductor and the gate insulator, so the switching process between the on and off states would be very sharp," Peterson said. "We were able to achieve switching at the fastest rate possible, according to fundamental physical limits at room temperature."

To do this, Peterson's group partnered with Mechanical Engineering Professor Neil Dasgupta, with whom they developed an atomic layer deposition technology for zinc tin oxide, which is a wide bandgap semiconductor that can be used for electronic and energy devices, such as TFTs, versatile sensors, and solar cells. Peterson's team took this technology one step further.

"We get the best results by depositing the two layers back-to-back within the same tool, without breaking vacuum," Peterson said. "This approach demonstrates a straightforward method to achieve optimal TFT performance."

Fabrication work was accomplished in the Lurie Nanofabrication Facility; Peterson serves as the Facility's Director.



Parag Deotare in one of his labs where he conducts research into excitons. Photo: Miranda Howard

Probing Exciton Energy Transport at Nanoscale Takes More than Ingenuity

> **"Excitonics can seamlessly bridge electronics and photonics to revolutionize not just energy applications, but energy consumption in the form of logic processing and communication."**
> —Parag Deotare

Electronics research is happening at the scale of atoms and photons. It takes vision and creativity to stay at the forefront of this field - but it also requires the most advanced equipment systems available to discover new potentially society-enhancing technologies. The labs in ECE will add a first-of-its kind tool to advance the study of exciton dynamics. Excitonic research could help define the foundation of future energy and energy conversion technologies, including LEDs and solar panels.

"Excitonics can seamlessly bridge electronics and photonics to revolutionize not just energy applications," said Prof. Parag Deotare, who is leading this area of research, "but energy consumption in the form of logic processing and communication."

An exciton is a negatively charged electron and a positively charged hole that stick together like a single particle. Excitons could be a preferable alternative to using electrons to move energy and information around in future devices. This is because excitons are charge neutral, and, unlike electrons, do not lose energy stored in parasitic capacitances as heat, which could help make devices more energy efficient.

An exciton is only a few nanometers in diameter, but the current tools to study how energy is transported at that scale have a resolution that is several orders of magnitude larger. So Deotare will be building a first-ever cryogenic system capable of near-field probing to be able to see what's happening at the nanoscale. The cold temperature (4 Kelvin, or -452ºF) is necessary to slow down the particles in order to be able to detect the target signal.

"We aim to build an ultra-high-resolution optical spectroscopy capability that can allow us to understand transport of energy at a resolution of tens of nanometers," Deotare said. "If we understand how energy flows at that scale, we can then contemplate controlling it at that scale."

While the tool is designed for excitonic research, the technique can be applied to the study of photonics as well as magnetics at nanoscale. Deotare hopes this will generate further avenues of collaboration with other researchers and facilities.

"My research is very multidisciplinary, and this will help us connect the theories with the materials growth to the actual devices," Deotare said.

Yixin Xiao (L) and Dr. Yuanpeng Wu working on the technology in Mi's lab. Photo: Brenda Ahearn

Breakthrough in Green Micro-LEDs for Augmented/Mixed Reality Devices

Building on their earlier breakthroughs on highly-efficient red micro light emitting diodes (LEDs), Prof. Zetian Mi and his research team achieved a new approach for the design, fabrication, and integration of high-performance green micro-LEDs on silicon. These highly stable micro-LEDs are important for a broad range of applications in on-chip optical communication, including emerging augmented reality/mixed reality devices, and ultrahigh-resolution full-color displays.

"It's very important to have a stable emission of all three colors – red, green, and blue – to achieve a high-quality display," said Mi. "And it's especially important to grow these small, stable LEDs directly on the silicon wafer for the future manufacturing and integration process."

LEDs, which are typically stacks of semiconductor thin films, have already revolutionized the lighting and display world.

However, LEDs have many limitations when it comes to supporting virtual and augmented reality, as well as other emerging optoelectronic applications. These applications demand micrometer or smaller LEDs that are highly stable, highly efficient, have ultra low power consumption, and can support full-color emission and brightness. In other words, they need to be one million times smaller than conventional broad area devices without sacrificing their quality.

"You can make very efficient large-area blue LEDs and large area red LEDs, but it is extremely difficult to make very efficient large area green LEDs. This is called the 'Green Gap,'" Mi said.

In addition, it's important for these micro- and submicron-LEDs to be grown on silicon, instead of the traditional sapphire wafer. Silicon wafers improve the manufacturing process, allow for improved scalability and integration with small electronics, and are more cost-efficient. But using silicon also creates a mismatch in the lattice parameter, for the crystal structure is different.

To address these challenges, Mi's team developed III-nitride submicron-scale green micro-LEDs using arrays of nanowires, each of which is only 100-200 nm in diameter and tens of nanometers apart. The result is the first high-performance, highly stable green micro-LEDs grown on silicon. They plan to apply the same sort of process for blue micro-LEDs. With red, green, and blue micro-LEDs, the future of next-generation display technology begins.

"It's very important to have a stable emission of all three colors – red, green, and blue – to achieve a high-quality display. And it's especially important to grow these small, stable LEDs directly on the silicon wafer for the future manufacturing and integration process."
—Zetian Mi

Engineering Sustainability and Justice

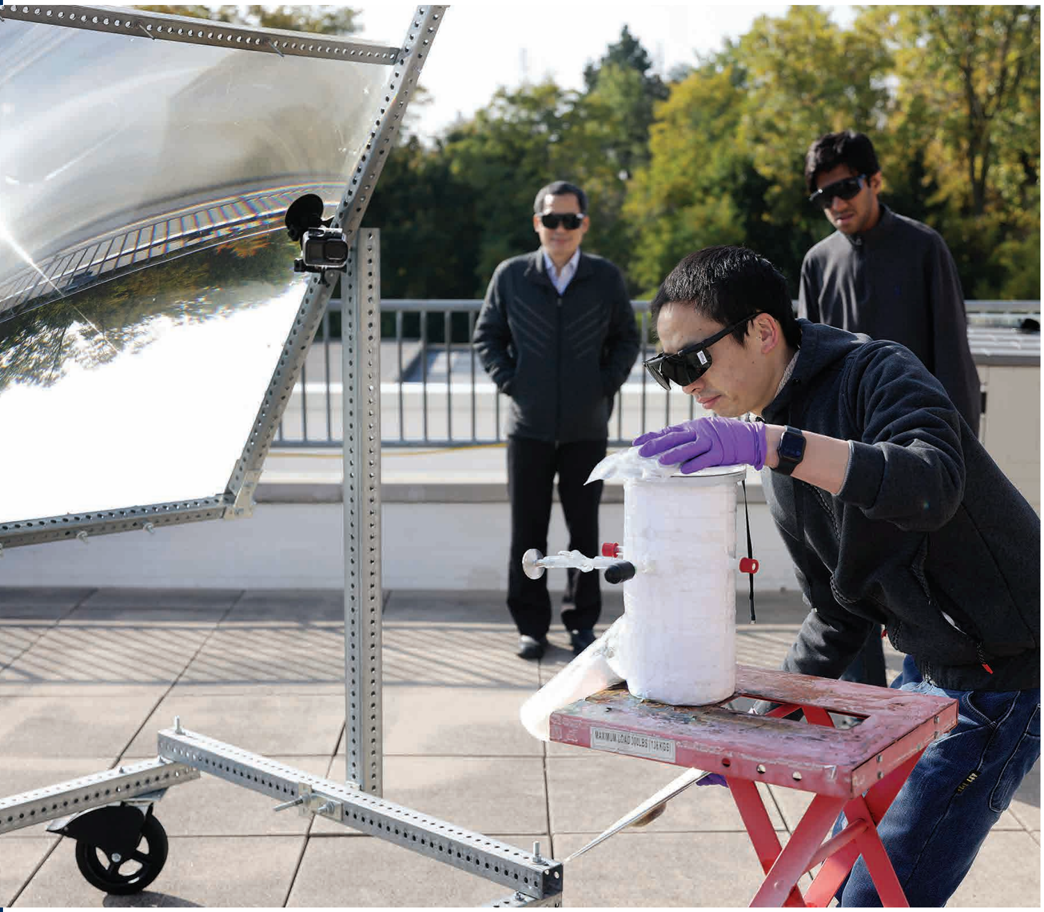
From revolutionizing clean energy to designing a wireless and batteryless future to battling inequality in energy access, our researchers are empowering a sustainable, healthy, and equitable future for all.

Cheap, Sustainable Hydrogen through Solar Power

Prof. Zetian Mi and his team developed a new kind of solar panel that has achieved 9% efficiency in converting water into hydrogen and oxygen, which is nearly 10 times more efficient than previous solar water-splitting experiments of its kind. Solar water-splitting, also known as artificial photosynthesis, is a process that replicates photosynthesis by using the sun to separate hydrogen from water. That hydrogen can then be used as a clean energy alternative to fossil fuels.

"In the end, we believe that artificial photosynthesis devices will be much more efficient than natural photosynthesis, which will provide a path toward carbon neutrality," Mi said.

As humanity tries to reduce its carbon emissions, hydrogen is attractive as both a standalone fuel and as a component in sustainable fuels made with recycled carbon dioxide. Likewise, it is needed for many chemical processes, including the production of fertilizers. Currently, humans produce hydrogen from the fossil fuel methane, using a great deal of fossil energy in the process.



Peng Zhou sets up an experiment to test the solar water splitting technology while Zetian Mi (back left), Ishtiaque Navid (back center), and Yuyang Pan (back right) observe. Photo: Brenda Ahearn.

Mi's method for splitting water into hydrogen and oxygen uses the power of the sun.

His team's improved artificial photosynthesis technology comes from two primary advancements. The first is the ability to concentrate the sunlight without destroying the semiconductor that harnesses the light. This offers a significant cost advantage because the semiconductor is far and away the most expensive part of a water-splitting solar panel.

"We reduced the size of the semiconductor by more than 100 times compared to some semiconductors only working at low light intensity," said Peng Zhou, ECE Research Fellow. "Hydrogen produced by our technology could be very cheap."

The second is using both the higher energy part of the solar spectrum to split water and the lower part of the spectrum to provide heat that encourages the reaction. The magic is enabled by a semiconductor catalyst that improves itself with use, while resisting the degradation that such catalysts usually experience when they harness sunlight to drive chemical reactions.

Higher temperatures speed up the water splitting process, and the extra heat also encourages the hydrogen and oxygen to remain separate rather than renewing their bonds and forming water once more. Both of these helped the team to harvest more hydrogen.

In a related project, Mi's team is working to stabilize perovskite-based solar cells to produce highly-efficient, low-cost, ultrastable green hydrogen fuel.

"Current solar cell technology is mostly based on silicon, but many people believe the next generation will be perovskite," Mi said. "This material has similar and even higher efficiency than silicon, yet it doesn't require as much of the material, and the overall cost is much lower."

However, it's also notoriously unstable.

"Ideally you want a solar cell panel to last for 20 or 30 years or more," Mi said. "But the stability of perovskite materials is often limited to hours or days, depending on how they're packaged."

To solve this problem, Mi's team will use gallium nitride (GaN), a material widely used in LED lighting and the electronics industry, to stabilize the surface of perovskite materials. This method is based on their recent work done in collaboration with Lawrence Berkeley National Laboratory and Lawrence Livermore National Laboratory through the Department of Energy's HydroGEN consortium, where they proved that with GaN surface protection, high-efficiency Si-based photoelectrodes can operate for more than 3,000 hours without performance degradation.

"We believe that artificial photosynthesis devices will be much more efficient than natural photosynthesis, which will provide a path toward carbon neutrality." —Zetian Mi

"Using gallium nitride to stabilize the surface of perovskite is very promising and could open many new possibilities for this amazing material," Mi said. "This could enable the stable operation of perovskite-based solar cells and other optoelectronic devices."

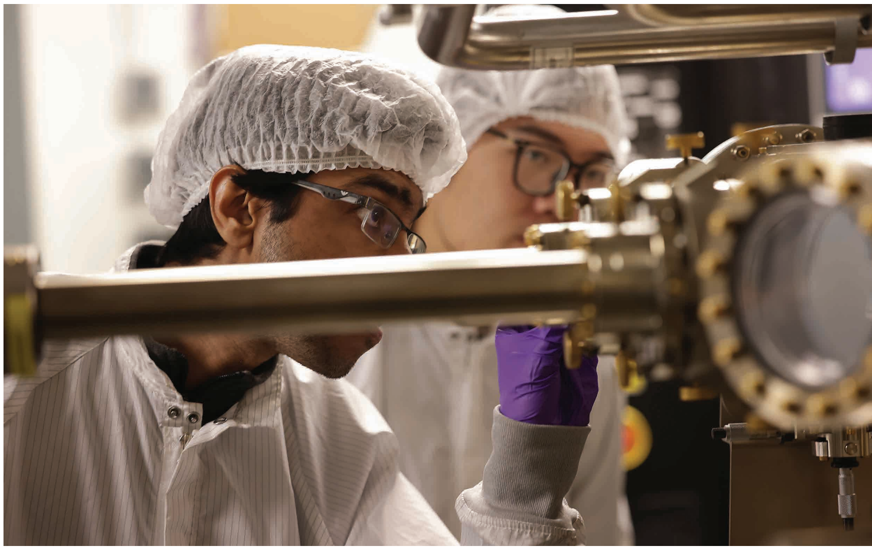
The development and synthesization of the perovskite material is led by Prof. Yanfa Yan from University of Toledo, who serves as a co-PI on the project. The project is funded through the DoE's Energy Earthshots Initiative, which seeks to reduce the cost of clean hydrogen by 80% to one dollar per one kilogram in one decade (known as the "1 1 1" initiative).

Next, Mi and his team will add their expertise to the new Global Hydrogen Production Technologies Center (HyPT) funded by the National Science Foundation and partner agencies from Australia, Canada, and the United Kingdom. The goal of the center is to bring together researchers from around the world to advance technologies to achieve low-cost large-scale hydrogen production with net-zero emissions of greenhouse gases.

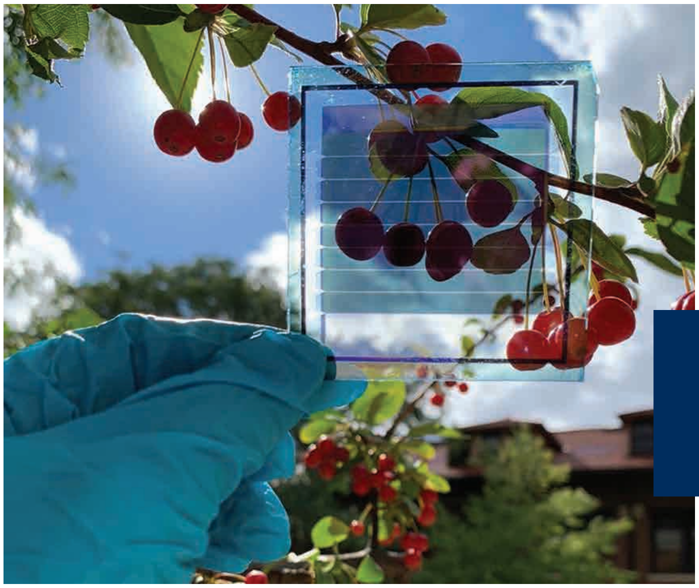
"Being part of the center provides us with excellent opportunities for collaborations with experts around the world as we explore new ways to synthesize our materials in order to reduce the overall cost of the technology," Mi said.

The center will also focus on policies, economics, and markets to help build a global hydrogen economy. This includes addressing the water resource and treatment dimensions for electrolysis and photocatalysis.

Some of the intellectual property related to this research has been licensed to NS Nanotech, Inc. and NX Fuels, Inc., which were co-founded by Mi.



LEFT: A close-up of the panel with the semiconductor catalyst and water inside. Photo: Brenda Ahearn **RIGHT:** Ishtiaque Navid and Yuyang Pan, ECE PhD students, working in Prof. Zetian Mi's Molecular Beam Epitaxy Lab, where they are growing Gallium nitride (GaN) based nanostructures that will be used to stabilize the surface of perovskite. Photo: Brenda Ahearn



Prototype of a see-through solar module utilizing near-infrared absorbing non-fullerene acceptor materials. Photo: Xinjiang Huang

Organic Solar Cells for Power-Generating Windows

Instead of installing opaque solar panels to roofs, semi-transparent solar cells could one day turn any window into a solar-powered generator, providing a home with abundant clean energy.

Stephen Forrest, the Peter A. Franken Distinguished University Professor of Electrical Engineering and Paul G. Goebel Professor of Engineering, and his team have previously shown that organic photovoltaics can achieve this transparency while being highly-efficient and long-lasting.

Now, they solved an issue in the fabrication process that limited the reliability of organic solar cells. This result, along with their previous work, brings them a step closer to manufacturing and testing power-generating windows at scale.

“The goal of much of our recent research on organic solar cells has been on understanding their stability during operation,” Forrest said. “We have found molecular designs that are more stable that will allow us to make highly durable, ultra-high efficiency, thin film, inexpensive, and flexible organic photovoltaics.”

Traditional silicon-based solar cells are efficient and long-lasting, but they absorb the entire spectrum of light, meaning they’re always opaque. Organic solar cells can absorb photons from different wavelengths of light while letting visible light pass through, making them suitable for windows. These energy-generating films can be applied directly to current window panes, and they can also be made with different colors, creating a stained-glass appearance.

“Buildings that can power themselves with clean energy would be a major improvement for sustainability,” said Yongxi Li, ECE Assistant Research Scientist. “Another advantage of our transparent solar cells is they can reflect heat, meaning buildings will be cooler in the summer, and we don’t have to expend as much energy on air conditioning.”

In their previous research, the team achieved record efficiencies of 10% along with 50% transparency, and estimated lifetimes of up to 30 years for organic solar cells. They did this by solving issues related to the stability of materials interfaces within the cells.

> **“Buildings that can power themselves with clean energy would be a major improvement for sustainability.”** —Yongxi Li

For this research, they focused on ternary organic solar cells, which are a type of solar cell that can achieve efficiencies of up to 20%. However, the team discovered a significant weakness in the molecules used in ternary organic solar cells, which severely limits their lifespan. They solved the problem by developing a new fabrication method that eliminates water from the process. And they created new molecular design strategies that avoid the problem altogether.

“This means we can get even longer-lasting, reliable, transparent solar panels with high efficiency,” Li said. “We’ll then be able to fabricate modules for large-scale, transparent solar window panels.”

The work was done in collaboration with Prof. Mark Thompson’s group at the University of Southern California, Prof. Aram Amassian’s group at North Carolina State University, and Prof. Larry Liao’s group at Soochow University.

Fabrication work was accomplished in the Lurie Nanofabrication Facility.

Agrivoltaics with Organic Solar Cells

Integrating solar cells into windows provides an intriguing opportunity to provide sustainable energy to residential and commercial buildings, which are estimated to account for about 40% of all energy consumption in the U.S. But this is brand new technology. Most solar panels are placed on land—land which might alternatively be used for food.

Attempts have been made to combine farming with solar farms, called agrivoltaic development, but those solar panels tend to be inorganic and opaque; installing these conventional solar arrays on farmland often decrease crop yields.

Recognizing the importance of this conflict, Prof. Stephen Forrest is leading a new project funded by U-M's Graham Sustainability Institute that seeks to eliminate the tradeoffs between farming and solar energy development by turning to organic, semi-transparent solar panels.

The research will focus on Michigan crops that are economically important, providing a framework that can be expanded to other types of crops, climate zones, and land use. By combining expertise in crop growth and ecosystem health with new semi-transparent solar cell technology developed by the researchers, the team aims to develop new products for specific agricultural applications adapted to the regions in which they are applied.

The technology is being implemented at U-M's Campus Farm. If successful, this simultaneous dual use of land could provide income from both the crops grown and the electricity produced, making local agriculture more profitable in temperate climate zones and in underdeveloped countries while providing abundant, clean electricity.

Chrome finish for cars is both an aesthetic demand and an important protection against rust, but it comes with a high cost to the environment and to workers.

"The current process for making chrome is extremely toxic," said Prof. Jay Guo. "The chemicals are so bad that they're actually banned in some parts of the country."

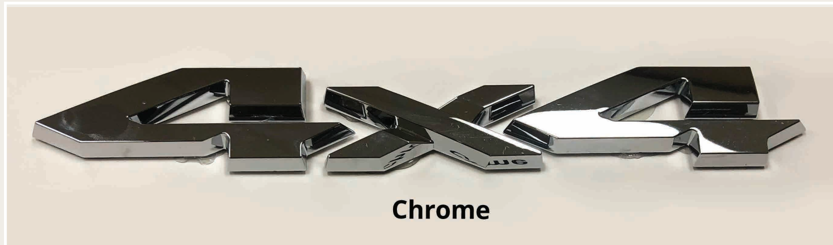
The shiny chromium look on automobile emblems, household fixtures, and decorative finishes is most commonly achieved through electrodeposition of hexavalent chromium (Cr (VI)). However, Cr (VI) is a known carcinogen and increases the risk of lung, nasal, and sinus cancer for workers who utilize it during the plating process. It also generates highly toxic emissions that pollute air quality, harming the health of both the environment and human populations.

"Automobile companies have been looking for replacement solutions that are safer and more environmentally sustainable," Guo said.

Guo led a team that designed novel thin film structures that preserve the chrome look but are made without using any chromium at all. Instead, these structures are made entirely with environmentally benign materials, such as common oxides, with or without any metals.

The new material offers an important technological benefit as well. Traditional chrome coatings can block the transmission of microwave frequencies, such as the sensors and wi-fi signals used to enhance the safety of today's vehicles.

"Our coating does not block these frequencies, so you can transmit signals very well," Guo said.



4×4 parts compare the look of actual chrome (top) with Guo's PVD samples (bottom).

Environmentally-Friendly and Technologically Savvy Chrome

To design this alternative coating, Guo's team first developed a reinforcement learning algorithm. This algorithm generated several potential designs. Guo's team then selected which design to test based on availability of the materials and the simplest method for fabrication.

> **"Automobile companies have been looking for replacement solutions that are safer and more environmentally sustainable."** —Jay Guo

However, despite its disadvantages, the most important function of traditional chrome coating is the protection it provides against rust.

"Our entire coating is less than a micron thick, so it can't protect against rust the way traditional chrome can," Guo said. "This is what we plan to work on next, because automobiles run in all sorts of weather, so this protection is very, very important."

Funded by the Michigan Translational Research and Commercialization Advanced Transportation (MTRAC) Innovation Hub, Guo's team will be working with industrial partners, including Sigma International, to advance their coating even more, such as providing anti-scratch protection.

Another goal for Guo's team is to refine the production process to be highly cost-effective and easy to mass-produce, so car companies could more easily transition to the new material and process.

Fabrication work was accomplished in the Lurie Nanofabrication Facility.

Wireless and Battery-Free Sensors for Sustainable Smart Cities

A new multidisciplinary project aims to make cities smarter, more efficient, and even more livable by creating wireless, battery-free sensors that can communicate seamlessly between human-made structures and the natural environment.

"Currently, it is very challenging to deploy sensors and truly forget about them, because their batteries need to be continuously replaced or recharged," said Prof. Aline Eid, who is developing the wireless communication system for the project. "I want to enable the deployment of sensors in locations that are considered challenging or difficult to reach and allow them to communicate critical information over long distances."

The team is working to develop explainable AI algorithms that will decipher the data collected by these sensors, which could help identify new patterns and relationships within and between infrastructure components. This plays a critical role in creating smart ecosystems that provide real-time data for informed decision-making policies, improving efficiency, sustainability, resiliency, and livability of infrastructure.

"Deploying smart responsive surfaces, also known as 'smart skins,' in both the living and civil infrastructures allows them to share sensing information that would be converted into digital twins used for modeling and predicting," Eid said. "Examples of these digital twins include smart traffic and waste management systems, as well as urban agricultural programs."

These sensors could also monitor the effects of pollution and climate change, which disproportionately impact communities of color and low-income communities. The resulting data would be useful in creating better interventions for addressing these impacts, thereby aiding environmental justice and reducing health disparities.

> **"These sensors will play a crucial role in making our cities more sustainable and livable by providing real-time data for smart decision-making."**
> —Albert Liu

"Imagine electronic tattoos that can be grafted onto the surfaces of both living and artificial matter, harvesting energy from water and sunlight, sensing changes in their surroundings, and communicating vital information without ever needing a battery," said Albert Liu, Assistant Professor of Chemical Engineering. "These sensors will play a crucial role in making our cities more sustainable and livable by providing real-time data for smart decision-making."

In addition to Liu and Eid, the team includes Abdallah Chehade, Assistant Professor of Industrial and Manufacturing Systems Engineering at U-M-Dearborn, and Brendan O'Neill, Assistant Research Scientist in the School of Environment and Sustainability.

Streamlining Home Assessments for Energy Justice

Prof. Johanna Mathieu is part of a partnership between academic, non-profit, and industrial leaders to design a common home assessment pilot for a variety of decarbonization, electrification, and renewable energy integration programs. The goal is to better connect low-income families of color in Detroit with available public resources that support housing and energy security.

