BINGZHAO LI

Bringing light and sound into computer chips

THE UNIVERSITY OF WASHINGTON DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING'S ANNUAL MAGAZINE

THE INTEGRATOR

2023 – 2024

IN THIS ISSUE:

ELECTRICAL & COMPUTER ENGINEERING

UNIVERSITY of WASHINGTON

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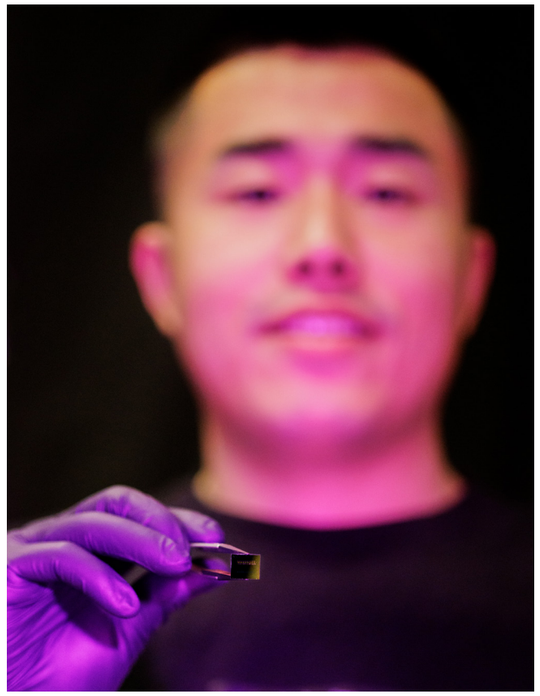

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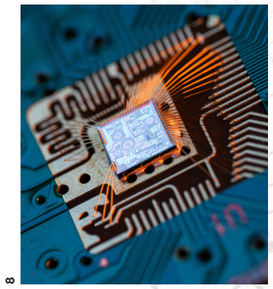

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2023 Yang Award recipient Bingzhao Li is a postdoctoral research fellow in UW ECE and Physics Professor Mo Li's UW Laboratory of Photonic Systems, conducting research on integrated photonic devices, optoelectronic materials, and quantum photonics.

#1
MOST INNOVATIVE PUBLIC UNIVERSITY IN THE U.S.
(Reuters, 2019)

#1
STARTUP GENERATOR OF ANY UW DEPARTMENT
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OUR MISSION

At UW ECE, we cultivate innovation and inspire through high-impact research. We educate and develop tomorrow's leaders to solve the world's most pressing challenges.

UW ECE's position as a top-ranked electrical and computer engineering department provides our faculty and student body with a vibrant learning culture. Students receive a robust education through a strong technical foundation, group project work and hands-on research opportunities. Our faculty work in dynamic research areas collaborating with academia, industry and government institutions.

UW ECE continues to lead in cutting-edge science and technology while advancing socially-responsible innovation. Our innovation ecosystem is critical in promoting an entrepreneurial mindset in our teaching, and is strengthened through diverse partnerships that address complex global challenges in health, energy, technology and the environment.

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LETTER FROM **THE CHAIR**

Dear UW ECE Community,

Photo by Dennis Wise | UW Photo

UW ECE student enrollment has been increasing at the undergraduate and graduate levels for well over a decade. In fact, 2023 marks yet another year of record growth for us. We now have almost 1,300 students enrolled, compared to about 800 students in 2013. This robust growth has created opportunities for new degrees, certificates, research efforts, and infrastructure for our students and faculty.

As you'll learn in the pages of this magazine, our graduate and postdoctoral students, under faculty guidance and supervision, continue to revolutionize technology. More students than ever before in our Professional Master's Program are growing their technical knowledge and careers. We are educating and guiding our undergraduate students through multiple knowledge pathways, which cover a wide range of fields and subject areas. And our faculty continue to lead their respective fields nationally and worldwide.

Our faculty numbers are increasing in anticipation of this continued growth. This fall, we welcomed two new assistant professors, Jungwon Choi and Hossein Naghavi. Choi's research focuses on power electronics, wireless power transfer, and magnetics, and Naghavi's expertise is in integrated terahertz electronics. In addition to these new faculty members, we are excited to welcome another new assistant professor, Ang Li, who was hired in 2023 and is slated to join our Department this year. This growth will continue. We are currently conducting a worldwide search for six more faculty members in all areas of ECE.

Speaking of growth, the CHIPS and Science Act of 2022 is making historic investments across the country in semiconductor research, workforce development and manufacturing. Most institutions of higher learning, including UW ECE, are feeling the impact of this landmark legislation. Billions of dollars are pouring into what has become a nationwide effort, and as explained in this issue of The Integrator, UW ECE is ready to make the most of these opportunities. Our faculty are leading and contributing to multiple proposals and initiatives that will leverage CHIPS Act funding.

One of our Department's strengths in semiconductor research is in the design of unique and innovative types of microchips. In fact, our cover story about Bingzhao Li, a postdoctoral research fellow in our Department and a Yang Award recipient, provides a great example of this. Bingzhao was a key part of a UW ECE research team that developed a new type of light detection and ranging (LiDAR) system on a chip, which uses a scanning laser beam that can help self-driving cars "see" distant objects with much better clarity and precision. Because it is on a chip, this LiDAR system is compact, inexpensive and has no moving parts. Compared to bulky mechanical systems that have quite limited lifetimes in the field, this solid-state LiDAR system is much more robust and potentially long-lived.