“The fundamental research questions are more on the social science side, but that affects how we design technologies and incorporate equity and fairness into the engineering work,” Mathieu said. “When we control things and optimize things and make things work better in the grid, we need to consider the inequities that exist. We don’t want to make things worse. Hopefully we can make things better.”

> **“When we control things and optimize things and make things work better in the grid, we need to consider the inequities that exist.”**
> —Johanna Mathieu

The project is led by research and development organization Pecan Street Inc. and is a collaboration with the Detroit-based non-profits, Ecoworks and Jefferson East Inc.

“Pecan Street’s goal is to find energy solutions that protect the climate and address historic energy inequality,” said Pecan Street CEO Suzanne Russo. “This project will help identify ways to include everyone in our clean energy future.”

On average, communities of color pay higher costs for energy than white households, which is known as the “energy burden.” This can lead to energy insecurity, or the inability to adequately afford their energy costs. There are many programs dedicated to addressing and mitigating the energy burden, but each of these programs requires its own assessments, which vary from online surveys to in-person home inspections. Having to complete multiple complex, often redundant, assessments discourages people from enrolling in these programs.

“It would be much better if we had one common home assessment that can collect all necessary information for both current and future programs,” Mathieu said. “With a common assessment, we could also potentially calculate impacts not only to the house, but to the grid itself.”

Weatherizing homes so they lose less heat/energy, transitioning from fuel-based to electric heating, integrating renewable energy sources such as solar panels into the home, and more, not only helps families lower their energy costs, but it also helps advance decarbonization, which is important for climate change mitigation.

“Having more distributed energy resources, such as more solar panels, should help with resilience, especially as disasters caused by climate change impact the grid,” Mathieu said. “If people have their own energy source and storage on site, when the grid goes down, they could still power their home.”

Pecan Street is leading the data collection, and Ecoworks and Jefferson East are serving as liaisons with the communities. Ecoworks works to provide services at the intersection of community development and sustainability, with a focus on energy conservation. Jefferson East is a community-based organization that is focused on growing Detroit’s East Jefferson corridor and its neighborhoods.

“This is not a ‘magic bullet’ project by any means,” said Ecoworks Manager Gibran Washington, “but it begins the hard work of asking how to better support all the partners that are working to connect home repair with the widespread decarbonization and electrification of residential homes in Detroit.”

ECE for Your Health

By advancing machine learning, imaging systems, brain-machine interfaces, and more, our faculty are creating diagnostic and treatment tools to improve human health.

A Brain Game May Predict Your Risk of Infection

If your alertness and reaction time is see-sawing more than usual, you may be at greater risk of a viral illness, according to a team of researchers at U-M, Duke University School of Medicine, and the University of Virginia.

“We all know that if we’re stressed, or haven’t slept enough, that predisposes us to have a less resilient immune system,” said Alfred Hero, the John H. Holland Distinguished University Professor of EECS. “This is the first exposure study in humans to show that one’s cognitive performance before exposure to a respiratory virus can predict the severity of the infection.”

The team studied a cohort of 18 healthy volunteers who took brain performance tests three times per day for three days and then were exposed to a cold virus known as human rhinovirus. The software provided 18 measures of cognitive function including reaction time, attention and rapid switching between numbers and symbols, which were combined to derive an index of variability.

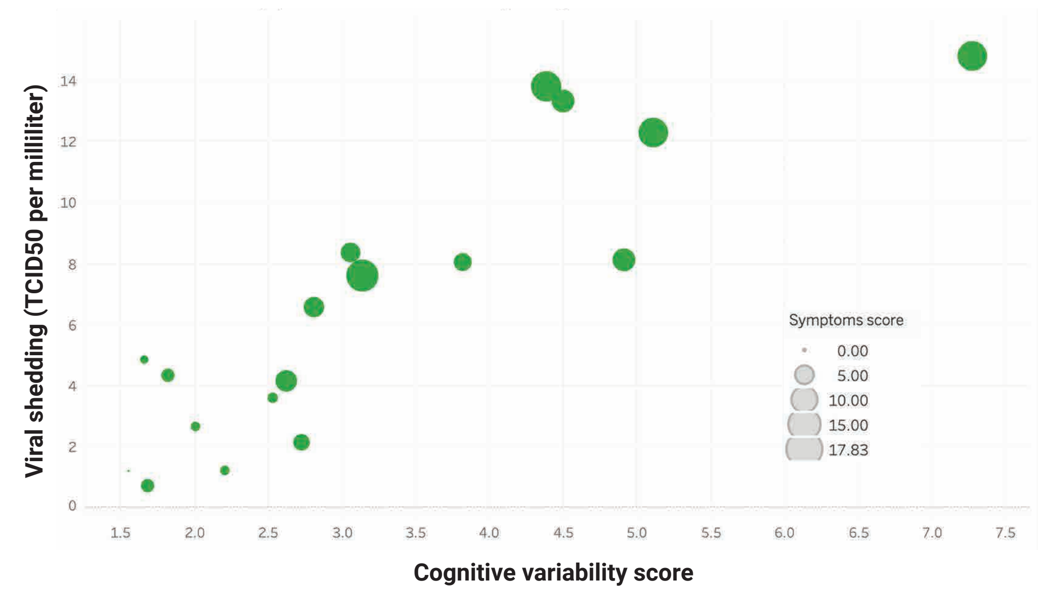
"In the beginning, we didn't find that cognitive function had a significant association with susceptibility to illness because we used the raw scores. But later, when we looked at change over time, we found that variation in cognitive function is closely related to immunity and susceptibility," said Yaya Zhai, a recent PhD graduate in bioinformatics at U-M. She and Hero led the development of the cognitive variability index.

The team assessed viral shedding by using a saline solution to wash out the nasal passages of participants. They determined the presence of viral infection and the quantity of virus in the fluid by growing the virus in a cell culture. As for symptoms, the team used the Jackson score, in which participants rated themselves from one to three on eight common cold symptoms.

> **"This is the first exposure study in humans to show that one's cognitive performance before exposure to a respiratory virus can predict the severity of the infection."**
> —Alfred Hero

"This is an interesting observation in a relatively small study. I hope that there will be a chance to confirm these findings in a larger, more definitive study," said Ronald Turner, professor emeritus of pediatrics at the University of Virginia, who ran the experiment.

Cognitive variability predicts how sick you get



This scatterplot shows a strong correlation between viral shedding and cognitive variability, with the size of the dot indicating symptoms.

The team is optimistic that smartphone use could eventually help identify times of heightened susceptibility to illness, monitoring cognitive indicators like typing speed and accuracy as well as how much time the user spends sleeping.

"Traditional clinical cognitive assessments that look at raw scores in a single time point often do not provide a true picture of brain health," said P. Murali Doraiswamy, director of the Neurocognitive Disorders Program at the Duke University School of Medicine, who designed the neurocognitive testing portion of the study. "At home, periodic cognitive monitoring, through self-test digital platforms, is the future of brain health assessment."

The experiment also discovered a few genetic markers that may indicate reduced immune function, which the team may explore further in future studies.

U-M and Duke have filed for patent protection for the cognitive variability index.

Non-Invasive Imaging Approach Could Improve Outcomes for Brain Injury Patients

Prof. Mohammed N. Islam led a team of researchers who developed a new cost-effective, portable, non-invasive means of determining brain health. In particular, the system can monitor cerebral, tissue, and organ metabolism and hemodynamics simultaneously.

The tool can aid the early detection of brain injury or neuronal dysfunction and also continually monitor brain health to help guide therapies and treatments for injury. Islam dubbed the system Super-Continuum Infrared Spectroscopy of Cytochrome C-Oxidase (SCISCCO).

"Internal bleeding due to traumatic injuries is a major cause of preventable deaths," Islam said. "Our noninvasive method for monitoring tissue metabolism could help improve the diagnosis and monitoring of conditions such as concussions, stroke, traumatic brain injury, and other medical conditions."

Traumatic brain injury (TBI) results in structural damage to the brain, and many patients require life-long assistance after recovery. While a TBI can happen to anyone, it is known as the signature wound for veterans of the wars in Iraq and Afghanistan, but the military still has no objective way of diagnosing it in the field.

About 75% of traumatic brain injury survivors experience a mild traumatic brain injury (mTBI), or concussion. Concussion is also very difficult to diagnose, and it can result in life-long cognitive or psychological challenges, such as memory problems and post-traumatic stress disorder.

Current methods to monitor changes in blood flow to the brain rely on hemodynamic neuroimaging systems, but these systems can't detect changes in the neural tissue itself. This can result in illness or injury going undetected and, therefore, untreated. To address this issue, Islam's team focused on measuring the optically active markers of cellular function through cytochromes - specifically Cytochrome C-Oxidase (CCO), which is a photo-sensitive enzyme that is responsible for more than 95% of oxygen metabolism in the body.

"Our noninvasive method for monitoring tissue metabolism could help improve the diagnosis and monitoring of conditions such as concussions, stroke, traumatic brain injury, and other medical conditions."
—Mohammed Islam

The conventional means of measuring CCO relies on lamp-based light sources to provide the illumination, but these systems are plagued with generally poor signal-to-noise ratio. Islam's team, by contrast, uses an all fiber integrated super-continuum light source for a noninvasive optical imaging approach. This approach greatly improves signal-to-noise ratios, and results in more definitive measurements of CCO.

"Our system can provide almost an order of magnitude improvement in brightness compared with the tungsten-halogen lamps typically employed for CCO measurements," Islam said.

The SCISCCO system is also extremely versatile.

"The SCISCCO system could be applied to a range of uses, from serving as a new tool for screening concussion patients—such as being used in the cognitive attention test results—to use in an intensive care unit to gauge a patient's organ response to treatments," Islam said.

The system can perform measurements of CCO, oxygenated hemoglobin (HbO), and deoxygenated hemoglobin (HbR) to determine the metabolic function of any organ, such as the liver, kidney, heart, and lungs. It can also be used to measure and monitor the metabolic function of tissues, such as muscle tissue, nervous tissue, and epithelial tissues.

Islam's team, which includes researchers at Northwestern University and UC Davis, is planning to perform human studies in an intensive care unit setting with the U-M Neurosurgery department.

Miniature and Durable Spectrometer for Precision Health

A team led by Professors P.C. Ku and Qing Qu have developed a wafer-thin chip-scale spectrometer that is suitable for wearable health applications. The robust gallium nitride lab-on-a-chip device can be adapted to do blood analysis by simply projecting light onto the skin, and measures a mere 0.16mm^2.

“As a wearable device, we’ll be able to put our device on a flexible substrate, such as sheets or fabric – or maybe on skin,” said Tuba Sarwar, ECE PhD student.

The optical spectrometer was developed with a specific purpose: measuring an athlete’s sweat in a device that could be worn as a skin patch. This application was determined by U-M’s Exercise and Sport Science Initiative (ESSI). The device needn’t last long; in fact, being disposable was a plus.

Making such a device would require extreme miniaturization of current devices available in the marketplace, which measure closer to 12 cubic inches and cost hundreds to thousands of dollars. It would also require creating a device that can work in real time under changing conditions.

“Commercially, there are a lot of spectrometers that can work better than ours,” said Sarwar. “But our focus was miniaturization, especially the thickness of the device. These two features can give us an analysis of an active sample, such as sweat. We don’t need to go into the lab to use sophisticated instruments to get very precise measurements.”

Ku, Qu, and their team took on the challenge of creating a device that could achieve ESSI’s goal, and created a miniaturized, low power, integrated device that works in visible light, specifically, within the wavelength range of 400-645nm.

ECE PhD student Tuba Sarwar tests the portable spectrometer in the lab.

The team’s spectrometer includes only 16 photodetectors, each responsive to a unique spectrum of the light, which was made possible by two key techniques. First, the team used strain engineering on gallium nitride (GaN)-based spectral encoders. Second, the team incorporated machine learning into the device’s operation in order to decode the signal emitted from the detector.

In terms of performance, the device was highly accurate in determining the peak wavelengths (with a standard deviation of 0.97%), but less accurate in measuring intensity ratio over different peak positions (with a standard deviation of 21.1%, or 10.4% after removing one outlier).

The team expects that the reading of intensity ratios can be improved by increasing the number of photodetectors, and further developing the machine learning algorithm, such as by applying deep learning techniques. They are also working on several other enhancements to the prototype spectrometer.

> **“We don’t need to go into the lab to use sophisticated instruments to get very precise measurements.”**
> —Tuba Sawar

In terms of future applications, Sarwar says that this miniature spectrometer could be built into a skin patch for health monitoring and diagnosis. The advantage it would have over existing devices is the fact that the excitation light source can be easily integrated onto a chip. The radiation hardness of the GaN semiconductors also makes the device potentially suitable for space exploration.

Work was performed in the Lurie Nanofabrication Facility.

New Kind of Biological Imaging Explores Cell Dynamics

Prof. Somin Lee has uncovered new insights into how self-organization is built into biological structures, without the need for central control, through a technique called superresolution.

Superresolution can reveal structures down to 10 nanometers, or about the same breadth as 100 atoms. It opened a whole new world in biology, and the techniques that first made it possible received a Nobel Prize in 2014. However, its weakness has been that it can only take snapshots over tens of seconds. This makes it impossible to observe the evolution of cells over long periods of time.

"We were wondering—when the system as a whole is dividing, how do nanometer-scale structures interact with their neighbors at the nanometer scale, and how does this interaction scale up to the whole cell?" said Lee.

To answer that question, they needed a new kind of superresolution. Using their new method, they were able to continuously monitor a cell for 250 hours.

"The living cell is a busy place with proteins bustling here and there. Our superresolution is very attractive for viewing these dynamic activities," said Guangjie Cui, ECE PhD student.

Lee's technique uses probes near the nanoscale objects of interest to shed light on them. But instead of using fluorophores, which degrade too quickly for practical purposes, they used gold nanorods.

These gold nanorods don't break down with repeated exposure to light, but making use of the light that interacts with them is more challenging.

Like the fluorophores, the nanorods can attach to particular cell structures with targeting molecules on their surfaces. In this case, the nanorods sought out actin, a protein that adds structure to soft cells. Even though the nanorods are often more than twice the diameter of the actin, the data they provide as a group can illuminate its tiny details.

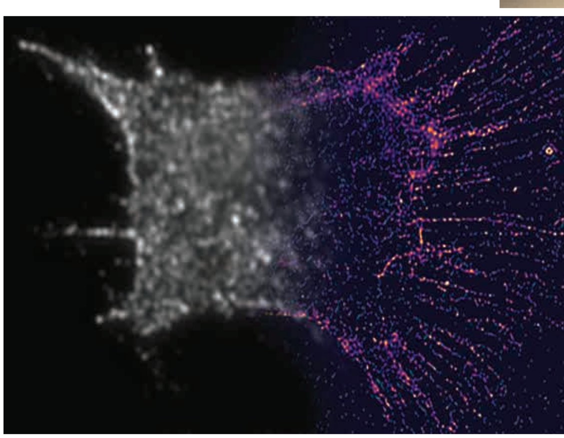
The team discovered three rules governing the way that actin self-organizes during cell division. They also found that the behavior of the actin is connected to the behavior of the cell—but the cell contracts when the actin expands, and it expands when the actin contracts. The team wants to explore this further.

> **"The living cell is a busy place with proteins bustling here and there. Our superresolution is very attractive for viewing these dynamic activities."**
> —Guangjie Cui

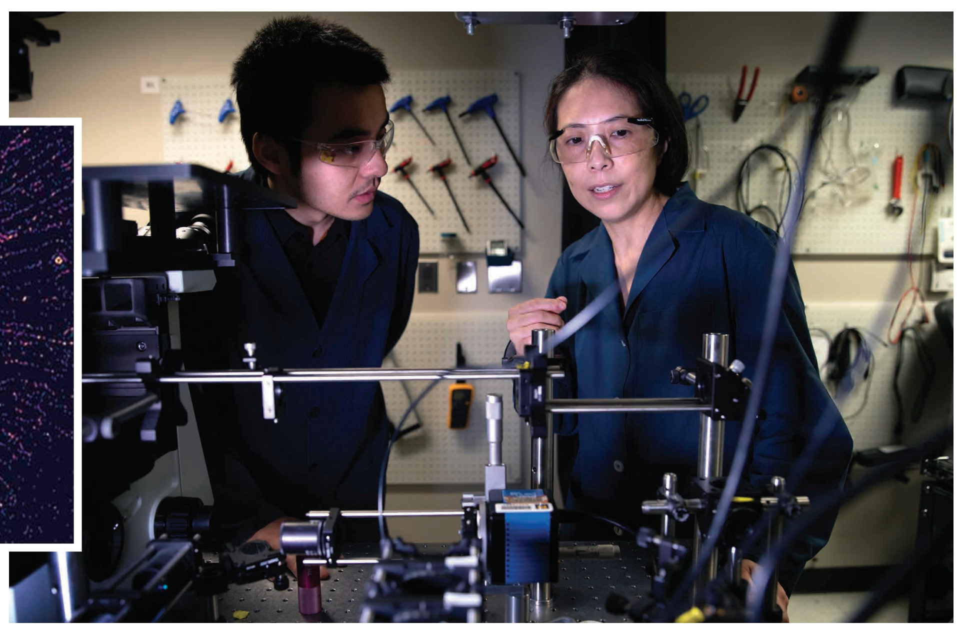
Ultimately, Lee hopes to use superresolution to understand how self-organization is built into biological structures, without the need for central control.

"Our genetic code doesn't actually include enough information to encode every detail of the organization process. We want to explore the mechanisms of collective behaviors without central coordination that are like birds flying in formation—in which the system is driven by interactions between individual parts," said Lee.

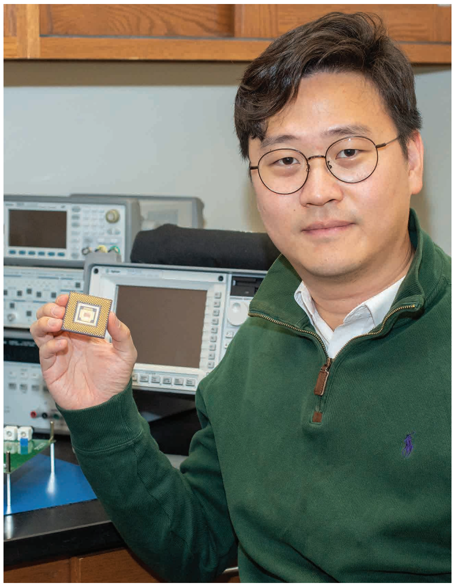
RIGHT: Somin Eunice Lee (right) works with ECE PhD student Gary Guangjie Cui in the Bioplasmonics Group lab. Photo: Marcin Szczepanski



ABOVE: Nanoscale emerges into macroscale (left: unresolved image, right: PINE resolved image)



A Better Circuit for Brain-Machine Interface Applications



Prof. Euisik Yoon's team developed a low-power neural recording front-end circuit designed for an implantable high-channel count brain interface system. In addition to improving the design of the neural recording front-end circuit, the team improved the overall interface system efficiency - especially in terms of the digital resources needed for post-processing work.

"With surging interest in brain-machine or brain-computer interfaces, this work can improve their performance, and eventually make them more useful for scientific research or clinical purposes," said Sungjin Oh, ECE PhD student.

Analysis of the complex neuronal network in the brain requires the sophisticated acquisition process of subcortical neural signals in multiple sites. Analog mixed-signal neural recording front-end circuits are able to conduct this important role of acquiring and conditioning brain signals in microvolt-scale. However, optimizing their power-noise performance is critical to achieving a high-quality and high-density neural interface.

An essential piece to implementing such an interface system, explained Oh, is a low-power neural recording front-end circuit that can operate with a small battery.

Such circuits require an analog-to-digital converter (ADC) to translate the brain signals into information that can be interpreted by a computer, but ADCs tend to be power hungry. This is especially true for incremental ADCs (IADCs), which are particularly well suited for the target application. Lowering the power consumption of the IADC makes it possible to be implanted along with neural probes, thereby providing much more information to scientists about the workings of the brain.

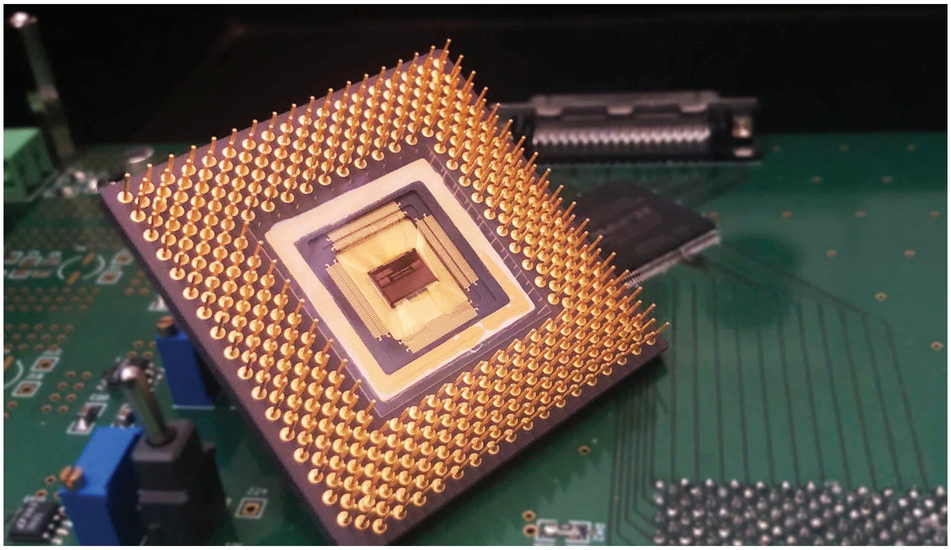
According to Oh, the power consumption of the IADC was dramatically reduced by exploiting the spectral characteristics of subcortical neural signal components in order to achieve an optimized energy-efficient signal acquisition system.

Through the novel technique of tracking and zooming into the neural signal dynamically, all the mixed components of neuronal activities were captured in low power analog-to-digital conversion with dual-band outputs.

The fabricated dual-band neural recording front-end chip was connected to a multi-channel neural probe and tested in an *in vivo* experiment using a mouse. The probe was developed under the NSF Multimodal Integrated Neural Technologies (MINT) program, led by Yoon.

This work received the Best Paper Award at the IEEE Biomedical Circuits and Systems Conference.

"With surging interest in brain-machine or brain-computer interfaces, this work can improve their performance,and eventually make them more useful for scientific research or clinical purposes."
—Sungjin Oh



TOP: ECE PhD student Sungjin Oh in the Yoon testing lab. **BELOW:** Fabricated dynamic zoom-and-tracking dual-band neural recording front-end chip

ECE does CHIPS

ECE researchers are leaders in the design of tomorrow's electronics. Our faculty contribute to the workforce by training some of the best talent in the world, and they are key members of new collaborative efforts across the region to aid the chip industry, more broadly known as the microelectronics and semiconductor industry.

Collaborations and Workforce Training

Collaborating with faculty in other disciplines is built into the culture of ECE faculty; they collaborate with colleagues across the College of Engineering, the University of Michigan, and with colleagues from other institutions and in industry. And they are bringing that same spirit of collaboration to solving the U.S. chip crisis.

On the heels of the global chip shortage, the University of Michigan is part of a new public-private partnership that will establish a global semiconductor center of excellence in Michigan that focuses on the auto industry.

The Semiconductor Talent and Automotive Research (STAR) initiative is led by semiconductor company KLA and Belgium-based technology innovation hub imec. The Michigan Economic Development Corporation, Washtenaw Community College and General Motors are also founding members. KLA CEO and ECE alumnus Rick Wallace announced the initiative at imec's ITF World event in Antwerp, Belgium.

The initiative will focus on developing the talent base and infrastructure necessary to accelerate advanced semiconductor applications for electrification and autonomous mobility and move the automotive industry forward.

"KLA is focused on investment in research and development to help address key challenges for automotive semiconductors," said Rick Wallace. "In 2019, KLA opened a second headquarters in Ann Arbor, putting us closer to automotive customers and the larger Michigan technology ecosystem. The STAR Michigan initiative accelerates our support for talent development, collaboration, and innovation in the region."

ECE and faculty across U-M have broad expertise in mobility and semiconductors. The world-class Lurie Nanofabrication Facility supports semiconductor research, hands-on education, and regional economic development. Over the past five years, 95 companies and 150 U-M faculty members have utilized the lab, as well as researchers from 40 other US universities.

MAVERIC, the Michigan Advanced Vision for Education and Research in ICs, is a semiconductor collaborative that is pulling together efforts from across the university to support a secure, resilient and innovative domestic semiconductor sector.

And finally, the University of Michigan is a founding member of two of the eight Microelectronics Commons regional innovation hubs announced recently by the U.S. Department of Defense.

One hub is the $32.9 million Silicon Crossroads Microelectronics Commons Hub, led by the Applied Research Institute (ARI) and the state of Indiana. The other is the $24.3 million Midwest Microelectronics Consortium Hub, led by the Midwest Microelectronics Consortium and the state of Ohio.

Microelectronics Commons hubs are funded for five years. Each will work in one or more of the areas identified as critical to the DoD mission: secure edge/internet of things (IoT) computing, 5G/6G, artificial intelligence hardware, quantum technology, electromagnetic warfare and commercial leap ahead technologies.

A Boost for the Workforce

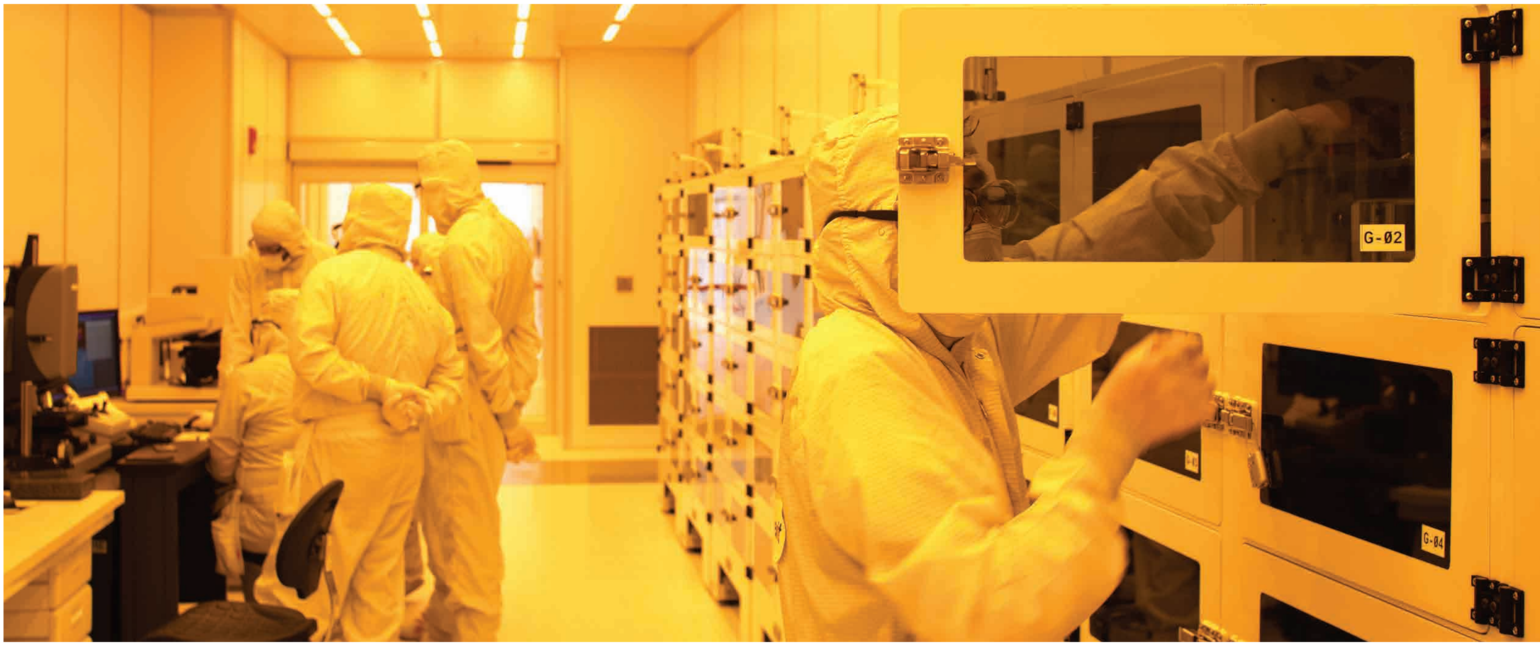
The Chips and Science Act provides significant funding for new foundries, and places an emphasis on workforce development so there are trained professionals ready to work in this burgeoning industry.

ECE faculty are ready to meet a surge in student interest and demand in semiconductor technology. We have the courses, and we have the facilities.

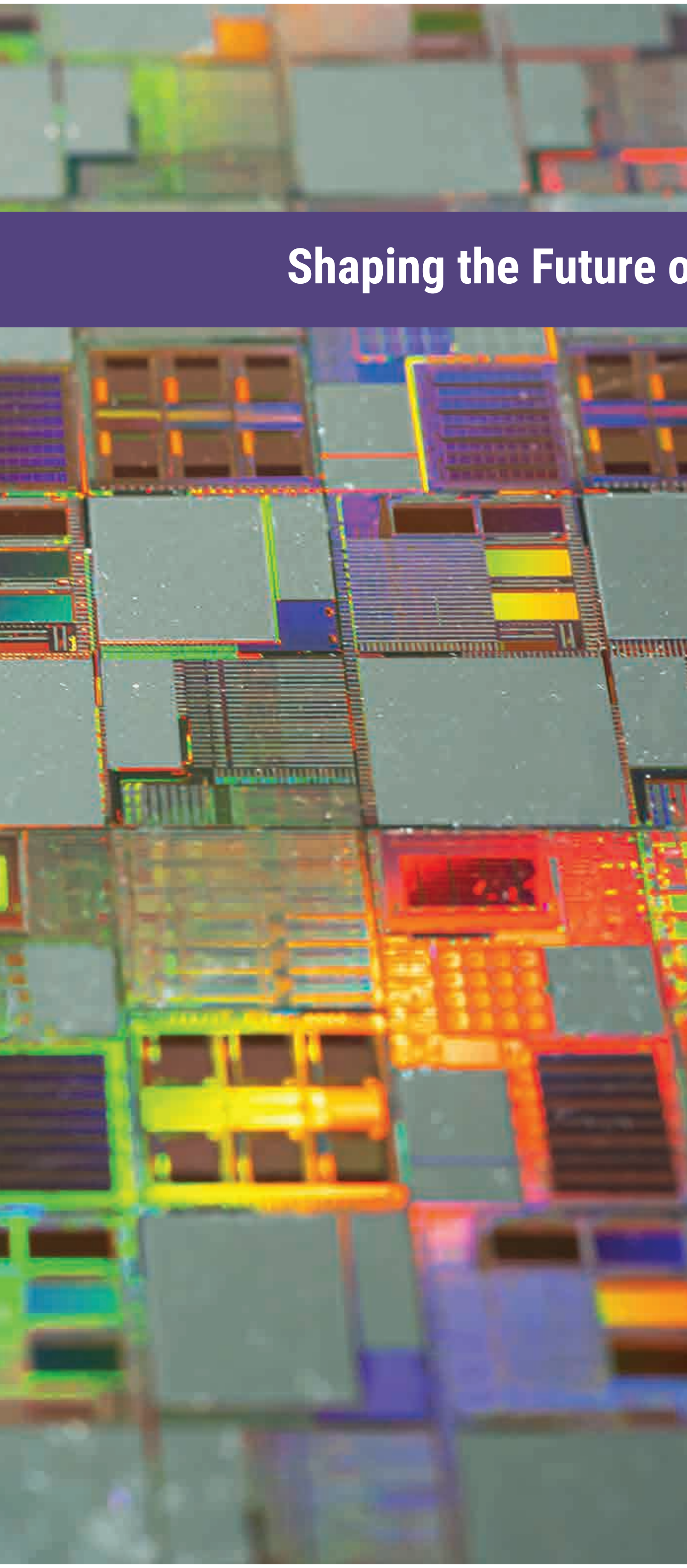
As director of the Lurie Nanofabrication Facility, Prof. Becky Peterson is leading the Michigan Semiconductor Hands-On Research Experience (M-SHORE) program. Read more about this program and its first cohort of students on page 43.

Peterson is also partnering on regional semiconductor workforce development through MSN Force: A Midwest Semiconductor Collaborative Network for Work Force Training, led by Wayne State University. The NSF-funded network will develop and run in-person and virtual training modules aligned with industry needs, with the goal of providing students and workers with equitable access to the semiconductor industry.

Read on to learn how our faculty are contributing to new multi-institution research centers that will help bolster the chip industry in the U.S., and are also helping to democratize chip design.



Student participants of the 2023 M-SHORE program in the Lurie Nanofabrication Facility. Photo: Brenda Ahearn



Shaping the Future of Microelectronics

Four ECE faculty are involved in new multi-institution research centers focused on next generation microelectronics. These centers are part of the Joint University Microelectronics Program 2.0 (JUMP 2.0) program, and each is funded at a level of approximately $30M over five years, thanks to the participation of the Semiconductor Research Corporation, DARPA, and industry and academic stakeholders.

"This research is at a scale that you wouldn't be able to do individually," said Prof. Zhengya Zhang. "It is only possible at the center level, which taps into all the resources that we already have."

The new centers complement the goals of the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act of 2022. But whereas most of the CHIPS Act money is going toward semiconductor foundries, the JUMP 2.0 program is focused on high-risk, high-payoff research "spurred by an increasingly connected world and a rapidly changing microelectronics landscape."

Each JUMP 2.0 center involves researchers from 12-13 institutions, while maintaining close collaborations with at least as many companies. These companies include ARM, Analog Devices, Boeing, EMD Electronics, Global Foundries, IBM, HRL Labs, Intel, MediaTek, Micron, Qorvo, Raytheon, Samsung, SK hynix, and TSMC.

> **"This research is at a scale that you wouldn't be able to do individually."**
> —Zhengya Zhang

> **"The key novelty is in the adaptive sensing. The entire system will change on the fly depending on the application and the scenario."**
> —Hun-Seok Kim

COGNISENSE: Center on Cognitive Multispectral Sensors

Professors David Blaauw, Michael Flynn, and Hun-Seok Kim are contributing to the Center on Cognitive Multispectral Sensors (led by Georgia Tech University), which is developing sensors that can effectively "perceive" everything around them and, like humans, focus on the information that really matters.

> **"We are making sensors smarter, to do more AI processing on the data as you measure it."**
> —David Blaauw

"The key novelty is in the adaptive sensing," explained Kim, who is co-leading the Analog-to-Insight theme. "The entire system will change on the fly depending on the application and the scenario."

Today's electronic sensors sample everything they "see" and generate an abundance of digital data, sometimes way too much for a machine to store, process, and make sense. The CogniSense center's goal is to change this paradigm by learning from biology.

Flynn will figure out how to extract only the most relevant features from the sensors, which will include data acquired by radar, lidar, and cameras. This computation will be done in the analog domain so that the features are extracted before converting the signal into digital representations, which will greatly reduce the amount of data fed into the backend digital processing.

Kim and Blaauw will work on the digital feature processing engine, which will perform sensor fusion to extract a refined representation of the scene from multiple sensors. For example, explained Blaauw, a typical imager pixelates every square of the image equally. An enormous amount of power could be saved by capturing in high resolution only the relevant portion of the image, possibly acquiring no data at all from an area where nothing is happening.

"We are making sensors smarter, to do more AI processing on the data as you measure it," said Blaauw. "An important impact on the entire system is to greatly lower the amount of data that needs to be transmitted, which makes it much lower power."

ACE: Center for Evolvable Computing

Prof. Zhengya Zhang is contributing to the Center for Evolvable Computing (led by University of Illinois Urbana-Champaign), which is advancing distributed computing technology, from cloud-based datacenters to edge nodes, so it operates with orders of magnitude more energy efficiency than today.

Zhang, one of the team leads in the Center, is focused on designing evolvable heterogeneous computing hardware that will accelerate the tasks, so that results can be obtained faster than could be accomplished on a conventional computer. Two applications that are the target of the ACE Center are edge computing and cloud computing.

"We want to dramatically limit the power required to process the data and the cost of the hardware, while still being able to process the data in real time," said Zhang. "We plan to put all our new techniques into these demonstrators, from hardware to software to networking to security – to see if we can achieve something we won't be able to do individually."

CUbiC: Center for Ubiquitous Connectivity

Zhang is also contributing to the Center for Ubiquitous Connectivity (led by Columbia University), which is advancing energy-efficient communications technologies for addressing the vastly growing connectivity bottlenecks between data-hungry wireless devices and deluged data centers. The Center's goal is to deliver seamless edge-to-cloud connectivity with transformational reductions in the global system energy consumption.

Zhang and his group will focus primarily on developing the signal processing hardware to support the massive scale of future wireless communication systems. These wireless systems are expected to involve a large number of distributed antennas. He will use signal processing to leverage those many antennas to improve the data bandwidth.

Democratizing Chip Design

ECE is part of a growing movement to make chip design more accessible through open-source process design kits (PDKs), EDA tools, and building blocks.

"The goal is to lower the barrier and access to silicon," said Dr. Mehdi Saligane.

Just last year, Saligane collaborated with Google and Efabless to develop an open-source, autonomously generated design for an autonomous temperature sensor. Professors David Blaauw and Dennis Sylvester, the core team behind the Michigan Micro Mote, a millimeter-scale computing system that can be adapted for a variety of sensing applications, also contributed to the project.

The fabricated chip has been distributed to other researchers to test whether an open-source chip will perform the same in different environments. Because these are physical devices, there's more room for variability compared to using open-source software or algorithms.

"In the software community, I can grab their code and know that it will perform exactly the same," said Sylvester. "We don't have that in hardware, but this is a movement in that direction, and I find that exciting."

Saligane partnered with the U.S. Department of Commerce's National Institute of Standards and Technology (NIST) in subsequent open-source designs, which resulted in one of the first successful chips using Google's open multi-project wafer (MPW) program. This chip, called simply MPW-5, was based on a new open-source tool called openFASOC, short for Open-Source Fully Autonomous System-on-Chip, developed by Saligane, Sylvester, and others.

The MPW-5 chip was designed to meet the emerging needs of the nanofabrication community, says Saligane, namely easy integration and easy benchmarking. It took less than two months to design and was among the first open-source chip designs of its kind.

Saligane followed the MPW-5 with designs of increasing complexity. The most recently fabricated chip, MPW-7, includes 5 different photodiodes with access circuitry, VCOs, and inductors. Collaborators on these designs included faculty at George Washington University and Brown University.

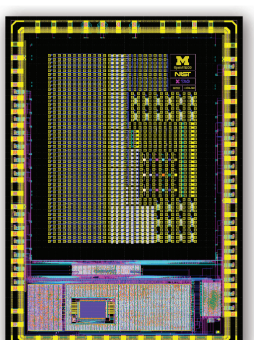
An important program initially funded by the government to facilitate open-source chip design is known as OpenROAD. Led by Prof. Andrew Khang at UCSD, with participation from Sylvester (co-PI), Blaauw, and Prof. Ronald Dreslinski, the OpenROAD project provides open-source semiconductor design automation tools.

And in an exciting development for open source IC design, NIST and Google announced last September that they would fabricate chips developed from open-source design kits at no cost to the developer. The potential savings in fabrication costs to researchers can reach hundreds of thousands of dollars.

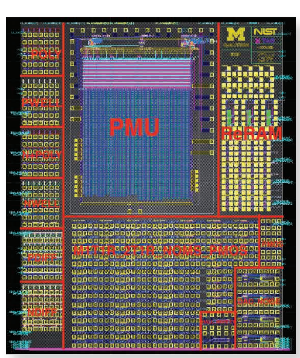
> **"It's an exciting time for anyone who wants to learn chip design."**
> —Mehdi Saligane

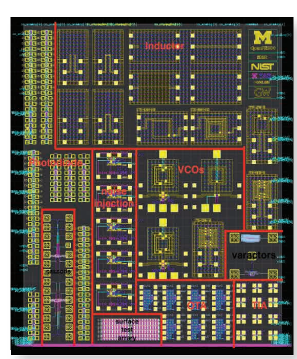
The greatest expected impact will be on individual researchers in regions that are underrepresented in chip design, as well as small companies, such as startups.

"The involvement of NIST and Google, and now the CHIPS Act, is catalyzing what's happening in the world of open-source IC design and semiconductor nanofabrication," said Saligane. "It's an exciting time for anyone who wants to learn chip design."



MPW-5 chip: one of the first successful chips created with open software.





The **MPW-6** and **MPW-7** chips were also created with open software, and show increasing complexity.

A Glimpse into Computer Vision in ECE

ECE faculty and students are exploring a number of critical problems in the area of computer vision, including detecting when images or videos have been manipulated, improving methods for video compression, and improving robot navigation

Feeding Our Love for Video

The general public seems to have an insatiable appetite for video. Nearly a third of the entire world's population uses YouTube. The popular video platform TikTok exploded onto the social media scene in 2016, influencing Instagram to introduce their video reels and YouTube to offer YouTube Shorts.

All this video content takes up a massive amount of storage space and transmission bandwidth. Prof. Hun-Seok Kim and his team are building on the success of existing deep neural network models to compress video data by adaptively selecting the best model to use throughout a video, which may involve using more than one model for the same scene.

The graphic below provides one example of the technique. The original video image is on the left. Using a technique called Feature Prediction (FP) provides sharp details, but loses some of the content, such as the rider's leg. Using a technique called Optical Flow conditioned Feature Prediction (OFC) results in particularly bad quality - as it gives the horse extra legs. Combining aspects of both FP and OFC, however, provides a faithful representation of the original video while also being compressed for faster video transmission and reduced storage space.

Kim has dubbed their method MMVC, for multi-mode video compression. Their method achieved competitive to improved compression while retaining good video quality over competitive state-of-the-art video compression schemes.

Raw FP OFC FP + OFC

Has that Photo or Video been Altered?

Fake images are being used to influence public opinion about a wide range of social, political or even scientific issues. Images have impact, and while some are meant to be innocently humorous, many are designed to deceive and distort the truth. The stakes are high to ferret out these doctored images, which are becoming more expertly created every moment.

Prof. Andrew Owens and his team have approached the challenge by going to an unusual source, the camera itself.

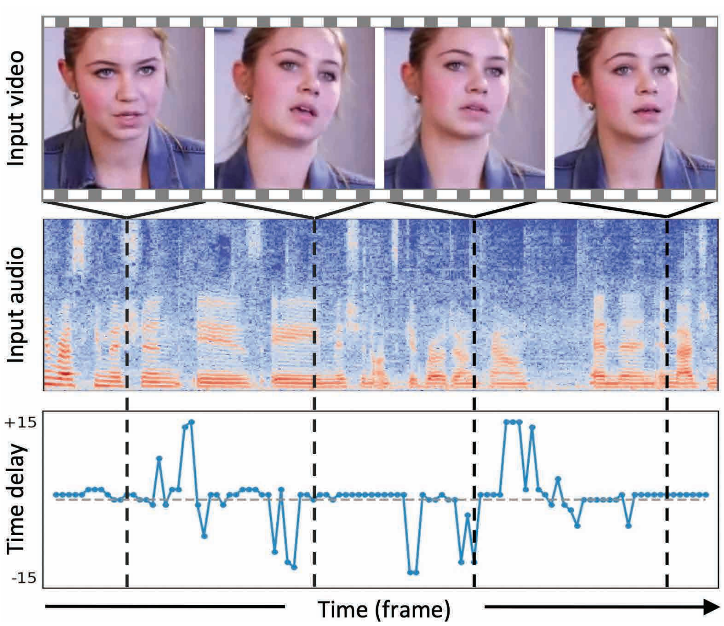
When inspecting photographs to prove their validity, there is information embedded in the camera that has proven to be helpful in applications such as image forensics and 3D reconstruction. But it is often overlooked.

Prof. Andrew Owens has found a way to work backwards from the image to determine the information found in a camera's metadata, which can include the camera settings, camera type, date and time - even the location the photo was taken.

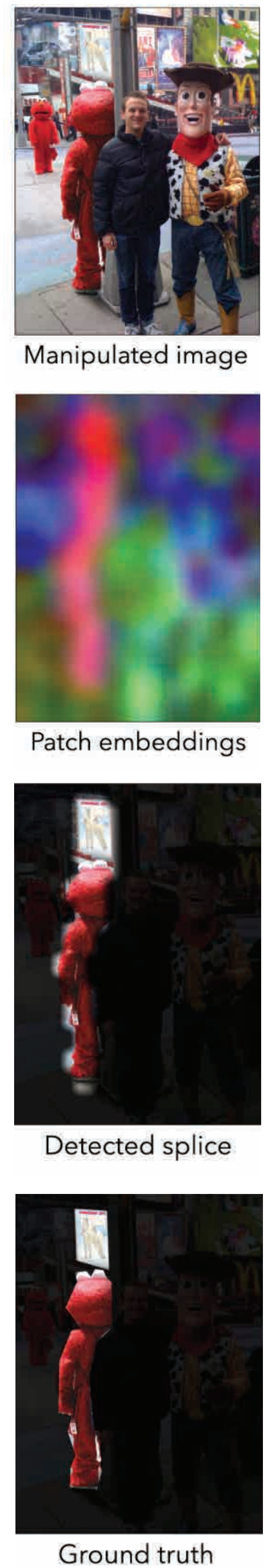
His team is using that information to help distinguish real from manipulated images.

In a related project, Owens created a video forensics model that can determine with high probability videos that have been manipulated.

His technique is particularly valuable because it works without having to rely on a large dataset of already-manipulated videos. Instead, his model is trained on reliable videos, which are much easier to find. By focusing on small inconsistencies between the visual and audio signals, his learning model was able to correctly identify videos that have been altered.

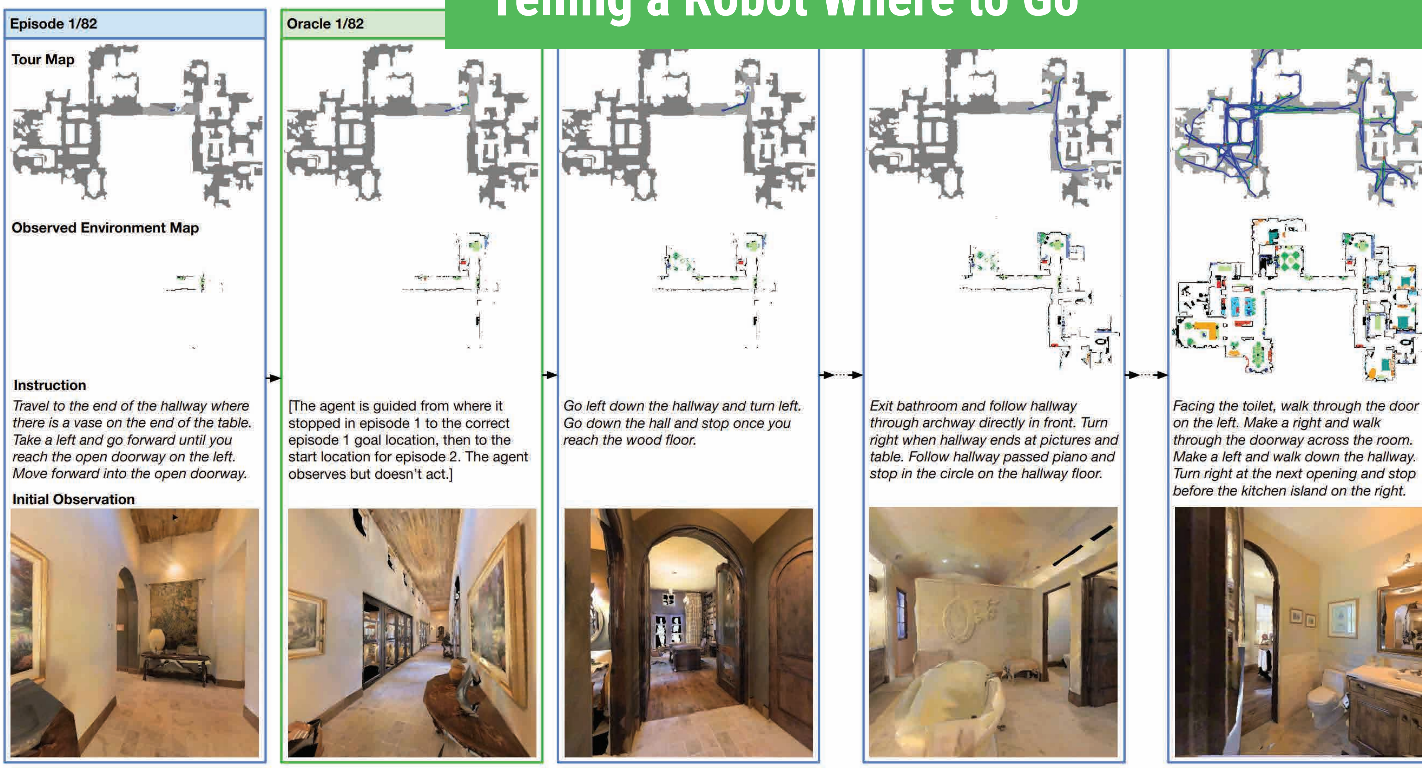


LEFT: This video was shown to be a fake because of the time delay between the audio and visual signals.



RIGHT: The Manipulated image was determined to be a fake, and a combination of two different images taken by two different cameras with differing metadata.

Telling a Robot Where to Go



Roombas have been wandering around homes picking up pet hair, dust and dirt for more than two decades, with more than 40 million units sold during that time. These simple robotic devices that clean floors have improved dramatically over the years, and now include a navigation system to improve their efficiency. You can even tell your voice assistant to tell your Roomba to start cleaning.

But you still can't tell Roomba to follow complex instructions, such as, "clean the living room, which is down the hall past the guest bedroom."

Prof. Jason Corso and collaborators from Google, Oregon State, and the University of Southern California have created an Iterative Vision-and-Language Navigation (IVLN) paradigm to improve a robots ability to do just that.

The figure above shows IVLN in action.

Robotic agents are given language instructions corresponding to a sequence of paths that form a tour around a 3D scene. After attempting to follow each instruction, the agent is given instructions to the correct goal location, then to the start of the next path where the next instruction is issued. Unlike conventional episodic paradigms, the agent retains memory between episodes.

Future applications go well beyond a simple vacuum cleaner to improving the ability of robotic personal assistants to help the elderly take care of themselves and remain in their homes as long as possible.

New Undergraduate Courses Prepare Students for the Second Quantum Revolution

Students in EECS 498 get a chance to discuss the material with each other and with Prof. Burgers (not pictured) at the beginning of each class.

> **"We're trying to develop this specialty in a way that's inclusive from the beginning."**
> —P.C. Ku

New undergraduate courses in Quantum Information Science and Engineering (QISE) at the University of Michigan are making the quantum world accessible to everyone. Starting with a sophomore-level course that has no college-level math requirements, these courses are designed to introduce a wide and diverse range of students to the field of quantum information; prepare some students for advanced research in the field by providing foundational knowledge; and equip all who take the courses with the ability to confidently handle new quantum-infused concepts and technology in their future careers.

"Quantum information science has the potential to transform society in a way that is as transformative as the advent of the computer and internet," said Prof. P.C. Ku, who has been overseeing development of the new undergraduate curriculum in QISE. "We're trying to develop this specialty in a way that's inclusive from the beginning."

ECE faculty have been working to create a sequence of undergraduate quantum courses for several years, and now have a suite of courses from the sophomore to senior levels.

EECS 298 (Intro to Quantum Inf. Science and Eng.): The Gateway to Quantum

The sophomore level course, Introduction to Quantum Information Science and Engineering, was offered for the first time in the Fall of 2022. The course introduces students to the important concepts, foundation, applications, and impact of QISE through in-class demonstrations. Quantum systems are introduced from both the physics point of view, and from the perspective of information and computing.

Teaching QISE and the associated concepts of quantum states, superposition, entanglement, teleportation, secure key distribution and more at the sophomore level is already a bit mind blowing. One might guess that it's ok for students who entered Michigan with lots of AP credits, and continued taking even more advanced math courses. But such a course would be inconsistent with the primary goal of attracting students from a diverse range of backgrounds.

Ku consulted with Russell Ceballos, who until recently was a professor at Chicago State University, an HBCU institution, as he was designing the course. The result is an introductory quantum course that has no specific math prerequisites beyond the high school level, ensuring access to most anyone with an interest in this highly complex field. The course was taught for the first time by Professors Jay Guo and Sandeep Pradhan.

"We had a lot of interactions," said Pradhan. "The students said we should have advertised it more, and that it was enlightening."

"This was the most interactive course I've ever taught," said Guo with a smile on face. "The students asked questions all the time."

EECS 398 (Intro to Quantum Inf. Tech.): Teaching a New Mindset

The new junior level course, "Introduction to Quantum Information Technologies," takes a deeper dive into the founding principles of quantum science and quantum information, followed by an overview of quantum technologies that have the potential to create far-reaching societal impacts. Even if students don't pursue additional coursework, their introduction to this emerging and rapidly growing field will expand their understanding of what's possible as they join the workforce.

"Our job is to help them get used to quantum mechanical philosophy," said Prof. Zheshen Zhang, who co-developed the course with Guo. "A lot of quantum effects are counterintuitive, like entanglement or quantum superposition. Nobody really has a full understanding of the foundations of quantum mechanics, but we can teach quantum effects and its profound impact on new ways of information processing and communications."

The course requires no prior knowledge of quantum mechanics, classical optics, computing or information.

Physics and computer science major Joel Huang said the best part of the course was the overview of quantum computing (including communication, algorithms, memory, security) that it provided. "I feel a lot more equipped to learn more on my own and delve deeper into the field," said Huang.

EECS 428: Introduction to Quantum Nanotechnology

Introduction to Quantum Nanotechnology was introduced in 2016 by Prof. Duncan Steel, who wanted to open up the world of quantum to undergraduate students by

Zheshen Zhang holds the cube used to split the optical power in research to create quantum entanglement for optomechanical sensors. Photo: Brenda Ahearn.

minimizing the need to solve complex differential equations. It is now taught by his former student, Prof. Alex Burgers.

The course introduces students to the foundations of quantum theory, quantum mechanics, and quantum mechanical systems. Students also gain an understanding of how the new physical properties found in quantum systems are revolutionizing how we approach the storage, transmission and processing of information.

> **"We have to train the new generation of engineers to speak the language of quantum technologies."**
> —Alex Burgers

"The subject matter is somewhat uneasy by its very nature," said Burgers. "Part of the goal of the course is to guide students to lean into that uneasiness." Once they do, they are prepared to discuss the topic in their future jobs.

"We have to train the new generation of engineers to speak the language of quantum technologies," said Burgers, "and then how to utilize that technology in systems that they're trying to build themselves."

EECS 498: Quantum Electromagnetics

Completing the series of undergraduate courses in quantum information science and engineering is the senior level course, Quantum Electromagnetics, first taught in 2022. The course introduces students to the quantum theory of electromagnetic radiation, matter and their interactions – which underpins all new quantum technologies.

According to Burgers, "EECS 428 introduces the quantum system, and then 498 explores how the quantum systems can be manipulated by external radiation, which we must also describe using quantum mechanics."

For the final project, teams of students take an application of quantum electromagnetism found in a current technology and describe its foundations, pitfalls, where the technology is going, and what it needs to get there.

A Senior-Level Quantum Lab Course

The four courses mentioned above do not include specific lab components, but that's about to change with a fifth course that is currently being developed. It is a senior-level quantum lab course.

"Seeing is believing," said Prof. Parag Deotare, who is currently developing a series of six labs that would serve as the foundation of the course.

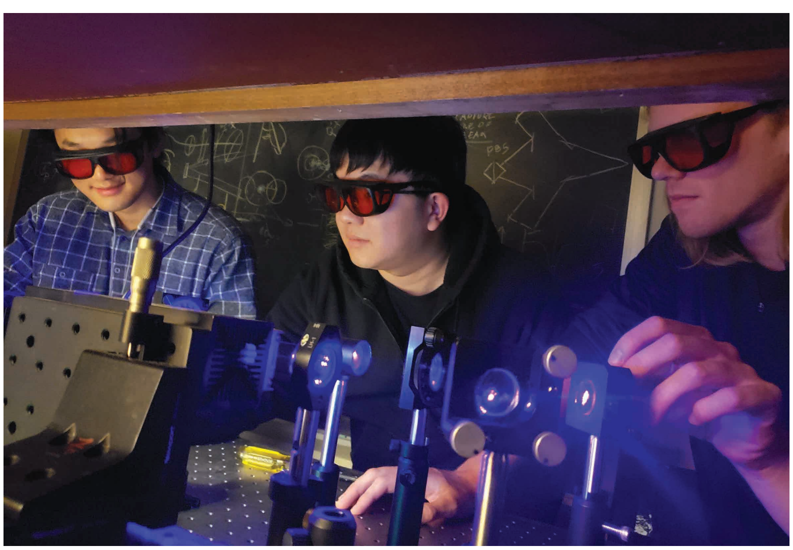
Once the new quantum lab course is up and running, students will be able to do some highly complex experiments such as entanglement, photon generation, and superposition.

And students in the earlier courses will be able to take mini field trips to the lab to watch how actual quantum experiments are done.

Gateway to the Future

Taking just one of these courses in quantum information science and technology offers undergraduate students from a wide range of disciplines the opportunity to understand the hype surrounding quantum engineering.

New courses will continue to be added to the curriculum as Michigan ECE prepares students to contribute meaningfully to the quantum future.



L-R: Saiwei Nie, Bohan Zhou and Colin Quinn experimenting in Deotare's teaching lab with spontaneous parametric down conversion to generate entangled photon pairs.

Introducing Young Engineering Students to the Sociotechnical Impact of Technology

Engineering students today want to solve problems – and not just those involving math. Their desire to have a positive impact on the world meshes with a society that has become more attuned to issues of environmental and social justice.

To help achieve this goal, a multi-institution team are developing several one-class course modules that can be easily incorporated into existing core courses in electrical engineering (EE), whether these courses are taught at large public research institutions like the University of Michigan (U-M), or small private colleges like the University of San Diego (USD).

The team was recently awarded funding from the National Science Foundation (NSF) to support their project, called "Collaborative Research: Integrating Sociotechnical Issues in Electrical Engineering Starting With Circuits." Prof. Cindy Finelli is co-directing the project with Prof. Susan Lord at USD.

"Including sociotechnical issues in a fundamental course such as Introduction to Circuits sends a powerful message to students about what is valued by the field," said Finelli. "That message can have a significant impact on students, particularly those who have been historically marginalized in EE including women and students of color."

The project will result in one-session modules that weave basic technical concepts taught in an introductory circuits course with broader societal issues. These modules will highlight different subdisciplines in EE – with each one exposing students to some of the ethical issues that may arise in their own careers.

For example, one module focuses on capacitors, which are found in most electronic circuits and are often made using tantalum. But tantalum is also classified as a conflict mineral, meaning its sale is actively being used to fund groups that are known to violate human rights. The module explores both the technical and ethical realities of capacitors.

Another module, piloted by ECE PhD student Gracie Judge, focuses on issues related to electric vehicles, such battery supply chains and raw materials, the electrochemistry that go into their design, the power electronics connecting them, and more.

"We're at a point where students and faculty alike are hungry for this kind of material," said Finelli. "We'll be able to give it to them."

Gracie Judge, ECE PhD student, teaches a sociotechnical module on electric vehicles.

"Including sociotechnical issues in a fundamental course such as Introduction to Circuits sends a powerful message to students about what is valued by the field."
—Cindy Finelli

Engineering Education Research Program Celebrates 5 Years

The Engineering Education Research (EER) program, launched five years ago by the College of Engineering and directed by Prof. Cindy Finelli, has reached a milestone in graduating its first cohort of PhD students.

The seven core EER faculty have produced new knowledge with real-world impact. Their contributions include developing classroom exercises that help students learn how to tackle realistic problems, launching organizations to informally mentor students and improve their sense of belonging, and identifying solutions to better support neurodivergent students, historically excluded students, and student mental health and wellbeing.

"By prioritizing more than just teaching technical skills, we can expand diversity in engineering, promote students' health and wellbeing, improve the way we mentor others, help practicing engineers make better design decisions, empower engineers to address ethical and socio-technical concerns in their work, and enable society to better understand what engineering is," said Finelli.

Students make connections at the meeting for the informal mentoring group, BIndex. From left: Chinwendu Nwokeabia (Robotics PhD student), David Nkansah (IoE Master's student), and Ngozi Aroh (IoE undergraduate student). Photo: Hannah Elliott

New Courses in ECE

EECS 298: How to Reduce Greenhouse Gas Emissions
Prof. Stéphane Lafortune

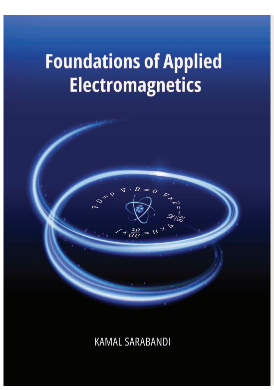
EECS 398: Introduction to Quantum Information Technologies
Prof. Jay Guo

EECS 498: Quantum Electromagnetism
Prof. Alexander Burgers

EECS 598: Artificial Intelligence in Biomedicine
Prof. Liyue Shen

EECS 598: Chip Fabrication Verification
Prof. David Blaauw

EECS 598: Mobile & Pervasive Sensing and Computing
Prof. Pei Zhang



New Book

Foundations of Applied Electromagnetics, Kamal Sarabandi

Distilling more than 15 years of experience teaching Electromagnetic Theory I for graduate students at the University of Michigan, Prof. Kamal Sarabandi published a new textbook, *Foundations of Applied Electromagnetics.*

The book is the latest addition to the Free ECE Textbook Initiative, which offers high quality textbooks free of charge to students, researchers, and faculty worldwide. Sarabandi's book is the first in the series written especially for graduate students.

Semiconductor Workforce Program for U.S. Students

2023 cohort of M-SHORE students. Photo: Marcin Szczepanski

In a program designed to help grow the U.S. semiconductor workforce, a cohort of college students from across the country spent the summer working in the University of Michigan's world-class Lurie Nanofabrication Facility (LNF), learning how to make, study, and improve advanced semiconductors.

No prior knowledge of nanofabrication was required for the 10-week Michigan Semiconductor Hands-On Research Experience, which is funded for three years by the National Science Foundation, with support from the Semiconductor Research Corporation. M-SHORE is designed to broaden participation in semiconductor-related engineering and encourage participants to pursue further academic studies in the field.

"The goal is to reach students who don't have access to a facility like the Lurie Nanofabrication Facility or who have never had this type of hands-on training," said Prof. Becky Peterson, LNF Director. "We want them to gain real experience making and testing devices in a lab—to go beyond putting together circuits in a class to building the physical layers that make the devices inside a cleanroom."

> **"The goal is to reach students who don't have access to a facility like the Lurie Nano-fabrication Facility or who have never had this type of hands-on training."**
> —Becky Peterson

Semiconductors are at the core of modern society, from our phones, tablets and computers, and the data center servers that form the internet, to cars, airplanes, robotic systems and even the industrial equipment used to manufacture these items. The recent chip shortage highlighted the need for the U.S. to expand the domestic semiconductor manufacturing industry and workforce.

"We need to focus on providing better training and expanding the number and types of students we train, so we can grow the workforce in this field in the United States," Peterson said.

The students worked with U-M faculty and graduate students from several departments on projects impacting power electronics and clean energy, computing, data storage, and sensing applications.

From ECE, students learned about artificial photosynthesis with Prof. Zetian Mi, power electronics with Professors Becky Peterson and Elaheh Ahmadi, and nanoparticles and plasmonic color with Jay Guo.

The student participants came from Embry-Riddle Aeronautical University; Union College; Sierra College; California State University, San Marcos; Purdue University-Fort Wayne; State College of Florida; Case Western Reserve University; and Trine University.

Going forward, U-M will work in partnership with two minority-serving institutions, the University of Texas at El Paso and Florida International University.

An M-SHORE student examines the results of an experiment in the Lurie Nanofabrication Facility. Photo: Marcin Szczepanski

ECE Expeditions Rides to the Lone Star State for a Tour of Engineering Companies

For its first in-person, out-of-state program since the pandemic began, ECE Expeditions took fourteen students to Texas for a behind-the-scenes experience at a variety of engineering companies in the Houston and Austin areas.

Students toured Hewlett Packard Enterprise, NASA, Ambiq, Dell Technologies, Torc Robotics, and National Instruments to learn more about the reality of working as electrical and computer engineers in industry. During these visits, they networked with Michigan alums, tested technology demos, and toured the companies' labs and campuses.

"ECE Expeditions is one of the most meaningful experiences I've had in my university years," said ECE Master's student Wenhan Kou. "It was great to hear engineers talk about how they got to their current positions and how they're working to improve the world."

Hewlett Packard Enterprise (HPE)

"HPE's impact extends far beyond being a computer manufacturer, and it was an eye-opening experience for me."
—Aashish Harikrishnan, EE undergrad

Torc Robotics

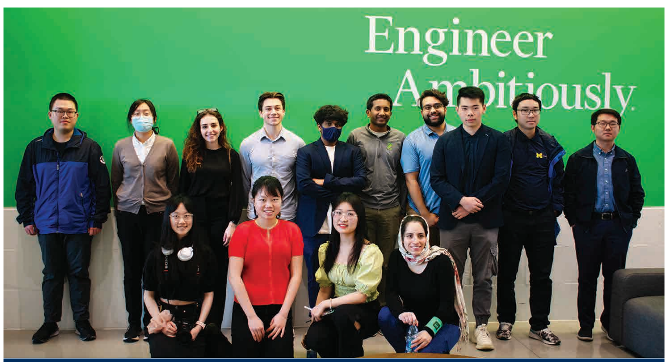
"Listening to the VP talk about the goal of the company was inspiring, and I learned a lot about how start-ups like Torc Robotics are pushing the envelope of technical marvels. It was stunning to see the future being crafted right before my eyes."

—George Paul, EE and Business Administration undergrad

NASA Lyndon B. Johnson Space Center & Space Center Houston

"One of the experiences I most enjoyed was talking with the alum from NASA [Adam Schlesinger (BSE EE 2005)]. He gave me some suggestions for my future career, and I left the trip feeling motivated and energized."

—Yihan Wang, ECE Master's student



National Instruments (NI)

"Eric [Starkloff, CEO of NI] left a lasting impression on me with his energy and passion. His enthusiasm motivated me to strive for more than just being a typical engineer and to truly be passionate about both work and life."

—Yilun Zhu, ECE PhD student

Dell Technologies

"I was astonished not only by their technological advancement but most importantly, by their ideologies about future technological development."

—Mingcheng Li, ECE Master's student

Ambiq

"[Ambiq] is a small yet dynamic company. I enjoyed learning about the speakers' life stories, especially how they transitioned from a U-M ECE student to an engineer or an entrepreneur. They were so friendly and gave really good advice."

—Xunhan Fan, ECE Master's student

> “I REALLY ENJOYED GETTING TO KNOW EVERYONE AND DESIGNING AND RACING OUR RC CARS.”
> —STUDENT CAMPER

Electrify

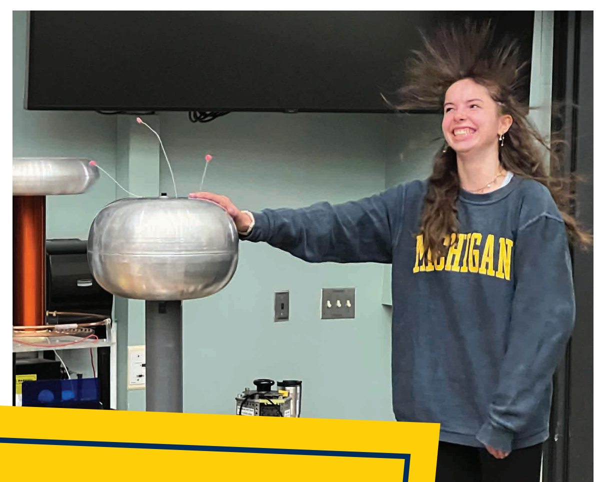
Electrify Tech Camps Recharged

The Electrify Tech Camps have been recharged – to the delight of more than 60 high school students who got a taste of nanotechnology, power and energy, and the world of optics through a week of intensive learning and fun activities this past summer.

“This was a really great experience for me to explore what I want for my future career,” said one of the young campers.

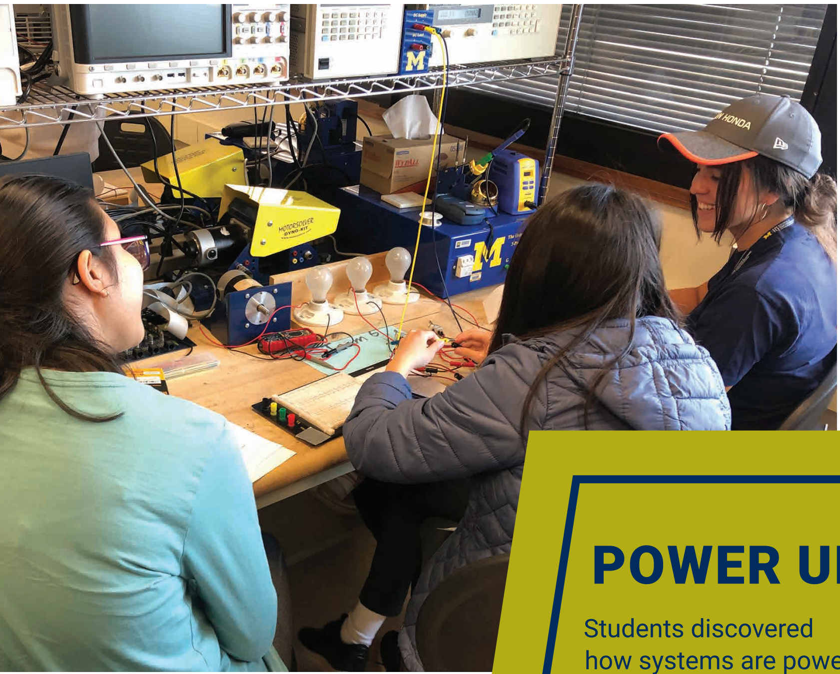
These week-long non-residential camps provide high school students with a hands-on engineering experience. The programs are developed and taught by U-M ECE faculty and graduate students, ensuring the highest quality of academic learning – and recreational activities are included every day.

The department offered three camps this year: Nano Size It; Power Up; and Zap It. All were offered in person as students experienced world-class lab facilities such as the Lurie Nanofabrication Facility and the U-M ZEUS Facility while learning from faculty, staff, and current students.



ZAP IT

Students explored laser engineering and plasma science through hands-on experience at the U-M ZEUS Facility, home to the most powerful laser in the U.S.



NANO SIZE IT

Students learned how nano-technology has transformed the world. They explored the technologies used to see and create small devices, and they designed and created their own solar powered car.

POWER UP

Students discovered how systems are powered and how electric vehicles work. They worked with circuits, solar cells, and electric drives, and raced cars that they optimized for maximum distance.

“I LEARNED HOW TO CREATE SOLAR CELLS AND ALSO HOW TO USE BREADBOARDS TO CREATE ELECTRICAL CIRCUITS THAT COULD BE USED IN A SOLAR POWERED CAR.”

—STUDENT CAMPER

“ALL OF THE EXCITEMENT FOR SCIENCE AND THE FACILITIES, TECH AND DEMOS WE GOT TO OBSERVE, EXPERIENCE AND LEARN ABOUT FIRST HAND. IT WAS REALLY AWESOME.”

—STUDENT CAMPER

Commemorating Juneteenth

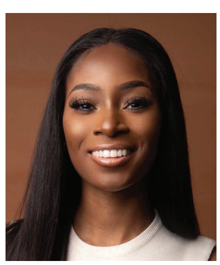
This year the EECS Department held its fourth annual Juneteenth event, called "Tech Empowering Communities." The celebration was hosted by Herbert Winful, the Diversity and Social Transformation Professor and Joseph E. and Anne P. Rowe Professor of Electrical Engineering at U-M.

"Today, we celebrate Black engineers and scientists who are making a difference in our communities," he said.

The event opened with EECS a performance of "Lift Every Voice and Sing," the Black National Anthem, by University Carillonist and Associate Professor of Linguistics Jessi Grieser on the Charles Baird Carillon, the largest instrument at U-M. Lt. Gov. Garlin Gilchrist (BSE CE/CS '05) also spoke on the significance of his EECS training in empowering him to effect change in his community. CSE DEI Project Manager Taj Williams then provided an overview of the history of Juneteenth.

A panel discussion featured three influential community leaders:

LEON PRYOR (BS EE '97), a Senior Game Producer at Meta, described his work with the Motor City Alliance, a consortium that aims to support middle and high school level robotics teams in Detroit.



MADELINE MILLER, an entrepreneur and PhD student in the School for Environment and Sustainability at U-M, discussed her startup NexTiles, a textile recycling company based in Detroit that converts textile waste from the automotive and apparel industries into eco-friendly building insulation.

DAVID TARVER (BSE MSE EE '75 '76) entrepreneur, educator, and community organizer, spoke about his work at the Urban Entrepreneurship Initiative, which seeks to support entrepreneurs whose businesses serve urban communities.

Michael Wellman, the Richard H. Orenstein Division Chair of CSE, and Heath Hofmann, the Associate Chair for Graduate Affairs in ECE, provided the closing remarks. They emphasized that, although progress has been made, there is still a lot of work to be done to make EECS and the field at large a more diverse and welcoming space.

"Today celebrates an important moment in history, but it also serves as a reminder of how far we have to go to achieve true equality for all," said Hofmann. "We are committed to achieving greater diversity in the department, and have been working hard towards this goal."

Gregory Robinson Details the Journey of NASA's James Webb Space Telescope

As this year's M. Alten Gilleo Distinguished Lectureship speaker, Dr. Gregory Robinson chronicled the many challenges and triumphs of NASA's James Webb Space Telescope (JWST or Webb). Since its launch two years ago, the JWST has delivered dazzling, never-before-seen views of the universe and revolutionized our ability to study distant galaxies, nebulae, and spectacular cosmic events.

"The Webb telescope is one of the most exciting feats of engineering in optics in the past decade, with a dramatic and successful launch," said Theodore Norris, the Gérard A. Mourou Professor of EECS.

The JWST is an orbiting infrared observatory that is 100 times more powerful than the Hubble Space Telescope. It studies every phase in the history of our Universe, ranging from the first luminous glows after the Big Bang, to the formation of solar systems capable of supporting life on planets like Earth, to the evolution of our own Solar System. As the premier observatory of the next decade, the JWST serves thousands of astronomers worldwide.

"Of course, the big questions are: how do we fit into this vast universe? How did we get here? And: are we alone?" Robinson said. "Webb is intended to help us better understand that."

The JWST began as an idea in 1989 and construction began in 2004. After years of engineering failures and delays, Robinson, a 33-year veteran of NASA, took over as head of the project and brought together 20,000 people across 29 countries and 14 U.S. states. The JWST successfully launched on December 25, 2021, from the European Space Agency (ESA) spaceport in French Guiana.

"Seeing that solar ray deploy was one of the best scenes I've seen in my life," Robinson said. "The control room just went nuts."

For his achievement, Time magazine listed Robinson as one of the 100 Most Influential People of 2022 and a Time100 Impact Award winner, which credited his leadership on the JWST as bringing us closer to understanding the universe. He was also named 2022 Federal Employee of the Year.

ABOVE: Robinson delivers his lecture, "Launching the Webb Telescope: Managing Global Teams In Turbulent Times" in STAMPS auditorium on April 10, 2023. **RIGHT:** This star-forming region 6,500 light-years from Earth is called Pillars of Creation. The photo was taken by JWST in 2022. Credit: NASA, ESA, CSA, STScI

Welcome New Faculty

With research expertise in biomedical AI, data science and machine learning, semiconductor optoelectronics, control with applications to neuroscience, organic optoelectronic and photonic devices, sustainable energy systems, and computer networks – ECE's newest faculty are striving to improve how people live and work in the world.

JIASI CHEN

Associate Professor

Research Interests:
Computer networks, mobile computing, multimedia systems, and augmented/virtual reality.

Jiasi Chen was most recently an Associate Professor of Computer Science at the University of California, Riverside. Her recent interests are in systems support for the metaverse, its security, and mobile generative AI. She received her PhD from Princeton University and BS from Columbia University, both in electrical engineering. While at UC Riverside, she received an NSF CAREER award and a Meta Faculty Research award. Chen joined Michigan Fall term 2023.

VLADIMIR DVORKIN

Assistant Professor

Research Interests:
Optimization, control and machine learning for sustainable energy systems; Data privacy and algorithmic fairness; Nexus of energy markets and optimization theory.

Vladimir Dvorkin obtained his Ph.D. in electrical engineering from the Technical University of Denmark in 2021. He was also a postdoctoral researcher at the Laboratory for Information & Decision Systems and Energy Initiative of the Massachusetts Institute of Technology. He received the Marie Skłodowska-Curie Actions & Iberdrola Group postdoctoral fellowship and the IEEE Transactions on Power Systems Best Paper Award. Dvorkin will join the Michigan Winter term 2024.

CHRIS GIEBINK

Professor

Research Interests:
Optoelectronic and photonic devices based on organic semiconductors, solar energy conversion, solid-state lighting, semiconductor lasers, and nonlinear optics.

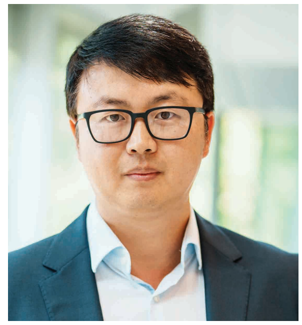
Chris Giebink comes to U-M after ten years in the Electrical Engineering department at Penn State University. He received his PhD in electrical engineering from Princeton University working on organic light emitting diodes and lasers, and holds undergraduate degrees in both Physics and Engineering Science from Trinity University. He holds 11 patents and is a senior member of the IEEE, OSA, SPIE, and National Academy of Inventors as well as a recipient of the DARPA YFA, AFOSR YIP, and NSF CAREER awards. Giebink joined Michigan Fall term 2023.

JING SHUANG (LISA) LI

Assistant Professor

Research Interests:
Distributed control theory with applications to neuroscience (particularly motor and sensorimotor control), biology, and large-scale engineering systems.

Lisa Li received her PhD in Control + Dynamical Systems from Caltech, and a BASc in Engineering Science from the University of Toronto. Her research is focused on control-theoretic analysis of biological systems, which yields novel scientific explanations as well as valuable design insights for engineering systems. She is particularly interested in how biology co-designs and implements controllers using organic components, which face unique challenges – but give substantial energy savings – compared to their electronic counterparts. Li joined Michigan Fall term 2023.



DI LIANG

Professor

Research Interests:
Semiconductor optoelectronics, compound semiconductor and silicon-based photonic devices, large-scale photonic integration for optical interconnect, sensing, and computing.

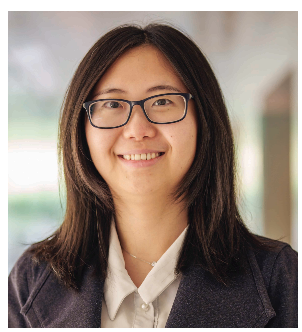
Di Liang had 14 years of experience in advanced semiconductor research and product development in HP Labs and Alibaba Cloud Computing prior to joining U-M. His work on heterogeneous photonic integration has helped generate several billions of dollars in revenue for leading semiconductor companies. He received his PhD degree in Electrical Engineering from the University of Notre Dame, and BS degree in Optical Engineering from the Zhejiang University in China. He has been granted more than 50 patents. He is a Fellow of Optica and associate editor of *Photonics Research* and *Journal of Quantum Electronics.* Liang joined Michigan Fall term 2023.

SAMET OYMAK

Assistant Professor

Research Interests:
Principled methods and theories for data science and machine learning to enable resource efficiency and trustworthy decision-making.

Samet Oymak was most recently an Assistant Professor of ECE at the University of California, Riverside, where he received a Google Research Scholar award and an NSF CAREER award. He received his PhD degree from Caltech in 2015, receiving a Wilts Prize for best EE thesis. After graduation, he was a postdoc at UC Berkeley as a Simons Fellow and also briefly worked at Google and in algorithmic finance. His recent research focuses on the foundations of transformers, language models, and their trustworthy deployment in AI systems. Oymak joined Michigan Fall term 2023.

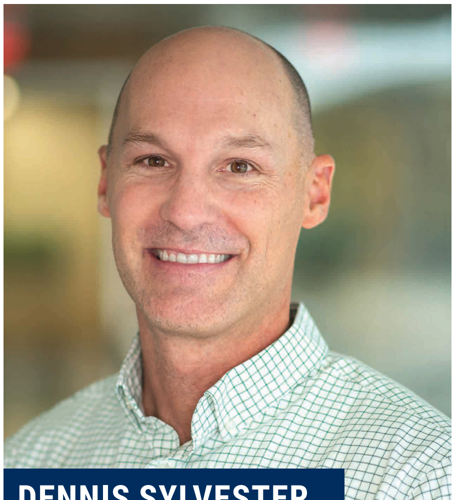


LIYUE SHEN

Assistant Professor

Research Interests:
Biomedical AI, medical image analysis, biomedical imaging, machine learning, computer vision, signal and image processing, AI for precision health, and bioinformatics.

Liyue Shen received her PhD in Electrical Engineering at Stanford University, and her Bachelor's degree in Electronic Engineering from Tsinghua University. Her research lies in the interdisciplinary area of Biomedical AI, and recently focuses on the generative diffusion models, implicit neural representation learning and multimodal foundation models. She was selected as a Rising Star in EECS by MIT and a Rising Star in Data Science by The University of Chicago. She is also chairing the Women in Machine Learning (WiML) workshop this year.



DENNIS SYLVESTER

Named Interim Chair of Electrical and Computer Engineering

Named Edward S. Davidson Collegiate Professor of Electrical and Computer Engineering

Elected to the National Academy of Inventors

Dennis Sylvester was appointed Interim Chair of Electrical and Computer Engineering, named the Edward S. Davidson Collegiate Professor of ECE, and elected to National Academy of Inventors, all in the past year.

Sylvester is an internationally recognized leader in the area of ultra-low power integrated circuit design. His research has resulted in more than 50 U.S. patents in the area of semiconductor integrated circuit design, and he co-founded two companies, Ambiq and Cubeworks. His former students have founded additional companies.

Ambiq provides ultra-low power semiconductor platforms and solutions for battery-powered IoT devices, particularly those requiring very low power. It earned the IoT Semiconductor Company of the Year in 2021, after selling more than 100 million chips. Sylvester co-founded the company in 2010 with colleague David Blaauw and former doctoral student Scott Hanson.

CubeWorks wirelessly tracks the temperature of individual and high-value, high-risk, products, such as biologics, for a product's lifetime. Founded in 2013, its technology is based on the Michigan Micro Mote (M^3), developed by Sylvester, Blaauw and others at Michigan.

A leader in both academia and the professional community, Sylvester is Editor-in-Chief of *IEEE Journal of Solid-State Circuits,* and a former member of the IEEE Solid-State Circuits Society Administrative Committee. He has served as General Chair or principal organizer for numerous professional workshops and conferences, and has served as a consultant to many major semiconductor companies.

He also excels as an educator. Sylvester has taught five different courses in the areas of digital integrated circuits and VLSI Design, both at the undergraduate and graduate level. He developed two of those courses, and co-authored the book *Statistical Analysis and Optimization for VLSI: Timing and Power.*

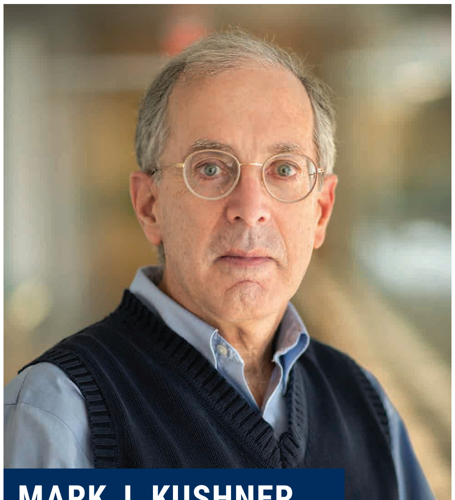
Sylvester accepted the position of Interim Chair of ECE after former Chair, Mingyan Liu, was called to take on the position of Associate Dean for Academic Affairs in the College of Engineering. He is an IEEE Fellow.

LOUISE WILLINGALE

Fellow of American Physical Society

Prof. Louise Willingale was named Fellow of the American Physical Society "For significant contributions to the experimental understanding of ion acceleration, electron acceleration and magnetic field dynamics resulting from relativistic laser plasma interactions."

Willingale conducts research in intense laser-plasma interactions including laser-driven ion acceleration, relativistic laser propagation through underdense and near-critical density plasmas, and proton deflectometry to study electric and magnetic fields generated during the laser-plasma interactions. She is Associate Director of the NSF Zettawatt-Equivalent Ultrashort pulse laser System (ZEUS) facility. ZEUS is among the highest-power lasers worldwide, and is open to researchers around the world.



MARK J. KUSHNER

William P. Allis Distinguished University Professor of Electrical Engineering and Computer Science

Mark Kushner was named the William P. Allis Distinguished University Professor of Electrical Engineering and Computer Science. His research on low-temperature plasma has been foundational in the creation of plasma-based energy systems, and is combined with a commitment to creating technologies that will benefit society.

He is the founding director of the Michigan Institute for Plasma Science and Engineering (MIPSE), and directs the Computational Plasma Science and Engineering Group (CPSEG). Through MIPSE, he directs the Graduate Certificate Program in Plasma Science and Engineering, and arranges for a wide array of activities such as an international seminar series, awards, and sponsored research.

The CPSEG develops computer simulations of low temperature plasmas and technologically important devices which use low temperature plasmas. Many of the computer models and CAD tools developed by the CPSEG are available for licensing and transfer to industry. In particular the Hybrid Plasma Equipment Model (HPEM) is now in use by semiconductor equipment suppliers and chip manufacturers.

He also directs the multi-university DoE Center for Low Temperature Plasma Interactions with Complex Surfaces (PICI). PICI is focused on research on atmospheric pressure plasmas (APPs) as used in environmental, materials processing, chemical conversion, and biotechnology applications.

Kushner has received numerous awards, including the Plasma Chemistry Award, IEEE NPSS Charles Birdsall Award, AVS Medard W. Welch Award, APS Will Allis Prize, Semiconductor Research Corp. Technical Excellence Award, Tegal Thinker Award for Plasma Etch Technology, the AVS Plasma Science and Technology Award, the IEEE Plasma Science and Applications Award, and the Semiconductor Industry Association University Researcher Award.

In addition to being elected a member of the National Academy of Engineering, he is a Fellow of IEEE, APS, AVS, OPS, Institute of Physics, Intl. Union Pure & Applied Chemistry, and Intl. Plasma Chemistry Society. Kushner is also the George I. Haddad Collegiate Professor of Electrical Engineering and Computer Science, and is affiliated with the Departments of Nuclear Engineering & Radiological Science and Chemical Engineering.

ZETIAN MI

Fellow of American Physical Society

Prof. Zetian Mi was named Fellow of the American Physical Society "For contributions to the development of III-nitride quantum nanostructures and their applications in ultraviolet optoelectronics and clean energy."

Mi has been making tremendous strides in the development of semiconductor nanostructures and their application in electronic, photonic, clean energy, and quantum devices and systems. His primary research areas include epitaxial growth and fundamental properties of semiconductor nanostructures, including quantum dots, nanowires, and two-dimensional atomic crystals; III-nitride materials and devices; light emitting diodes, lasers, and UV photonics; quantum photonics; as well as artificial photosynthesis, solar fuels and clean energy. He is PI of a MURI program on the development of next generation semiconductors for clean energy.

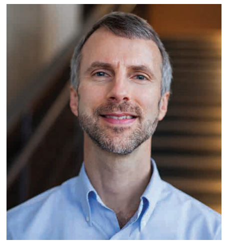
Additional Faculty Honors and Awards

LAURA BALZANO
Associate Professor

2023 North Campus Deans' MLK Spirit Award

DAVID BLAAUW
Kensall D. Wise Collegiate Professor of EECS

2022 MICRO Hall of Fame



JEFFREY FESSLER
William L. Root Collegiate Professor of EECS

2023 CoE Stephen S. Attwood Award

MICHAEL FLYNN
Fawwaz T. Ulaby Collegiate Professor of ECE

2023 CoE Staff-Faculty Partnership Award

BRIAN GILCHRIST
Professor

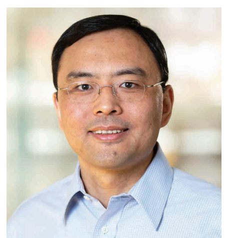
2023 CoE Neil Van Eenam Memorial Undergraduate Teaching Award

JAY GUO
Professor

2023 Wise-Najafi Prize for Engineering Excellence in the Miniature World

MINGYAN LIU
Alice L. Hunt Collegiate Professor of Engineering

CoE Assoc. Dean for Academic Affairs



WEI LU
Professor

2023 Ted Kennedy Family Faculty Team Excellence Award

JOHANNA MATHIEU
Associate Professor

2023 IEEE Power and Energy Society Wanda Reder Pioneer in Power Award

R&D 100 Award

ZETIAN MI
Professor

2023 IEEE Nanotechnology Council Distinguished Lecturer

KAMAL SARABANDI
Fawwaz T. Ulaby Dist. University Professor of EECS

2024 IEEE Electromagnetics Award

PETER SEILER
Associate Professor

2023 HKN Professor of the Year in ECE

VIJAY SUBRAMANIAN
Associate Professor

2023 Ernest and Bettine Kuh Distinguished Faculty Award

LOUISE WILLINGALE
Associate Professor

EECS Outstanding Achievement Award

EUISIK YOON
Professor

2023 CoE Monroe-Brown Foundation Research Excellence Award

Michelle Chapman Earns CoE Staff Excellence Award

Michelle Chapman is a Research Administration Senior Manager who embodies excellence, service, and compassionate leadership. She has been praised for being precise and lightning fast in her work processing and managing the research grants of about 30 faculty. These faculty are constantly breaking new ground with their entrepreneurial approach to research, and they rely heavily on her expertise and support. Chapman also supervises six staff members, and provides outstanding support to more than 125 graduate students.

“Michelle works tirelessly, produces the highest quality results, is a calm leader through adversity and change, and I feel is an inspiration to all of us,” said Prof. David Wentzloff, Lab Manager for the Michigan Integrated Circuits Laboratory.

ECE Staff Recognized for Contributions to ECE Community

The College of Engineering recognized six ECE staff members with the 2022 Staff Incentive Award, which recognizes staff who have demonstrated creativity, innovation, and daring in helping the College build its culture of diversity, equity, and social impact in engineering.

“I feel very fortunate to work with such a talented group of individuals,” said Lisa Armstrong, ECE Department Administrator. “They inspire me every day and are the backbone of ECE.”

SILVIA CARDARELLI
ECE Alumni and Corporate Relations Manager

JULIA FALKOVITCH-KHAIN
Web Designer and Administrator Senior

GORDY CARICHNER
ECE Engineer in Research Senior

MICHELLE CHAPMAN
ECE Research Administration Senior Manager

ROBERT GORDENKER
ECE Engineer in Research Lead

LINDA SCOVEL
ECE Faculty Affairs Coordinator

IAN HISKENS

Paraglides into Retirement

Ian Hiskens, the Vennema Professor of Engineering, officially retired from the University of Michigan on August 31, 2023, after serving as a faculty member at U-M for 15 years.

"Prof. Hiskens has made important theoretical and practical contributions towards solving humanity's biggest challenge: the transformation from fossil fuels to sustainable energy sources," said Prof. Heath Hofmann.

Hiskens is a renowned expert in power system analysis with a special focus on integrating renewable energy sources into the grid. His research interests lie at the intersection of power system analysis and systems theory, in particular modeling, optimization, dynamics and control of large-scale, networked, nonlinear systems.

He made fundamental contributions in theoretical and practical techniques for assessing voltage collapse, trajectory sensitivity analysis for hybrid dynamical systems, optimal power flow, and algorithms for inverse problems.

"Ian has been an amazing mentor and advocate for me, and also a great friend," said Prof. Johanna Mathieu.

Prof. Jim Freudenberg helped recruit Hiskens to the university, specifically so he could lead the development of a power and energy research group. Today, the power and energy group is known as the Michigan Power and Energy Lab (MPEL).

Hiskens earned his Bachelor of Engineering in Electrical Engineering (1980) and Bachelor of Applied Science in Mathematics (1983) from the Capricornia Institute of Advanced Education. He earned his PhD (1991) from The University of Newcastle, Australia.

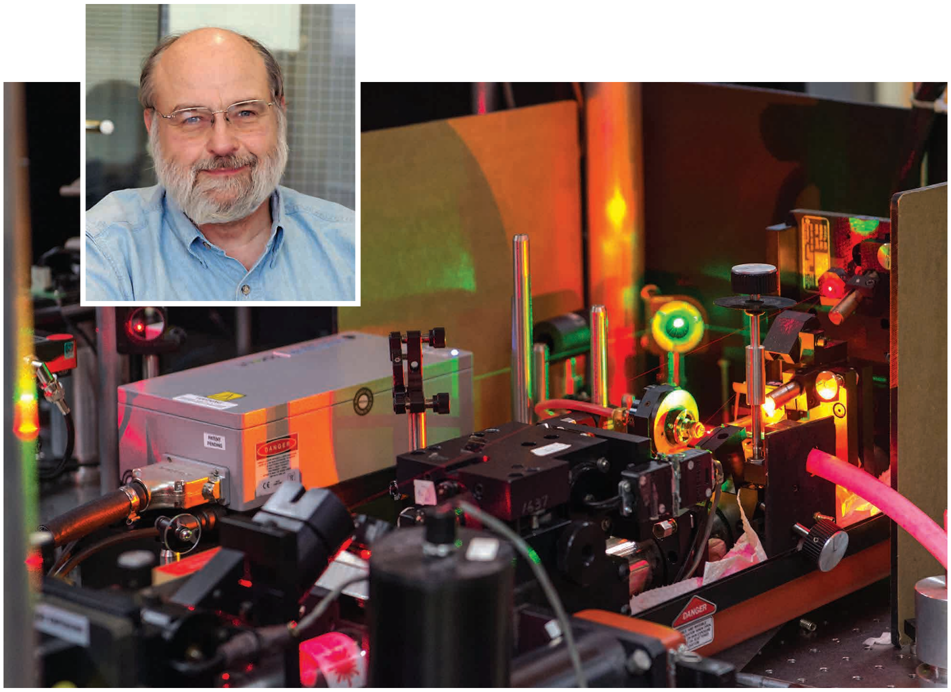
He worked in transmission operations and planning at the Queensland Electricity Commission for nearly a decade before joining academia in 1992. He taught at several different institutions before he joined the University of Michigan faculty as a professor in 2008 and was appointed Vennema Professor of Engineering in 2009. He has supervised 24 PhD students and 15 MS students. In addition, he has authored 2 books, 10 book chapters, 86 refereed journal papers, and 180 conference papers.

"The university takes the view that faculty are the best in the world at what they do, so let's support them as best we can," Hiskens said. "That's helped me to be more creative and productive, and that's been one of the most memorable aspects of being at the University of Michigan."

In addition to his robust career, Hiskens has a very full personal life. He and his wife, Judy, have been married for 42 years and have five children. One of his children, David, earned his bachelor's and master's in Electrical Engineering from U-M. David even took a course taught by his father, and the two would race each other to class on their bicycles.

One of his favorite hobbies is paragliding. While Hiskens has always paraglided in tandem (meaning strapped to a trained glider), one of his goals for retirement is to gain certification to paraglide solo.

Hiskens has served on the Editorial Board of *Proceedings of the IEEE*, as chair of the board of directors of the International Institute for Research and Education in Power System Dynamics (IREP), and as Vice-President Finance of the IEEE Systems Council. He is a Fellow of the IEEE, a Fellow of Engineers Australia, and a Chartered Professional Engineer in Australia. He is also a recipient of the M.A. Sargent Medal from the Electrical College board of Engineers Australia.



DUNCAN STEEL

Retires, leaving a Quantumly Inspired Legacy

Duncan Steel, the Robert J. Hiller Professor of Engineering, retired May 31, 2023, leaving a legacy felt across several disciplines and deep in the hearts of many individuals.

Steel's history at Michigan began as a master's student in electrical engineering back in 1972. His doctoral work centered on spectroscopy, and learning the early quantum theory of the laser. He helped build the first Z-pinch machine on North Campus.

After receiving his doctoral degree in Electrical Engineering and Nuclear Engineering in 1976, Steel began a decade-long stint at Hughes Research Laboratories. He found himself working on cutting-edge theory as he investigated optical phase conjugation, a non-linear optical process.

"Suddenly quantum mechanics was front and center in terms of how things were working at the electronic level, and I was learning all this stuff that was just fantastic," he recalled.

In 1985, Steel was recruited back to Michigan by his thesis co-chair and then Dean, Jim Duderstadt. He ultimately graduated 62 doctoral students (25% were women), from a variety of disciplines that included physics, electrical engineering, applied physics, biophysics, and biochemistry. And he was on the thesis committee of 128 additional students from an even wider range of disciplines.

This diversity in degrees reflected Steel's relentless curiosity, which led to his joint appointments in the departments of EECS, Physics, Biophysics, the Applied Physics program, and the Institute of Gerontology. He served as the Director of the Biophysics Enhanced Program between 2007-2009.

Even before arriving at Michigan, Steel was asked to create a center of optics within engineering. Within three years, he had helped recruit future Nobel Prize winner Gérard Mourou and many other faculty to Michigan. Steel served as the first director of the current Optics and Photonics Lab between 1988 and 2007.

His own research was focused on the development and application of various laser-matter interaction studies and quantum optics in fields including plasmas, optical phase conjugation, atomic and molecular spectroscopy, condensed matter physics, protein folding and – most recently – quantum computing, where he has made several groundbreaking contributions. Steel also excelled as an educator. He created graduate courses in quantum mechanics and one called Quantum Theory of Light. He also developed the department's first undergraduate course in quantum nanotechnology, for which he authored the textbook, *Introduction to Quantum Nanotechnology*.

His doctoral students are engineers, medical doctors, professors, and leaders in industry. One, Alex Burgers, recently returned to Michigan as an assistant professor. Another, Steven Cundiff, is the Harrison M. Randall Professor of Physics and co-director of the new Quantum Research Institute.

The extent to which Steel was quantumly entangled with his colleagues and former students came to light during his two retirement parties. His impact was so widespread, one retirement party couldn't do him justice, and they were filled with testimonials from former students and his colleagues.

Steel's last student, Darwin Cordovilla Leon, echoed the sentiment of many others when he stated, "Duncan is one of the most caring people I have ever met. More than just an academic and career mentor, Duncan was a friend and ally to me. Much like him, I hope to make a contribution to the world, and especially to the next generation of scientists and engineers."

MASA Achieves Liftoff with Record-Setting Rocket

On May 14th, the Michigan Aeronautical Science Association (MASA) successfully launched Clementine, a 20-foot tall liquid bipropellant rocket – the largest to ever be built by college students.

“We wanted to push the limits of what’s possible for a college team to accomplish,” said Evan Eidt, a Computer Engineering undergrad who is MASA’s Avionics Subteam lead.

MASA’s goal is to design, build, and launch liquid-fueled rockets. Through this experience, they focus on providing high quality practical training, which is especially useful for students planning to pursue careers in industry.

“I think we have some of the best collegiate rocket engineers in the world on this team,” Eidt said. “I’m so grateful that we can learn about these technologies, because it’s going to help us to do great things in the future.”

MASA currently operates on a two-year cycle. The first year is focused on designing and testing various technologies and components, and the second year is construction and launch. While their rockets are not the type that would send supplies or astronauts to space, they would be suitable for Earth-bound missions, such as depositing an atmospheric sensing device at high altitudes.

Since their rocket is so large, MASA has a separate space in the GFL building for construction, in addition to an assembly area for larger systems in the Wilson Student Team Project Center. This year, they completed their rocket integration and vertical testing out at MCity. They used liquid nitrogen and water instead of live propellants, which allowed them to test the fluid system and identify bugs in the electrical and software systems.

The MASA launch crew in front of Clementine at the the Friends of Amateur Rocketry launch site in the Mojave Desert.

“People know about the aerodynamics or the propulsion side of rockets, but they don’t often think about all the electronics that drive the system,” Eidt said. “For us, there are two major electronic elements: the ground support side and the rocket avionics side.”

The ground support team conducts coldflow and hotfire tests and manages the fluid systems, which requires high fidelity data acquisition systems. It also supports the propellant filling and pressurization steps of launch.

“Those systems have to be able to collect data very fast and have good control systems,” Eidt said. “For example, we might have to actuate some valve and record pressures at a high rate to accurately control tank pressures.”

The rocket avionics group focuses on regulating various functions, such as keeping the fuel tanks at a constant pressure by designing control algorithms. They’re also responsible for managing the radio communication and the camera systems. They design their own custom boards for a variety of applications, such as battery management, and they provide their own firmware as well.

“As a freshman, I was shocked that I was allowed and able to make a board myself,” Eidt said. “So I really loved getting the hands-on electrical and software experience.”

In addition to their work on campus, MASA conducted their hotfire test– a one-second engine burn with live propellants – at the Reaction Research Society site out in the Mojave Desert, which is near the Friends of Amateur

MASA members working the final integration of the Clementine avionics bay at the Friends of Amateur Rocketry launch site.

Rocketry site where they later conducted the official launch.

Around 100 team members contributed to the project over the past two years, and of those, a little more than 20 (including Eidt) were selected to serve as the launch crew. The launch crew had nearly a week at the site to prepare for launch. They set up stations to assemble the rocket, which had to be shipped in parts, and made use of a semi-clean room, where they could protect more delicate components from the dust. They also set up their mission control section, which included their computers and camera monitors.

“We’d drive out to the site early in the morning,” Eidt said. “It was hot, and there was a lot of dust and a lot of bugs.”

Like with NASA, the weather conditions have to be right for MASA to launch.

“The biggest issue for us in the desert is wind,” Eidt said. “If we launch in winds that are too strong, the rocket won’t be stable. The direction of the wind also matters – we don’t want the rocket to get blown into some nearby town or back toward us.”

But the wind patterns in that area of the desert were predictable, so the team was able to plan for their best launch window. In addition to the launch team, dozens of other team members, family, and friends, as well as MASA alumni in the area, came out to witness the event.

“Seeing something that I’ve spent the last two years on go up in the air was absolutely awesome,” Eidt said.

The team is now focused on breaking the liquid altitude record with their next rocket, Limelight.

Improving Control of Robotic Prostheses with Brain-Machine Interfaces

“Knowing I could possibly help people regain movement and independence was one of the main reasons that I decided to go to grad school.”
—Olivia Lee

What if we could control technology with our minds? For ECE PhD student Olivia Lee, it could mean greater movement abilities and improved independence for those using robotic prosthetic limbs.

“I want to create devices and systems that can restore movement to people who have been paralyzed or have lost limbs,” Lee said. “The goal is to create equitably accessible and clinically viable medical solutions to improve people’s health and well-being.”

Lee, an incoming ECE PhD student this fall who completed her bachelor’s degree in Electrical Engineering from U-M this spring, was selected for the National Science Foundation Graduate Research Fellowship Program (GRFP). The GRFP recognizes and supports outstanding graduate students in NSF-supported science, technology, engineering, and mathematics disciplines.

“‘Brain-computer interfaces’ or ‘brain-machine interfaces,’ is when technology directly interfaces with the brain and the nervous system,” Lee said. “In my PhD, I want to explore this intersection through circuit design and machine learning.”

In her junior year, Lee worked with Cynthia Chestek, a professor of Biomedical Engineering and ECE, (who is also a courtesy professor in ECE). Chestek’s Cortical Neural Prosthetics Lab is focused on designing circuits, algorithms, and electrodes that can interpret neural signals and then send commands to the desired technology.

As a grad student, Lee will continue her research on neural interface probes in a collaboration between Chestek and David Blaauw, the Kensall D. Wise Collegiate Professor of Electrical Engineering and Computer Science. Blaauw and his team have developed probes so small they can operate for a long time without scarring the brain tissue itself. The goal is to combine hundreds to thousands of these probes to realize “neural recording dust” for the first time. Neural dust refers to a type of brain-computer interface where nanometer-sized devices are deployed to operate as wirelessly powered nerve sensors. These implantable neural recording systems could help restore limb function for paralyzed and severely injured individuals.

“It is amazing to see how technology can impact people’s lives,” Lee said. “Knowing I could possibly help people regain movement and independence was one of the main reasons that I decided to go to grad school.”

Sensors that Help Protect These Little Piggies in Their Pens

It's not just the Big Bad Wolf piglets have to fear – they're also at risk of being trampled in their pens or prevented from nursing by their mother. The mortality rate of piglets is nearly 18%, with much of this loss being caused by sow behavior. This is highly problematic for anyone who raises pigs, and especially for the swine farming industry. To address this issue, ECE PhD student Jesse Codling uses sensors to monitor and classify the vibrations in a pig pen, which can help identify when piglets are in danger and track their feeding habits.

Jesse Codling (far left), Prof. Pei Zhang (third from left) and the research team at one of the pig farms where they install their sensors.

> **"We're listening to the floor, and the floor tells us what's going on."** —Jesse Codling

"It's kind of like in an old movie where a guy puts his ear on the train tracks, and he can tell you when a train is coming," Codling said. "We're listening to the floor, and the floor tells us what's going on."

Codling installs geophones, which are vibration-detecting sensors, to the underside of the metal pens where the piglets are raised. His team then uses a combination of machine learning-based data models, physics models, and heuristic models to classify behavior in the pen based on the pattern of vibration. For instance, vibration patterns can indicate when a mother sow is getting tired and is in danger of collapsing on top of the litter, or when the piglets are feeding.

The project, affectionately called "The Sh*tty Project" due to the researchers having to crawl through a lot of pig muck to install the sensors, is in collaboration with the U.S. Department of Agriculture. The USDA has relied on other monitoring methods in the past, such as live camera feeds of the pens and wearables on the pigs themselves, but these methods have many limitations.

For instance, internet connectivity is very spotty in rural areas where pig farms are most common, making live video feeds difficult. Wearables only work if they remain on the pig, which is no easy task. Aside from the fact that piglets grow rapidly, which would require a new harness practically every week, pigs are rather destructive to technology in general, something that Codling has experienced personally.

"In one of our first deployments, a sow got loose and immediately ran to the wall and unplugged the central box that was powering all of the sensors," Codling said. "We lost all of our sensor data for like an hour because of that."

In general, the sensors are far more protected from the pigs than wearables and cameras, for they are located beneath the pen platform. The team is now exploring a similar approach to detect walking patterns in children with muscular dystrophies, so their caregivers can get a more granular view of the progression of their disease.

Codling is advised by Prof. Pei Zhang. The research won a Best Presentation award at the European Conference on Precision Livestock Farming. In addition to the USDA, the team includes researchers from Stanford University and Carnegie Mellon University.

Building a Fault-Tolerant Quantum Computer and Exploring Quantum Machine Learning

PhD student Mohammad Aamir Sohail is one of three U-M students to be awarded an inaugural Quad Fellowship. The Quad Fellowship is a joint initiative between Australia, India, Japan, and the United States that is designed to build ties among the next generation of scientists and technologists, and features robust programming with each country's top scientists, technologists, and politicians.

"I was interested in this fellowship because I will get to meet a lot of different people from different disciplines," Sohail said, "and learn how my research can apply to all these different domains."

Sohail specializes in Quantum Science and Technology, specifically the theoretical aspects of quantum information technology and quantum computing. He is interested in how to build a fault-tolerant quantum computer, as well as how to speed up optimization and computation with quantum machine learning. This has many useful applications, including optimizing the design and placement of sensors in cars.

Sohail is also working on deriving the bounds of quantum information theory, such as proving what rate you can send and receive messages using quantum channels and counterintuitive quantum phenomenon.

"Let's say we replace 5G or 6G communication with quantum communication," Sohail said. "I work on determining what rates we could provide and what the best way to achieve that would be."

Sohail's recent research includes computation over a classical-quantum multiple-access channel (CQ MAC), which could help reduce the complexity of quantum communication.

"With computation over MAC, when you have interconnected networks of quantum computers, you don't have to transmit as much information, so you can increase the rate of transmission," Sohail said. "This could help reduce the complexity of deep space satellite communication."

Last year, Sohail mentored a team in the 10th Annual NYUAD International Hackathon for Social Good, held in Abu Dhabi. The goal of the hackathon was for students to apply their quantum computing skills to make a positive impact on the future of society. Sohail's team, which won third place, developed a web application, mediQal, to optimize mobile medical services in a society that is aging, with the added goal of reducing greenhouse emissions.

Sohail earned his Bachelor of Technology in Electrical Engineering from the Indian Institute of Technology (IIT) Hyderabad. He is advised by Prof. Sandeep Pradhan.

> **"I was interested in this fellowship because I will get to meet a lot of different people from different disciplines, and learn how my research can apply to all these different domains."**
> —Mohammad Aamir Sohail

Mentors and team members of the mediQal hack. Sohail stands fourth from the right.

Reducing Energy Burdens in Detroit

A team of doctoral students working to improve home energy efficiency and to lower monthly utility bills for low- and moderate-income (LMI) households in Detroit have been recognized with a Michigan Difference Student Leadership Award. Joshua Brooks and Xavier Farrell are PhD students in ECE, and Madeline Miller is a PhD student in the School for Environment and Sustainability (SEAS).

Xavier Farrell and Joshua Brooks accept the Michigan Difference Student Leadership Award at the award ceremony on March 23, 2023.

"If successful, this project can serve as a scalable model for how to effectively mitigate the energy related hardships experienced among low-to-moderate income households," Farrell said. "This means reducing the number of 'heat-or-eat' type decisions where persons are forced to choose between paying for energy expenditures and other physical or medical necessities."

Some Detroiters spend up to 30% of their monthly income on home energy bills, which can result in household energy insecurity, or the inability to adequately afford their energy costs. Energy insecurity can lead to or exacerbate a host of physical, social, economic, and health issues, particularly in communities of color.

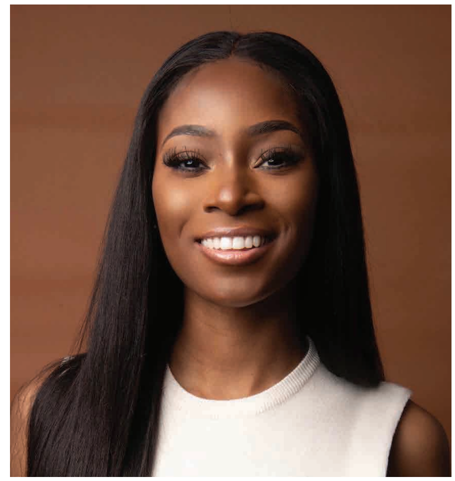
"Behind the metrics, numbers and data, there are real people in our communities experiencing cold winters, financial hardships, and insecurity relating to their energy that are in need of help," Farrell said. "As engineers and compassionate people, we are equipped with many tools to help them."

The team has been exploring how smart meter data can be used to improve utility programs and rate recommendations. They are also researching possibilities for reforming the utility rate structure to provide the basic electricity needs of LMI households for free while ensuring that the utility provider's costs are covered.

"There is very little real-time data on energy usage for low-income single and multi-family homes," Miller said. "The information that comes out of this project can be used to inform realistic, impactful, data-driven decisions for the most vulnerable residential utility customers."

> **"If successful, this project can serve as a scalable model for how to effectively mitigate the energy related hardships experienced among low-to-moderate income households."**
> —Xaxier Farrell

Brooks, Farrell, and Miller are specifically working with community-based organizations in the Jefferson Chalmers and Southwest Detroit neighborhoods and the Villages at Parkside, a multifamily public housing community.



Madeline Miller is a PhD student in the School for Environment and Sustainability.

"I was born and raised in Detroit myself, so this project felt like a natural extension to try and help people in the community I've called home for most of my life," Brooks said.

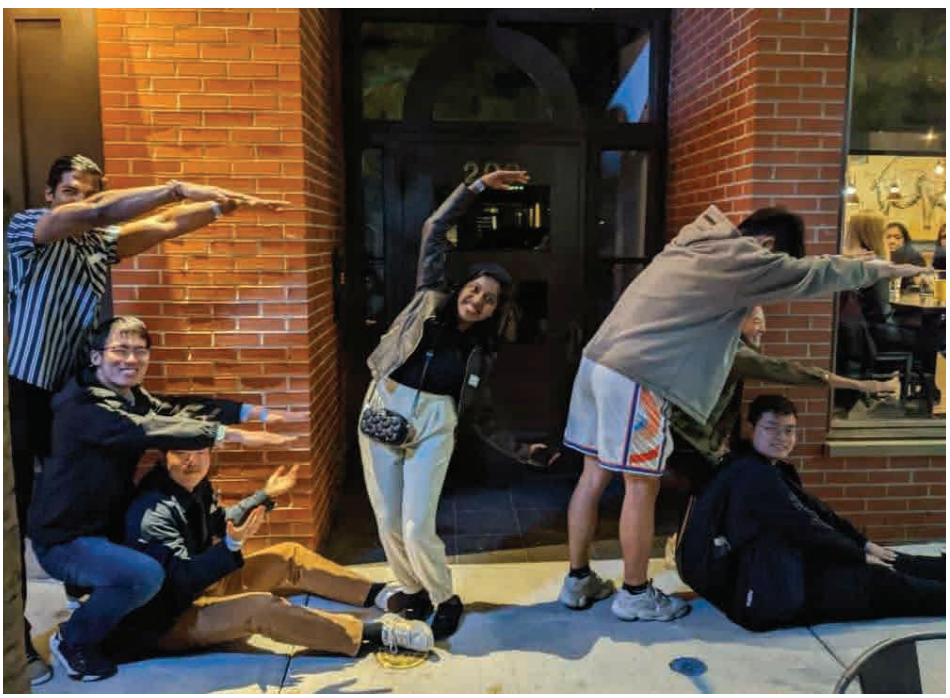
Prof. Johanna Mathieu co-leads the project with Marie O'Neill of the School of Public Health, Carina Gronlund of the Institute for Social Research, and SEAS faculty members Shelie Miller and Tony Reames. Mathieu advises Brooks and Farrell, and Reames and S. Miller co-advise M. Miller.

The project is funded by a $2.1 million grant from the U.S. National Science Foundation's Smart and Connected Communities program. 30% of the funding goes to U-M's community partners in Detroit: Jefferson East Inc., Friends of Parkside, Southwest Detroit Environmental Vision, and EcoWorks. DTE Energy is also a collaborator.

Designing the Control Systems of the Future

> **"I want to make machines do what we can do."**
> —Swetha Sakunthala Subbiah

When ECE Master's student Swetha Sakunthala Subbiah was little, her room was full of miniature rocket models given to her by her grandfather. He worked for the Indian Space Research Organization (ISRO), and he inspired her to attend the Indian Institute of Space Science and Technology, where she earned her Bachelor of Technology degree in Electrical and Computer Engineering. For one of her class projects, she was tasked with making a computer game similar to Battleship, and everything clicked into place.



Subbiah (center) and friends form a human 'ECE' during an ECE social event.

"The fact that I could make a computer think like a human and play a game with you — it blew my mind," she said. "I was like, this is what I want to do. I want to make machines do what we can do."

Subbiah followed her grandfather's path and joined the ISRO as a control systems engineer. She worked on the realization and operation of checks for electrical, power, and control systems for rocket subassemblies. She then decided to pursue a master's degree, so she could develop her skills and gain more experience in control systems engineering.

"I chose Michigan, because I liked the research that was happening," Subbiah said. "I was looking at the work happening with MCity and Michigan's partnership with Ford, and I was very inspired."

Subbiah spent an entire summer working at Mcity on a project to mitigate motion sickness in autonomous vehicles, led by Mechanical Engineering Prof. Shorya Awtar.

She also worked with Prof. Yogesh Gianchandani and Dr. Yutao Qin on a Microfabricated Gas Chromatograph, which is a fully electronic micro gas chromatography system that detects and monitors indoor air pollutants. Subbiah helped advance the algorithm responsible for detecting and identifying peaks in the chemical data.

Subbiah also served as a Student Coding Coach for the Joy of Coding summer program taught by Prof. Raj Rao Nadakuditi. The program is an online course designed for high schoolers where students learn how to use Python and study how coding powers apps such as TikTok, Instagram, Snapchat, and Siri.

After graduation, Subbiah will be working for Skyryse, which is a startup focused on autonomous flight, specifically helicopters.

"What I'll remember most about U-M is the culture of everyone being really nice and kind and down to earth," Subbiah said. "There's always someone around to help you, and it inspires you to want to do the same and give back to society. I'm definitely going to miss it."

Broadening the Engineering Perspective through Coastline Conservation in Middle Earth

This past summer, Electrical Engineering undergrad Nora Desmond traveled to the other side of the world to learn more about the environmentally-conscious culture of New Zealand.

"I went because I wanted to see more of the world, and I specifically wanted to see how different cultures handle different problems in engineering," Desmond said.

The trip was sponsored by the U-M Engineering Global Leadership (EGL) Honors Program. Desmond and fellow U-M engineering students worked with Sustainable Coastlines, a local non-profit that works to clean up beaches, prevent litter, and overall connect people with nature.

"I was surprised to find how much litter there was on the New Zealand beaches, but the tides bring in trash from all over the world," Desmond said. "In the end, it really does become everybody's problem."

While environmental contamination has severe consequences for health and industry, it can also have devastating impacts on age-old cultural traditions. Native cultures around the world are particularly vulnerable to having their customs disrupted by environmental destruction, and the Māori, the indigenous people of New Zealand, are not exempt.

"Our guide was of Māori descent, and she was telling us that where she grew up, they used to swim in the local rivers," Desmond said. "But now it's too polluted. They can't continue this tradition that's been in their family for generations."

Despite the extent of the problem, Desmond was inspired by how Sustainable Coastlines combined real world action – picking up trash – with a strong data-driven focus to help shape national policies for conservation. Through Litter Intelligence, Sustainable Coastlines work in close collaboration with New Zealand's Ministry for the Environment and Department of Conservation and Statistics to track the flow of litter across ocean currents.

"By knowing the precise nature of the litter, you can put policies in place to help control it," Desmond said. "It's a huge step up from where we are in the U.S."

Desmond's engineering focus has been on developing more sustainable batteries, but her experience learning about the lifecycle of litter impacted her perspective.

"Learning how trash circulates made me think of how we're still struggling to dispose of batteries, and the environmental hazards because of all the toxic materials and chemicals that go into them," Desmond said. "Even the mining process for the materials is very, very harmful for the environment. So while I definitely agree that batteries are the next step in sustainability, I can't imagine they're the final step, because the way they're done right now, they're just not environmentally friendly."

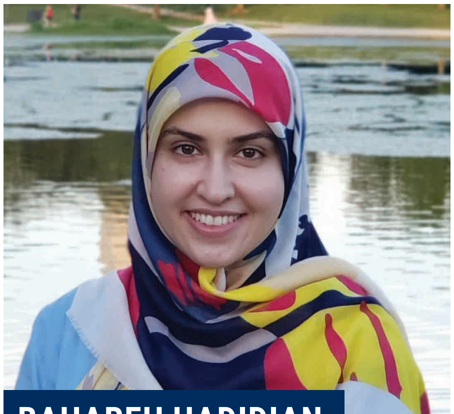
While the primary purpose of the trip was academic, students also got to explore much of New Zealand's cities and activities. One of Desmond's most memorable excursions was in a remote area deep in the South Island of New Zealand. Nestled along the border of Fiordland National Park, Desmond crossed the sparkling Lake Te Anau in a glorified canoe. She and a handful of fellow adventurers were off to explore the twisting limestone passages, the underground waterfalls, and above all, the sparkling wonder of billions of glowworms in the Te Anau Caves.

Nora Desmond holds up litter she and her team gathered on a beach in New Zealand.

"They were like little underground stars," Desmond said. "I've never seen anything like it. And getting there was an adventure in and of itself, because there's no way to get there by road. It's surrounded by mountains and the lake. Even the guides had to take the boat to get back civilization at the end of the day."

ECE PREDOCTORAL FELLOWSHIP **AWARDS**

Shaping the Next Generation of Wireless Communications



BAHAREH HADIDIAN

Bahareh Hadidian received a Barbour Scholarship to support her research in high-frequency fully integrated circuits for the next generation of wireless communications and sensing technologies. She is focused on the development of high-speed and energy-efficient wireless transmitters for mobile applications with different modulation schemes. This is important for any application requiring massive amounts of wireless data transfer that is fast, reliable, and secure.

"I want to pave the way for technology, specifically high-speed wireless communication, to be in people's homes all over the world to make life easier for them, and help them feel more connected to the world: from big and advanced cities to small villages," said Hadidian.

Hadidian's dissertation title is "Exploiting mm-Wave and Terahertz Bands for Ultra-Wideband Communication and Sensing." She is advised by Prof. Ehsan Afshari.

Helping make Sensing Devices Trustworthy and Confidential

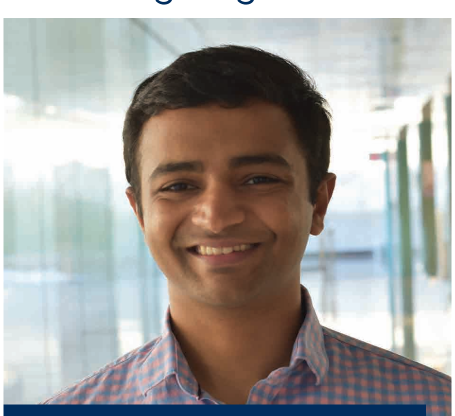
YAN LONG

Yan Long received a Rackham Predoctoral Fellowship to support his research that stands at the intersections of sensing, embedded system security, and mobile computing. The goal of his research is to ensure that the information received from sensing devices is not only trustworthy, but also confidential. Long has discovered innate vulnerabilities in how sensors operate, and is developing techniques that can prevent potential security and privacy threats posted by the sensors.

"Internet of Things (IoT) and mobile devices depend on sensors to make life-critical decisions ranging from steering an autonomous vehicle to defibrillating a patient's heart," Long said.

Long's proposed dissertation title is "Modeling and Mitigating Side Channels in Optical and Embedded Sensing Systems." He is advised by Professors Mingyan Liu and Kevin Fu.

Creating High-resolution Imaging Radars



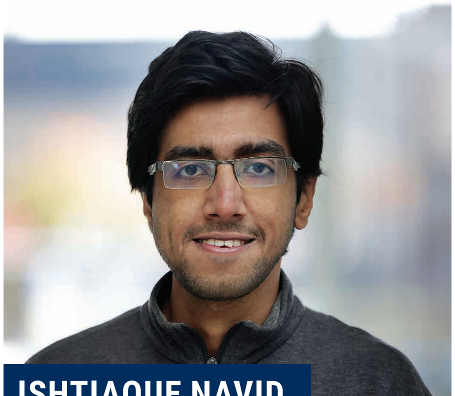
ADITYA VARMA MUPPALA

Aditya Varma Muppala received a Rackham Predoctoral Fellowship to support his research in imaging radars. His goal is to make high-resolution imaging radars that are 200 times cheaper and 100 times smaller than what is currently available. Imaging radars can see inside things without using hazardous ionizing radiation. This means they can be safely used for concealed weapons detection, navigation in times of low to no visibility, and the detection of people trapped in burning buildings or hidden in post-earthquake disaster areas.

"Like any mature technology," said Muppala, "in order for imaging radars to be integrated into the infrastructure of our future more widely, they must be cost-effective, compact and scalable."

Muppala's proposed dissertation title is "High-resolution Millimeter-wave Imaging Radars for a Safe and Equitable Future." He is advised by Professors Kamal Sarabandi and Ehsan Afshari.

Advancing Artificial Photosynthesis and Next Generation Nanoscale Optoelectronics



ISHTIAQUE NAVID

Ishtiaque Navid received a Rackham Predoctoral Fellowship to support his research in III-Nitride nanostructures for artificial photosynthesis and next generation nanoscale optoelectronics. Artificial photosynthesis promises to be one of the key sustainable energy technologies of the future, enabling clean, storable, and affordable energy (i.e., hydrogen and other fuels) from just sunlight and water.

“My research work will provide a scalable and stable platform for low-cost green energy production,” said Navid. “This could make a significant impact on the vast community involved in solar and photonics research.”

Navid’s proposed dissertation title is “Nanoscale and Alloy Engineering of III-Nitride Semiconductors for High Efficiency Solar Photocatalysis and LEDs.” His advisor is Prof. Zetian Mi.

Helping Improve the Safety of Smart Systems

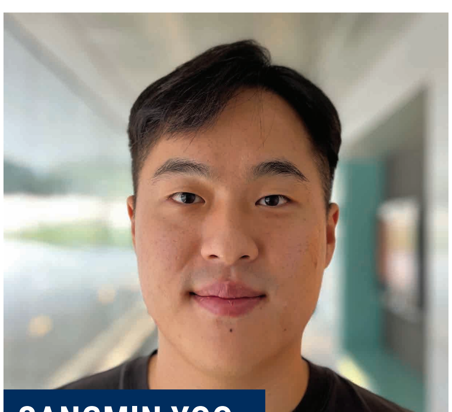
ANDREW WINTENBERG

Andrew Wintenberg received a Rackham Predoctoral Fellowship to support his research in the areas of computer and network security for both cyber and cyber-physical systems. Cyber-physical systems (CPS) refers to dynamic systems composed of a physical component along with a software component, both tightly intertwined. Typical examples include smart power grids, autonomous vehicles, medical devices, robotic systems, and industrial control systems.

“As we observe an unprecedented explosion in communication between humans and technology, there is a growing need for formal guarantees of the privacy and security of our communication networks,” says Wintenberg.

Wintenberg’s proposed dissertation title is “Privacy and Utility in Dynamic Systems: Verification and Enforcement.” He is advised by Necmiye Ozay and Stéphane Lafortune.

Advancing Memory Technologies for Artificial Intelligence



SANGMIN YOO

Sangmin Yoo received a Rackham Predoctoral Fellowship to support his research that focuses on advanced memory technologies for applications in artificial intelligence. With computing devices about as small as they are ever going to get, Yoo is focusing his attention on new computing devices – and in particular, the memristor (also referred to as resistive random-access memory, or RRAM).

“A key theme in my research is to find out the way to tune memristors’ physical dynamics and utilize the tunable dynamics to build the application-specific neural network hardware equipped with native learning rules and information processing capabilities for diverse tasks,” Yoo said.

Yoo’s proposed dissertation title is “Theoretical discovery and experimental characterization of memristor internal physics and physics-based neural network systems for Artificial intelligence.” He is advised by Prof. Wei Lu.

STUDENT HONORS + **AWARDS**

AAKASH BHARAT
Undergraduate CE Student

William L. Everitt Student Award of Excellence

JACOB BLOCK
Undergraduate EE Student

EECS Outstanding Achievement Award

Richard K. Brown Memorial Scholarship

NEOPHYTOS CHARALAMBIDES
Doctoral Student

2022 SIAM Conference on Mathematics of Data Science Best Poster Award

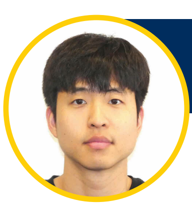
The 22nd IEEE Statistical Signal Processing Workshop Best Paper Award

CORBIN FLEMING-DITTENBER
Undergraduate CE Student

EECS Outstanding Service Award

ALI HAMMOUD
Undergraduate CE Student

Winning Code-a-Chip design at 2023 Int. Solid-State Circuits Conference



KYUMIN KWON
Doctoral Student

The 2023 International Conference on Synthesis, Modeling, Analysis and Simulation Methods, and Applications to Circuit Design Best Paper Award

AMY LIU
Undergraduate EE Student

William Harvey Seeley Prize

EECS Community Impact Award

YAKSHITA MALHOTRA
Doctoral Student

SPIE Optics and Photonics Education Scholarship

LNF Poster Contest Third Place

The Metropolitan Detroit Chapter of Society for Information Displays Academic Award

SAAKETH MEDEPALLI
Undergraduate EE Student

William L. Everitt Student Award of Excellence

ISHTIAQUE AHMED NAVID
Doctoral Student

SPIE Optics and Photonics Education Scholarship

Richard and Eleanor Towner Prize for Distinguished Academic Achievement

SVCF John B. Fenn, Sr. Foundation Endowed Scholarship

KOHEI NISHIYAMA
Undergraduate EE Student

CoE Distinguished Academic Achievement Award

AVA PARDO-KEEGAN
Undergraduate CE & CS Student

EECS Community Impact Award

AAYUSH SUJIT RAJANKAR
Master's Student

Michigan Difference Student Leadership Quiet Influence Award

PETER REDMAN
Undergraduate EE Student

EECS Outstanding Service Award

KALEO ROBERTS
Doctoral Student

American Indian Science and Engineering Society Scholarship

J. Robert Beyster Computational Innovation Graduate Fellowship

KAMAL RUDRA
Master's Student

JN Tata Scholar

IEEE EDS Masters Student Fellowship

KALEB SCHMOTTLACH
Undergraduate CE Student

EECS Commercialization/ Entrepreneurship Award

EMILY SU
Undergraduate CE Student

EECS Collaboration, Respect, and Inclusion Award

AMANDA WHITLEY
Undergraduate EE Student

EECS Collaboration, Respect, and Inclusion Award

YIXIN "ARTHUR" XIAO
Doctoral Student

SPIE Optics and Photonics Education Scholarship

SVCF Scholarship

WENTAO XU
Undergraduate CE Student

EECS Outstanding Research Award

SAMUEL YANG
Undergraduate EE Student

EECS Outstanding Research Award

JUSTIN YU
Undergraduate EE Student

EECS Outstanding Achievement Award

JIALE ZHANG
Doctoral Student

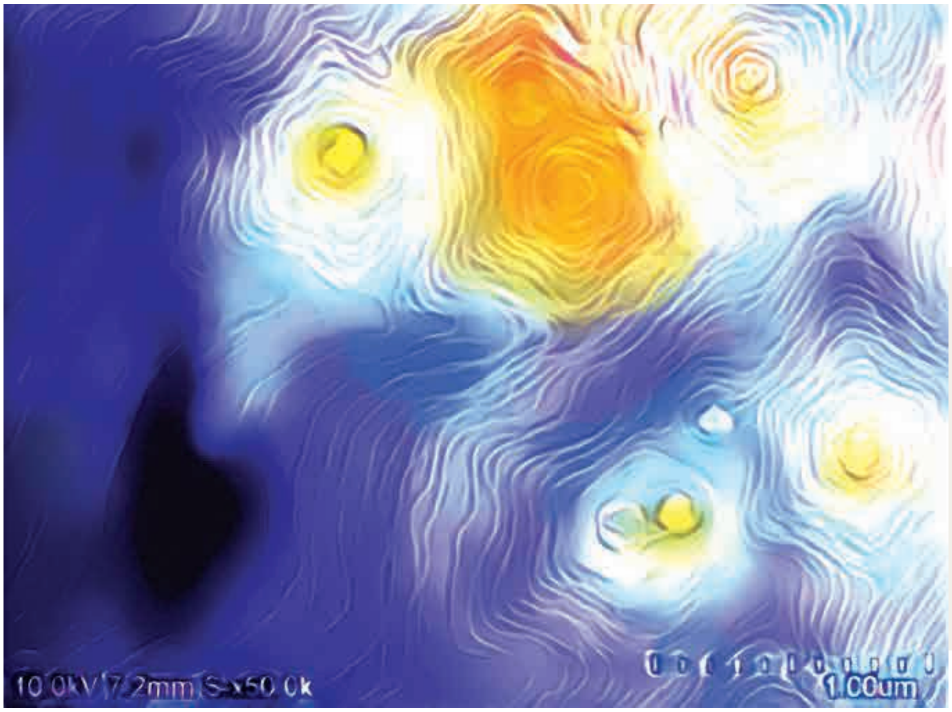
Qualcomm Innovation Fellowship

KAN ZHU
Undergraduate CE Student

EECS Outstanding Achievement Award

CoE Distinguished Academic Achievement Award

ECE Sweeps LNF Calendar Photo Contest



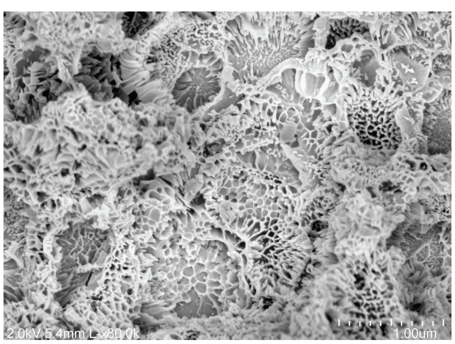
ECE graduate students sweeped the annual Lurie Nanofabrication Facility (LNF) photo contest, sponsored by the LNF User Committee and ArtsEngine.

FIRST PLACE (LNF/ARTSENGINE)

Mingtao Hu (MS ECE)

"Crystal Starry Night"
This is an SEM (Scanning Electronic Microscope) photo of the GaN epitaxial surface.

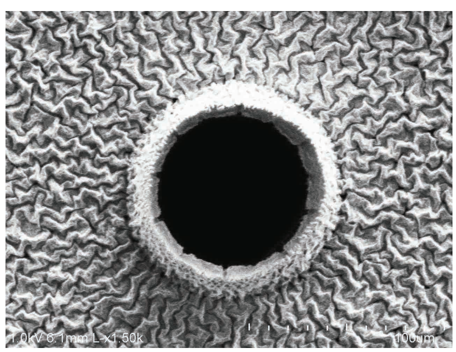
FIRST PLACE (ARTSENGINE)



Ruby Wellen (PhD ECE)

"Metallic Coral Reef"
This is a photo of a GaN substrate that has been etched with electrochemical etching. Wellen was attempting to achieve a porous sample but instead etched away at the surface.

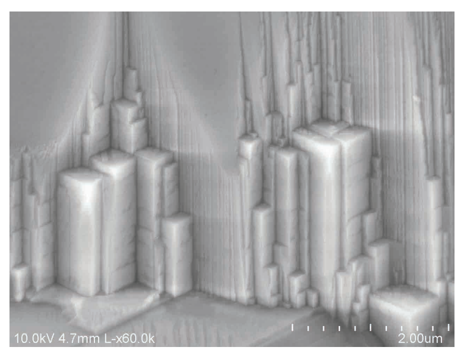
SECOND PLACE (LNF)



Behnoush Rostami (PhD ECE)

"Black Hole"
This image captures a popped air pocket within a thick layer of photoresist after long term DRIE.

THIRD PLACE (LNF)



Jiangnan Liu (PhD ECE)

"A Sketch from the Scratch"
The picture was taken on a scratched piece of single-crystalline nitride material. The crystallography creates the skyscraper-shaped structure.

Photo: Kristen Thornton

Diwali

Celebrated: October 24, 2022

Diwali (Deepawali) is the Hindu Festival of Light, which lasts for four or five days, depending on the region. Lighting a lamp symbolizes the destruction – through knowledge – of all negative forces, such as wickedness, violence, lust, anger, envy, greed, bigotry, fear, injustice, oppression and suffering.

Photo: Silvia Cardarelli

Pie a Prof!

Celebrated: March 14, 2023

The Pie a Prof! fundraiser raised money for a wide variety of initiatives benefiting students, faculty, and staff. A special thanks to the "winners" of the campaign, Professors Fred Terry, David Wentzloff, and Alex Burgers, for being such good (pie-faced) sports.

Photo: Marcin Szczepanski

Lunar New Year

Celebrated: January 20, 2023

Also known as Chinese New Year and the Spring Festival, this holiday began as a ceremonial day to pray to gods for a good planting and harvest season, but it is also associated with the myth of Nian. Nian was a monster who came every New Year's Eve until a boy repelled it with firecrackers and red decorations.

RUBA BORNO, Technology Leader and VP of AWS

Ruba Borno (MSE PhD EE), Vice President of Worldwide Channels & Alliances for Amazon Web Services (AWS), gave a fireside chat with the ECE community as recipient of the ECE Rising Star Award.

"I love Ann Arbor, and it feels like just yesterday that I was walking the halls, working in the Lurie Nanofabrication Facility, and taking classes," Borno said. "If I look back on my career, both academic and professional, it's built on a foundation of learning and developing new skills."

Borno is a Palestinian refugee who fled Kuwait during the first Gulf War with her family in 1990. "We came to the United States with nothing," Borno said. "The only thing that my parents had was their education. Education is the one thing that no one can take from you, and that's why I feel so strongly that it is the single best investment you can make."

Borno earned her B.S. in Computer Engineering from the University of North Carolina at Charlotte. She then came to U-M, where she was an Intel PhD Fellow at the NSF ERC for Wireless Integrated MicroSystems. After graduation, she joined the Boston Consulting Group (BCG), where she was a leader for the Technology, Media, & Telecommunications, and People & Organization practices.

Following BCG, Borno joined Cisco, a leader in IP-based networking technologies, where she held several leadership positions over the course of her six-year tenure. She was leading a team of 18,000 employees when the pandemic hit. Nearly overnight, her team's workload tripled as companies began to rely on Cisco's virtual collaboration and security tools for their now distributed workforce.

"The whole technical support team at Cisco did not think we were going to be able to deliver on the new workload overnight," said Borno, "but we did, and we delivered the highest customer satisfaction measurements ever recorded in the company's history."

In November 2021, Borno joined AWS, which is the world's most comprehensive and broadly adopted cloud platform. She specifically leads the AWS Partner Organization (APO), which is a global team that serves over 100,000 companies in more than 150 countries.

A believer that companies should be committed to sustainability, she is excited about AWS' goals in this area, including their goal to reach net-zero carbon emissions by 2040. "In the technology industry, we have a responsibility to build a better world and to give back to the communities in which we live," said Borno.

Borno described four key pillars to effective leadership: empathy, emotional intelligence, resiliency, and accountability. But another essential practice for being a good leader is making sure her team is taking time to care for their physical and mental health, something she discovered after too many years of burning the candle at both ends. For Borno, that's accomplished by climbing mountains.

"That's a really good moment to be with myself," Borno said. "I can just be with my thoughts a few nights on a mountain, recognizing how small I am compared to the vast universe out there."

"In the technology industry, we have a responsibility to build a better world and to give back to the communities in which we live."

–Ruba Borno

Cybernet CTO **CHARLES COHEN** Works to Shape the Future of Computing

When Charles Cohen began as an Electrical Engineering Systems doctoral student at U-M in 1989, his first task – like the other students in his program – was to find an advisor.

“To me, Lynn [Conway] was the smartest one there, so I made a deal with her,” he said. “I’d be her T.A. if she agreed to be my PhD advisor.”

Conway, Prof. Emerita of EECS, is internationally renowned for her role in transforming the global microelectronics industry with the invention of VLSI, or Very Large-Scale Integration, which allowed small teams of individuals to design powerful chips. She agreed to work with Cohen, and she also brought on robotics specialist Prof. Daniel Koditschek, who is now at the University of Pennsylvania, as co-advisor.

But it was Conway’s gift of Strunk and White’s *The Elements of Style* that proved to be instrumental in his later career.

“Lynn knew that learning how to write well was extremely important,” Cohen said. “Thanks to my graduate school training, I have been awarded dozens of projects because of my writing. Even more than the tech itself, it was the most important skill I ever gained.”

After graduation, Cohen joined Cybernet Systems Corporation, which was founded in Ann Arbor in 1988 by Dr. Heidi Jacobus and her husband, Chuck, to advance human performance through advanced technology. Today, Cybernet is a research, development, and production business focused on bleeding edge technologies for the commercial and defense markets.

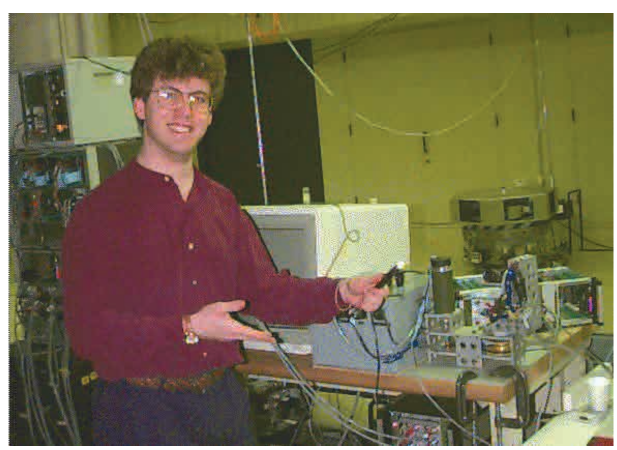
Cohen has held multiple positions at Cybernet, including VP for Research and Development. He was recently promoted to Chief Technology Officer, where he is responsible for all of Cybernet’s research and development efforts, including human-computer interaction, robotics, and artificial intelligence.

Cybernet has partnered with both the U.S. Government and private contractors on a wide-variety of high-profile projects. They are currently working with the U.S. Army to develop a prototype for an unmanned Assault Breacher Vehicle, which is used to breach minefields and complex obstacles during an assault operation.

Cybernet had also worked with the Department of Defense to develop Automated Material Handling Technology, which they integrate with forklifts, trucks, and tugs for autonomous handling and delivery of supplies to workers. Then they partnered with Toyota Tsusho America, Inc. to bring the technology to market. One specific application is for the airport industry, regarding baggage transportation, which has long been an issue of safety for airport operation.

“The reality is that there’s not enough truckers and forklift operators out there, so we’re not replacing jobs,” Cohen said. “The idea is that with our technology, one operator can now manage a small fleet of tugs. They get paid more and get a much better work-life balance, and at the same time, overhead is reduced because the system is safer.”

Cohen plans to leverage his skills as a leader as Cybernet continues to grow in the future. He now gifts *The Elements of Style* to others, and continues to brainstorm wild ideas with Conway.



Charles Cohen in the basement of the AI Lab with his first robot and camera system, doing gesture recognition. From sometime in the mid 1990s.

KAI CUI Empowers Consumers to Make Sustainable Fashion Choices with Her New App

When Kai Cui (MSE ECE) goes shopping, she considers more than just price and style. She supports brands that work to reduce their impact on climate and practice fair and just labor standards. That's why she founded CarbonTag™, a startup that developed the first carbon emission calculator for consumer fashion products.

"I created CarbonTag™ so everyone can see the environmental price we pay collectively, as a society, for different garments," Cui said. "I want to empower people to make more sustainable choices when they shop."

According to the World Economic Forum, the fashion industry (and its supply chains) is the third largest polluter in the world. This impact is only expected to worsen as "fast fashion" – in which people buy and discard as much as 60% more clothes than ever before – becomes more prevalent.

"I want to see more women leaders, innovators, and change makers. And I want to be one of those who lead the change and inspire others."
—Kai Cui

"CarbonTag™ analyzes the entire manufacturing process to give you an accurate estimate of the total emissions that result in producing a garment," Cui said. "Say you want to buy a cotton T-shirt – it'll tell you the emissions cost throughout the supply chain, from the cotton growing and harvesting to the yarn spinning and ginning to the fabric cutting and sewing until the product is transported to the customer."

In addition to producing harmful impacts on the environment, fast fashion is known for exploitative labor practices, such as forcing long working hours for low pay. Workers are often exposed to hazardous substances used in production, and many are forced to engage in unsafe processes to meet time constraints with a minimal budget. CarbonTag™ includes this information in its Life Cycle assessment, so consumers can support brands that align with their values.

While at U-M, Cui took Project Management and Consulting (ENTR 560) and Innovative Business Models (ENTR 520) through the Center for Entrepreneurship, which helped shape her professional goals and tactics. She also participated in a Detroit-based hackathon on creating solutions to eliminate inventory waste by shifting from a made-to-stock to a made-to-order model.

"That was when I really started to think about how unsustainable the entire fashion system is, and what I could do to help solve the problem," Cui said.

Above all, Cui hopes her ambitions will inspire others, especially fellow women of color, to pursue their entrepreneurial goals.

"There are not many women, let alone women of color, pioneers," Cui said. "I want to see more women leaders, innovators, and change makers. And I want to be one of those who lead the change and inspire others."

Kai Cui in front of the Lurie Bell Tower on the University of Michigan's North Campus.

Rising Star **TANYA DAS** Helps Shape Nationwide Science Policy

> **"Science policy affects all of us in real ways, and there are many different ways that you can get involved."**
> –Tanya Das

Dr. Tanya Das (BSE EE) received the 2022 ECE Rising Star Alumni Award for her work helping to shape science policy nationwide. Das is the Associate Director of Energy Innovation at the Bipartisan Policy Center, and she previously served the Biden Administration as the Chief of Staff of the Office of Science at the U.S. Department of Energy.

"It's about deciding: what do we as a nation want to prioritize and invest in for our science and technology future?" Das said.

After completing her MS and PhD degrees in Electrical and Computer Engineering from the University of California, Santa Barbara, Das took a one-year appointment as an American Association for the Advancement of Science legislative fellow in the Office of U.S. Senator Chris Coons, where she fell in love with the work. She was then hired into the U.S. Congress on the House Committee on Science, Space, and Technology headed by Chairwoman Eddie Bernice Johnson.

"I covered everything from commercialization programs to manufacturing emissions to the electric grid to cybersecurity," Das said.

Das worked on the committee for three years, and was then appointed as the Chief of Staff of the Office of Science at the U.S. Department of Energy by President Biden. There, she helped implement Biden's priorities for the Office of Science, with a major focus on diversity and inclusion efforts and environmental justice.

She joined the Bipartisan Policy Center (BPC) last year as the Associate Director of Energy Innovation. BPC is a Washington D.C. based think tank focused on policy research, and it strives to build bipartisan support for a variety of science and technology policies.

"We are living through some wild times, where there is a lot of polarization in the political sphere," Das said. "But having grown up in Michigan where people have all sorts of political affiliations, it was always important to me to help people come together to advance ideas instead of focusing on our differences."

Das also encouraged everyone to think more about how their engineering work intersects with the policy world.

"Science policy affects all of us in real ways, and there are many different ways that you can get involved," Das said. "You can develop interdisciplinary research questions to apply your engineering focus to something that incorporates social science. You can get involved in local politics. If you think that we should be spending more on research, you can also talk to your member of Congress and advocate for that. You can make your voice heard."

PAUL DEBEVEC honored with Emmy Lifetime Achievement Award for Inventing a New Kind of Movie Magic

"I loved the idea of contributing to a cool storytelling process,like making it look like people are flying through space, because it felt like a way to be connected to a larger audience."

–Paul Debevec

Great Scott! A flying Chevette!

Well, actually, a computer-generated visualization of Paul Debevec's car, inspired by the opening sequence of *Back to the Future, Part 2*. Debevec (BSE CE, BS Math) created the model by combining techniques from computer vision and computer graphics while he was an undergrad at the University of Michigan in 1991. The passion project set him on a career path that would one day revolutionize filmmaking and earn him The Charles F. Jenkins Lifetime Achievement Award given by the Emmys.

"This all started with the Chevette Project," Debevec said, while accepting the award at the 74th Engineering, Science & Technology Emmy Awards on September 28th, 2022. "So, thanks to my mom for giving me a 1980 Chevette. If she'd given me a cooler car, I wouldn't have had to put so much effort into trying to make it fly using computer graphics."

Debevec was honored for his pioneering work combining high dynamic range imagery with image-based lighting, which makes it possible to record and reproduce the light of both real and virtual environments to create a seamless transition between the two. His methods are now essential techniques used in computer graphics for VFX and Virtual Production.

What's more, Debevec pioneered the Light Stage, which uses LED lighting in virtual production and is becoming the mainstay tool for lighting actors on virtual stages. For example, the Disney+ *Star Wars* show *The Mandalorian* uses this technology to project digital environments behind the actors on the set, creating a more detailed, realistic environment for the actors and crew to interact with. The tool is expected to become the norm for all kinds of film and television productions going forward.

Debevec has worked directly on many films, including *Spider-Man 2,* where his techniques made possible the famous close-up shot of Doctor Octopus (Doc Ock) drowning in the river at the end. He's also known for *Avatar, The Hobbit, Blade Runner 2049,* and *Free Guy*.

But one of his most impactful works was his 1999 short film *Fiat Lux*. In it, he digitally recreates St. Peter's

Basilica. Falling mirrored globes, as well as tumbling life-sized dominoes, are an abstract representation of the conflict between Galileo and the church. The film showcased new techniques in image-based modeling, rendering, lighting, and high dynamic range rendering, and it led Debevec to his next project – applying the same techniques to accurately recreate human faces.

Debevec created the first Light Stage to study how light reflects off skin, eyeballs, and bone structure at different angles. By incorporating details about the translucency of skin, which makes us look different than plastic mannequins, Debevec paved the way for digital renderings of humans that look almost real.

“All computer graphics challenges are about, how do you render realistic environments? How do you render realistic people and clothing hair and all of this?” Debevec said. “What’s going to happen in the future is that AI will be able to generate animations of people who don’t exist, and it will be so real you won’t be able to tell the difference.”

This new frontier of filmmaking will not require living actors to simulate realistic-looking people on screen. It has the potential to revolutionize not only movies, but video games, advertising, and other media as well. But Debevec does not think this will replace movie-making as we know it – or actors for that matter.

“I think back to when movies first came out,” Debevec said. “I wonder what actors thought of this new medium where you can be recorded on film and your performance can be re-lived even after you’re gone. What a mind warp that would have been! But people adapted to it, and then they adapted to talkies.”

For Debevec, the new technology simply opens up more avenues for creative storytelling, and, he hopes, will allow more people to tell more kinds of stories. In addition, it can enrich interactive virtual entertainment, like online games, but there’s still much that can’t be replaced.

“We’ll always have that prerendered, pre-authored entertainment,” Debevec said. “There’s a great deal of artistry required for really interesting plot twists and well-developed characters. These new tools really help democratize the process, and I’m thrilled to be part of that. I hope to honor all of the history and help take it forward in a good way.”

Wolverine inspiration

Debevec grew up in Illinois. His father was a professor of nuclear physics at the University of Illinois, which partly inspired Debevec’s interest in academia, and his mother was a social worker. Debevec loved both art and math, and he especially loved movies. As a kid, he was fascinated by a documentary about the making of the special effects seen in the *Star Wars* films.

“It was adults getting to play with grown up toys – stop motion animation and blue screens and compositing and motion control cameras – and just doing very cool stuff,” Debevec said. “I loved the idea of contributing to a cool storytelling process, like making it look like people are flying through space, because it felt like a way to be connected to a larger audience. The final result is something that you can share with anyone.”

When Debevec entered high school, he joined the school yearbook team as the photo editor.

“I developed tons of film in the school dark room, which served me very well when I began doing movies,” Debevec said. “Some of the work in high dynamic range imaging that the Emmy is recognizing me for was inspired from my work on photography in those early days.”

But Debevec’s biggest interests always lay in computer programming and mathematics. He spent a lot of time tinkering around with old commodore computers, getting familiar with the rudimentary aspects of computer graphics and design.

“I had no idea that you could actually study computer science,” Debevec said. “It felt so new, like my own little hobby. But when my dad drove me to Michigan

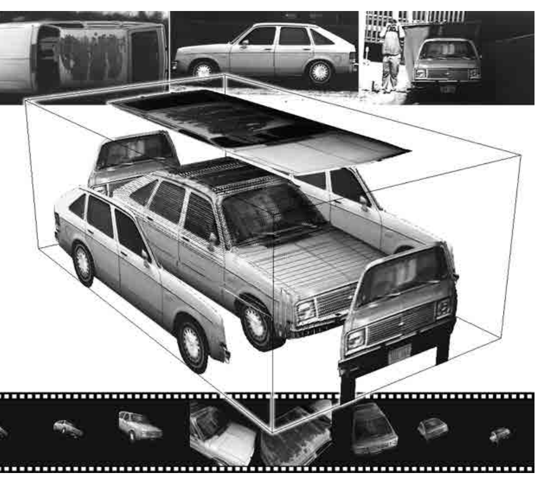
Paul Debevec accepts the Charles F. Jenkins Lifetime Achievement Award at the 74th Engineering, Science & Technology Emmy Awards held at the Maybourne in Beverly Hills, CA, on September 28th, 2022.

for campus visit day, I was looking through the list of majors and saw you could study computer engineering, and I thought, 'I like computers! I should study that.'"

Debevec chose Michigan for its midwestern charm and excellent academic reputation, but he also found himself enjoying the sport culture (in Debevec's freshman year, Michigan football won the Big10 championship and defeated USC in the Rose Bowl, and Michigan Basketball won the NCAA National Championship). Above all, he was most excited about the variety of opportunities available to him as a wolverine.

"I am very glad that I went to Michigan," Debevec said. "Michigan prepared me a lot for embracing the sheer variety of ideas out there, and it's a place where you can find what you need. If you want to do something that might be a little different, Michigan will make it happen."

Debevec ended up double majoring in Computer Engineering and Mathematics, which meant he got to embrace the experiences of both the College of Engineering and the College of Literature, Science, and the Arts (LSA). In LSA, he took classes on Shakespeare, Egyptology, and modern European History. These experiences sparked his interest in archaeology and later inspired the subject of his groundbreaking 2004 short film, *The Parthenon,* where he debuted some of his early techniques using high dynamic range imaging, image-based lighting, and photogrammetry.



Paul Debevec's process of modeling the Chevette. Three of the six original photos taken June 14, 1991 are shown across the top. Ken Brownfield appears at right, holding a backdrop to assist in image segmentation. The box shows how the segmented Chevette images are used to carve out the shape of the car and then to color it in; the central view is computer-generated. A sampling of frames from an animation using the Chevette model are shown at bottom.

As an undergrad living on North Campus, Debevec bonded with his synthesizer-playing roommate and took the graduate-level Computer Vision class taught by Prof. Ramesh Jain, a renowned researcher in Computer Vision, Artificial Intelligence, Multimedia Computing, Experiential computing, and Digital Health, who founded and directed Michigan's Artificial Intelligence Laboratory in 1987.

"That was the most influential class I took at Michigan," said Debevec, who also acknowledged Jain during his Emmy-accepted speech. "I got really excited about this idea that you can throw images into a computer and pop out a 3-dimensional model that you can fly around. That's the course where I had the idea that if you solve for a 3D model of a scene from photos and you re-project that photo back onto the scene, it creates a very photo-real look. It's like a texture map of the scene."

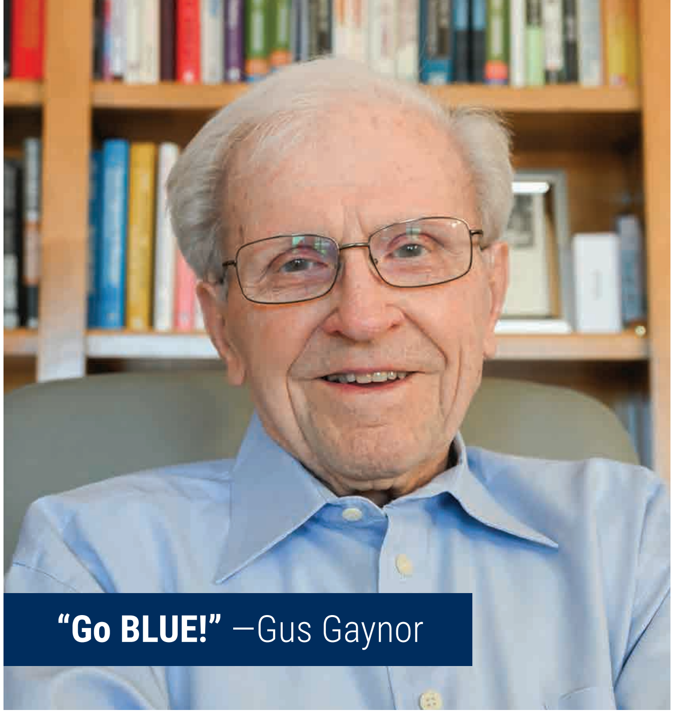
Jain wrote Debevec a letter of recommendation for grad school at UC Berkeley, and it was at Berkeley where Debevec's influence on the film industry became official. His 1997 short film, *The Campanile Movie,* demonstrated new image-based modeling and rendering techniques, in particular those from the "Facade" photogrammetric modeling system that was the focus of Debevec's PhD thesis.

The film premiered at the SIGGRAPH 97 Electronic Theater in Los Angeles, where it attracted the attention of visual effects supervisor by the name of John Gaeta. Gaeta used these techniques to create the Oscar-winning visual effects of the bullet scene in *The Matrix*.

Paul Debevec's lifetime achievement Emmy compliments his home decor celebrating tech.

"That was an incredible moment," Debevec said. "Here was this little project I did in a lab, and it ended up playing a small but significant part of something that was absolutely huge – that reached so much of the world."

Today, Debevec is Adjunct Research Professor at the USC Institute for Creative Technologies, as well as the Director of Research, Creative Algorithms, and Technology at Netflix. He has won two Academy Awards – a Technical Achievement Award and a Scientific and Engineering Award. He is also a governor of the visual effects branch of the Academy of Motion Picture Arts and Sciences. The Emmy lifetime achievement award recognizes "a living individual whose ongoing contributions have significantly affected the state of television technology and engineering."



Centenarian **GUS GAYNOR:** Tech Leader, Entrepreneur, and Communicator

Gerard "Gus" Gaynor, a technology leader who received his bachelor's degree in electrical engineering from the University of Michigan 72 years ago, still carries the memories of lessons learned from his favorite faculty.

One of those faculty was the iconic William Gould Dow (1895-1999).

"On the first day of Dow's senior course on industrial electronics," said Gaynor, "he came in, sat on the edge of his desk, and said, 'I wrote this book, but you have every reason to doubt what's in it. Just because I said it, doesn't mean it's true – so keep that in mind.'"

He also took courses from the renowned educators Arthur D. Moore and math professor George Piranian.

"I had great experiences with those professors," said Gaynor. "What we got from our professors in those days was not just the information and knowledge about the courses, but they provided us with a philosophy of engineering. Faculty like Prof. Dow came with industrial experiences because of WWII, and they all came with a different attitude."

Dow gave Gaynor a taste for research by inviting him to be part of his team working on the Aerobee rocket project in the department. He worked on the rockets' instrumentation, which was used to measure atmospheric temperature and pressure.

"That was an amazing time to be part of the department," recalled Gaynor. "There was a lot of top-secret research."

As a student, he shared a dorm room with the editor-in-chief of *Michigan Technic* (the College of Engineering magazine at the time) and would later become editor-in-chief himself.

"My responsibilities included serving as chair of the engineering Slide Rule Ball Committee, the annual formal dance," said Gaynor.

After graduating, Gaynor's technical prowess was exploited in his first job, where he helped develop an electromagnetic flow meter. After ten years, he left to start his own company, called Electromechanisms Corporation. "It went on for about 3 years and I made good money," said Gaynor. "Then we had a bit of a recession."

Gaynor next joined 3M, and happily brought his family of nine to Italy and Brussels for seven years. He was the Chief Engineer responsible for modernizing the manufacturing operations. He later was named director of engineering for 3M Europe.

After his retirement in 1987, Gaynor was not nearly done. He launched a new career in service to IEEE that lasted more than 30 years, and also turned his attention to writing. Gaynor translated the wisdom he gained as a tech leader into six books after he retired, several of which have been translated into multiple languages.

Ever the innovator, Gaynor was founding editor of the IEEE magazine *Today's Engineer*. He also served as VP of publications for the IEEE Technology and Engineering Management Society. He is an IEEE Life Fellow, "For contributions to engineering and technology management."

Looking back on his career, Gaynor says, "I met so many good people in my career, I'm just blessed to have met them."

Gaynor offered a few words of wisdom for students, such as accepting some level of risk, getting along with people, and especially not giving up. But most importantly, said Gus, "Go BLUE!"

ELI NEUMMAN and the Skill of Selling Technology to Businesses

"As soon as you walk onto that campus, you fall in love with it."
–Eli Neumann

For over thirty years, Eli Neumann (BSE Computer Engineering) has been leading worldwide technical sales engineering teams. In his current role as Senior Vice President of Worldwide Sales Engineers at Tenable Inc. – a cybersecurity company known for creating the vulnerability scanning software, Nessus – he oversees a team of 250 security engineers who act in partnership with the company sales team in client interactions. Now, with a new Technical Sales class he co-designed at Michigan, he's hoping to use his expertise to inspire and train the next generation of technical sales engineers.

"In the vendor world, we struggle to find people, because you need to have three, four years of experience presenting to people," Neumann said. "If you're in college, how do you get that? So that's where my focus came in to say, why don't we have a minor in colleges? Some schools have one, but this semester was my attempt to bring that into Michigan and open that world up."

Neumann connected with Kurt Skifstad, the Dixon and Carol Doll Executive Director of the Center for Entrepreneurship and Adjunct Lecturer at the College of Engineering. Together, they developed a one-credit mini-course, "Technical Sales," where students study sales organization and processes, and they practice selling technology to businesses. Neumann and Skifstad plan to create enough additional courses to eventually qualify for a minor degree program.

The choice to develop this course at U-M was simple for Neumann: Michigan is a family legacy. Ever since Neumann's father, an electrical engineer, spent a sabbatical at Michigan, nine members of the family have earned degrees from U-M. The most recent to do so was Neumann's daughter, who graduated from the School of Information in 2021.

One of Neumann's favorite places to socialize was The Pretzel Bell. He also enjoyed how compact the campus was – Engineering was still located on Central Campus, so he could easily walk from playing video games with his friends at Pinball Pete's on South University to a study session in the UgLi (undergraduate library). Above all, he appreciated getting to meet and work with people from all over the world.

"It was a lot of hard work, but I also have a lot of good memories at Michigan," Neumann said. "As soon as you walk onto that campus, you fall in love with it."

Prior to Tenable, Neumann worked at Computer Associates, webMethods/Software AG, and NetSuite in Vice President and Senior Vice President positions. He went on to serve as the Vice President of Global Security Engineers at Sourcefire, and he then joined Cisco as the Vice President for Worldwide Security Engineers. Today, he holds an Advisory Board position at the PreSales Leadership Collective.

CHRISTOPHER RUTLEDGE Honored with the 2023 Willie Hobbs Moore Distinguished Alumni Lectureship

From left: Michigan alums Kwesi Rutledge (BS EE; PhD ECE), Chris Rutledge (MS EE), and Lee Rutledge (BS MEng CS) at Lee's U-M graduation.

Christopher Rutledge (MS EE), a Distinguished Engineer at Verizon, was awarded the 2023 Willie Hobbs Moore Distinguished Alumni Lectureship in recognition of his distinguished career.

Rutledge is currently responsible for the development of Verizon's Mobile Device Management platform, which helps users manage mobile devices and keep mobile data and devices "purposed" and protected. Over a period of five years, the platform grew from six Verizon Business customers to well over 260,000, which included over a half-million students learning remotely during the pandemic.

"If you like to solve problems, if you run toward hard stuff, then you are the chosen folks," Rutledge said. "We are the intellectual first responders."

Prior to Verizon, Rutledge designed and built AT&T's Advanced Communication Labs' largest real-world HFC test bed. He was also a member of the technical staff at Bell Labs (known at the time as "AT&T Bell Laboratories"), where he worked on proof of concept and key interference testing for new wireless advanced access technologies. There, he worked with Jesse Russell, one of the pioneers of wireless technology.

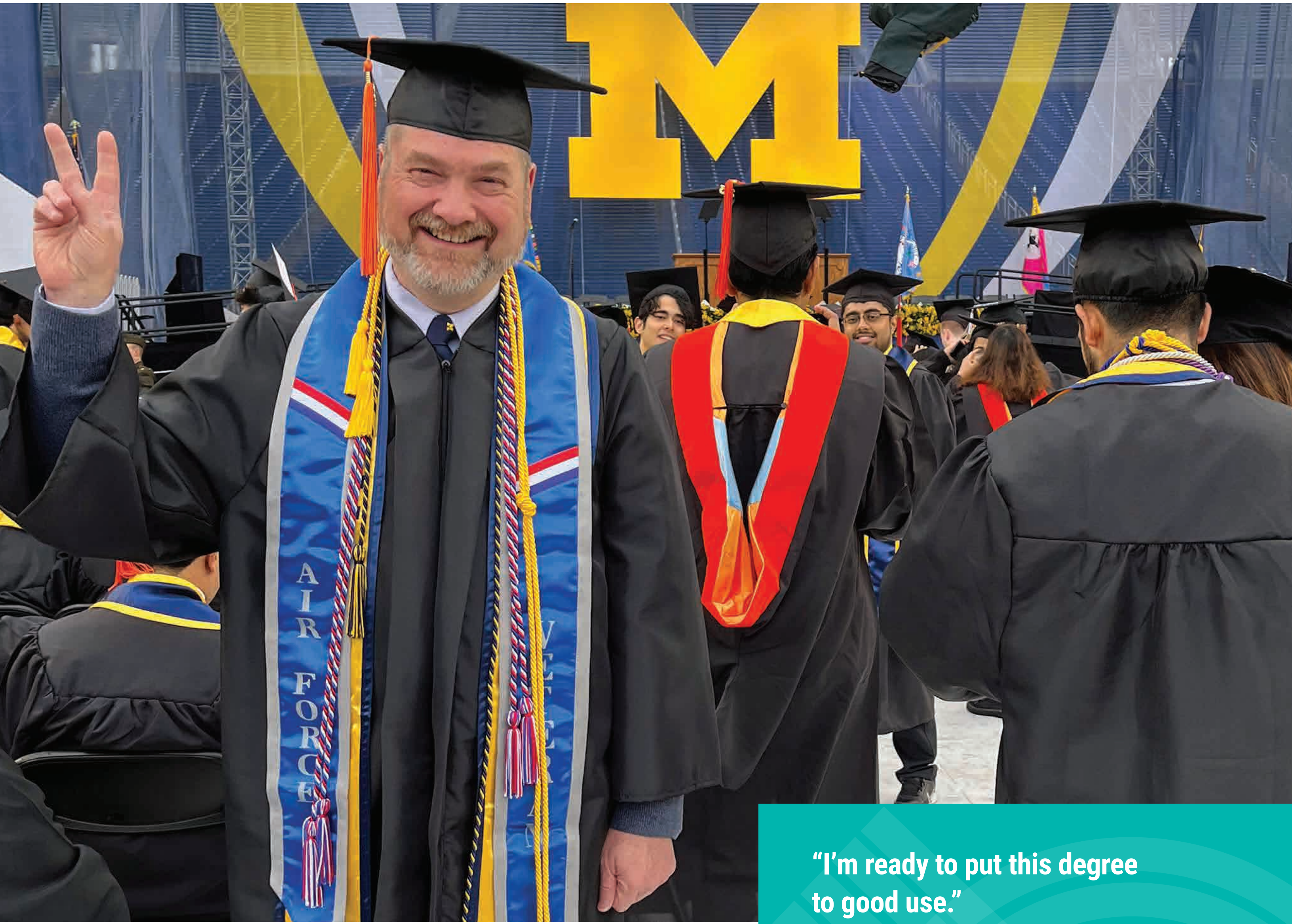
"He taught me that the journey to get to a place where no one's ever been involves a lot of smaller steps that teach you the right tools to use," Rutledge said. "And each step is likely patentable."

"If you like to solve problems, if you run toward hard stuff, then you are the chosen folks."
–Chris Rutledge

Both of Rutledge's sons followed in his footsteps and studied engineering at U-M. Kwesi Rutledge earned his BS in Electrical Engineering and his PhD in ECE from Michigan (he earned his MEng in ECE from UC San Diego), and he is currently a postdoc at MIT. Lee Rutledge earned his BS and MEng in Computer Science from U-M, and he is currently a software engineer at Qualcomm.

Rutledge earned his BS in Electrical Engineering from Prairie View A&M University. He holds numerous patents in next generation communications technology. He lives in New Jersey, and in his spare time, he enjoys coaching track athletes.

Michigan Man **JACK UNDERWOOD** Achieves Lifelong Dream with EE Degree



Jack Underwood celebrates his graduation at the 2023 University of Michigan commencement ceremony.

"I'm ready to put this degree to good use."

–Jack Underwood

Jack Underwood (BSE EE) always wanted to earn a degree in engineering, but life kept getting in the way. He spent five years flying B-52s in the U.S. Air Force before he took a job at Michigan Medicine as a network engineer.

"The guy who hired me told me that if I could fly a B-52, I could probably learn how to do computer networking," Underwood said.

Underwood earned a bachelor's in computer technology from Eastern Michigan University in 1986, while he was a member of U-M's ROTC. He later spent ten years working in industry at Anixter, Inc. and AT&T, but he returned to Michigan Medicine in 2006, where he is currently the Network & Communication Support Services Manager. He led the IT staff during the design and construction of Michigan Medicine's $52 million data center, where he served as manager from 2009 to 2017.

Despite all his success, Underwood never gave up on original dream of obtaining an engineering degree – from U-M, specifically. His father, an electrical engineer, had taught him how to solder and tinker with electronic circuits as a child, and his mother was a registered nurse at U-M's University Hospital in the early 1960s. His great-grandfather, Arthur A. Limpert, was a model ship builder for the Department of Naval Architecture and Marine Engineering during the 1930's and 1940's.

"There's a big mural on the wall in West Hall, and my great-grandfather is pictured in the middle of it with one of his model boats," Underwood said.

Some advisors attempted to discourage Underwood from pursuing U-M, but he ignored them. He took several required preliminary courses from Washtenaw Community College, and in 2015, he was accepted into U-M Engineering.

Once in ECE, Underwood focused on electromagnetics, but he also became fascinated by the courses offered in microelectromechanical systems (MEMS).

"To be able to design something that is so tiny, literally nanometers in size, and it actually works, is amazing," Underwood said. "The multidisciplinary nature of it is also fascinating. Like I designed a machine that could interface with fiber optic cables for communications, which actually applies to the field I work in."

In addition to his decades-long career at Michigan Medicine, Underwood was born at the U-M hospital, and his high school graduation was held at the Crisler Center. But he had never been to the Big House – until April 29, 2023, for Commencement.

"It was overwhelming," Underwood said. "Everyone was really enjoying the opportunity even when it started to rain."

Underwood didn't know the students he sat next to during the ceremony, but it didn't matter. They offered to take photos of him and cheered for him to pose in celebration. He greeted the ROTC cadets and congratulated them for making second lieutenant. And as the university procession filed up the aisle, President Santa Ono paused and shook Underwood's hand.

"That was so special to me," Underwood said. "It felt like a true culmination of everything I'd worked toward for decades. Now, I'm ready to put this degree to good use."

Jack Underwood during flight training for the U.S. Air Force in 1987. The aircraft is a T-38 Talon supersonic jet trainer.

Jack Underwood working in the Lurie Nanofabrication Facility (LNF) on campus.

VIKRAM VERMA Talks about the Value of Engineering and Leadership to Society

Vikram "Vik" Verma (MSE EE) was named the 2022 ECE Alumni Impact Award winner for his distinguished 30-year career leading technology companies. Verma has served in executive roles at Savi Technology, Lockheed Martin, 8×8 Inc., and more.

"The education I got [at Michigan] was the foundation of pretty much everything I've ever been able to do in my life," Verma said.

Verma earned a bachelor's degree in Electrical Engineering at the Florida Institute of Technology before he was recruited to Michigan by Prof. Emeritus Thomas B. A. Senior. Senior was renowned for his fundamental contributions to electromagnetic and acoustic scattering, as well as his excellence as an educator.

"When I first came to Michigan, I think this may have been a trick by Dr. Senior, he had me visit the campus around August time," Verma said. "The sun was shining, birds were singing, not a single cloud in the sky. I looked at it said, 'This is Florida without the hurricanes, this is awesome.'"

After Michigan, Verma started his doctoral studies at Stanford University, but left to join the startup Savi Technology. Over the next few years, Savi became the leader in radio frequency identification-based tracking and security solutions and a pioneer in the Internet of Things. Within five years, Verma was Savi's Chief Operating Officer, and helped negotiate the acquisition of Savi by Texas Instruments. He then became President and CEO of Savi post acquisition. Savi was ultimately acquired by Lockheed Martin for over 35 times its buyout price.

At Lockheed Martin, Verma served as the President of Strategic Venture Development. In that role, he was responsible for monetizing existing Lockheed Martin technologies and programs in new global commercial markets. He left Lockheed Martin after seven years and was appointed the CEO of the Silicon Valley-based cloud communications company, 8×8, Inc.

Under Verma's leadership, 8×8 acquired eight companies, increased its annual recurring revenue from ~$100M to over $500M, and added more than $1.5B to its market capitalization. Verma retired from 8×8 in December of 2020.

"Engineering teaches you discipline, it teaches you collaboration, it teaches you how the sum is much greater than the individual, it teaches you that ideas are just the beginning," Verma said.

Verma serves on the Board of Directors of several companies, the Board of Trustees of Florida Institute of Technology and he is a member of the U-M ECE Council. He has been granted eight patents and honored with various accolades, including being named a Tau Beta Pi Williams Fellow and a "Technology Pioneer" by the World Economic Forum.

"The education I got was the foundation of pretty much everything I've ever been able to do in my life."

–Vik Verma

ECE Chair Prof. Mingyan Liu presents the 2022 ECE Alumni Impact Award to Vik Verma on October 28th, 2022.

The ECE Council (ECEC) is a prestigious group of alumni and friends of the department who are committed to ECE's goal of being a national and global nexus of positive and transformational change across all industries. The ECEC provides guidance and help with key priorities, including alumni engagement, industry engagement, development, diversity, entrepreneurship, education innovation, and future initiatives.

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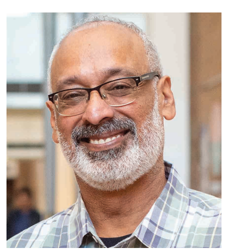

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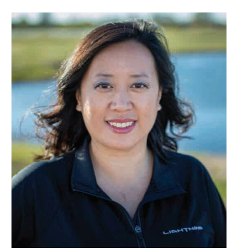

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