As Bingzhao notes in our article about him, the diversity of ideas, people and courses offered here at UW ECE are an important part of our students' success. Achieving greater diversity, equity, and inclusion traditionally has been challenging in the broad field of electrical and computer engineering. I recognize that we still have much work to do in this area. Our Department is taking concrete steps to move in a positive direction, and we are actively engaging our faculty, students, and staff. Learn more about this topic on the next page.

We are fortunate to have many outstanding alumni who are committed to improving diversity, equity, and inclusion in education and the workplace as well. One of those outstanding alums is Dr. Gabriela (Gaby) A. González, who is a member of our UW ECE Advisory Board and was the keynote speaker for our 2023 Graduation Celebration. Gaby is the founder and CEO of CihuaTEC Connect LLC and the former director of Intel Corporation's Science, Technology, Engineering and Mathematics (STEM) Education Research Office. She focuses on technology, engineering, and computing education across the U.S. and around the world, and you can learn more about her in this issue of The Integrator.

Our alums, like Gaby, tend to be outstanding, and as our student enrollment increases, their numbers are growing. Many recent alumni, such as Abhi Saxena and Frank Liu, continue to produce research advances and innovative work well after graduation. And many of our longtime alumni, such as Professor Donald Wunsch, make significant, groundbreaking contributions throughout their careers. You can learn more about Saxena, Liu, Wunsch, and their many accomplishments in the "Spotlights" section of this magazine.

To put it succinctly, UW ECE is thriving! As we expand, we continue to cultivate innovation, producing high-impact research across the spectrum of electrical and computer engineering. And we continue to keep our focus on educating tomorrow's leaders to solve the world's most pressing challenges. To our donors and alumni, I am very grateful for your continued engagement with and support of the Department. You help to make possible many of the advances and accomplishments described in this magazine. As always, it is my honor to serve as Department chair. I look forward to continuing our work together developing the future of technology and the next generation of electrical and computer engineers.

Eric Klavins
Professor and Chair
UW Department of Electrical & Computer Engineering

Diversity, Equity, & Inclusion
AT UW ECE

UW ECE STRIVES TO MAKE OUR EDUCATIONAL AND RESEARCH PROGRAMS accessible and welcoming to everyone by carefully creating an environment of respect, support, mentorship, and creativity as we address society's greatest challenges. These efforts are led in the Department by **Professor Denise Wilson**, associate chair for diversity, equity, and inclusion, and a leadership team that includes students, faculty, and staff. In addition, UW ECE works cooperatively with the UW Office of Minority Affairs and Diversity and the UW College of Engineering's Office of Inclusive Excellence.

Many UW ECE alumni are involved in DEI efforts as well. Some establish scholarships and endowments aimed at supporting underrepresented groups, such as Senior Vice President and Chief Operations Officer of Puget Sound Energy **Booga Gilbertson** (BSEE '85), who established the "You Rock" Endowed Scholarship at UW ECE to help support undergraduates in the Department, especially those from disadvantaged communities and first-generation students. Some alumni improve DEI in other ways. For example, Executive Vice President and Chief Information Officer at the Walt Disney Company **Diane Jurgens** (BSEE '85, MSEE '86) has worked throughout her career to support neurodiversity and women in STEM. And **Dr. Gabriela A. González** (BSEE '92) is a leading advocate dedicated to improving DEI in engineering education across the nation and around the world.

From 2022 to 2023, UW ECE funded, supported, and implemented several DEI-related initiatives, courses, and events that fit within broad, strategic categories established by our DEI leadership team. These efforts are ongoing and include:

BUILDING STRONG, INCLUSIVE COMMUNITY

- **Assistant Professor Mentorship:** The chair's office has established a new mentorship program that increases and improves support for all assistant professors at UW ECE.
- **WAFER — WomXn at the Forefront of ECE Research:** This is a biennial workshop run by UW ECE graduate students in which women and nonbinary researchers and engineers present their research and experiences. The event is open to the engineering community and the public. The most recent WAFER event was held on Nov. 7, 2023, with great success.
- **Student-led DEI programs:** These events include coffee chats focusing on DEI-related issues, an annual DEI event to raise awareness of contemporary DEI issues, space for student groups to practice presentations and engage across research labs, and similar gatherings that build DEI across UW ECE.

RAISING AWARENESS OF DEI CHALLENGES IN ECE

- **"Sex, Gender, and Engineering" course:** This new course at UW ECE is taught by Professors Denise Wilson and Sam Burden. It explores professional issues faced by women as well as sexual and gender minorities (LGBTQ+) in the engineering workplace and at school.
- **DEI Book Club:** This book club is open to UW ECE doctoral students, faculty and staff. The Club meets once a quarter to discuss a contemporary book that explores DEI issues and talk about how to apply concepts learned to work, studies and UW ECE.

ADDRESSING EQUITY ISSUES

- **ECE Student Emergency Support Fund:** This fund serves as an avenue of financial support for UW ECE students experiencing severe financial hardship. Students may submit requests for unexpected situations, such as health care costs, car repairs, legal fees, travel for family emergencies, stolen goods, and housing and food insecurity.
- **ECE Student DEI Conference Travel Awards:** UW ECE undergraduate and graduate students planning or seeking to attend conferences focused on underrepresented groups in engineering are encouraged to apply for travel assistance from this program. Students who are presenting DEI-related papers or planning to attend substantive DEI activities at other conferences within ECE fields are also encouraged to apply.

BUILDING UNDERSTANDING FOR FUTURE DEI EFFORTS

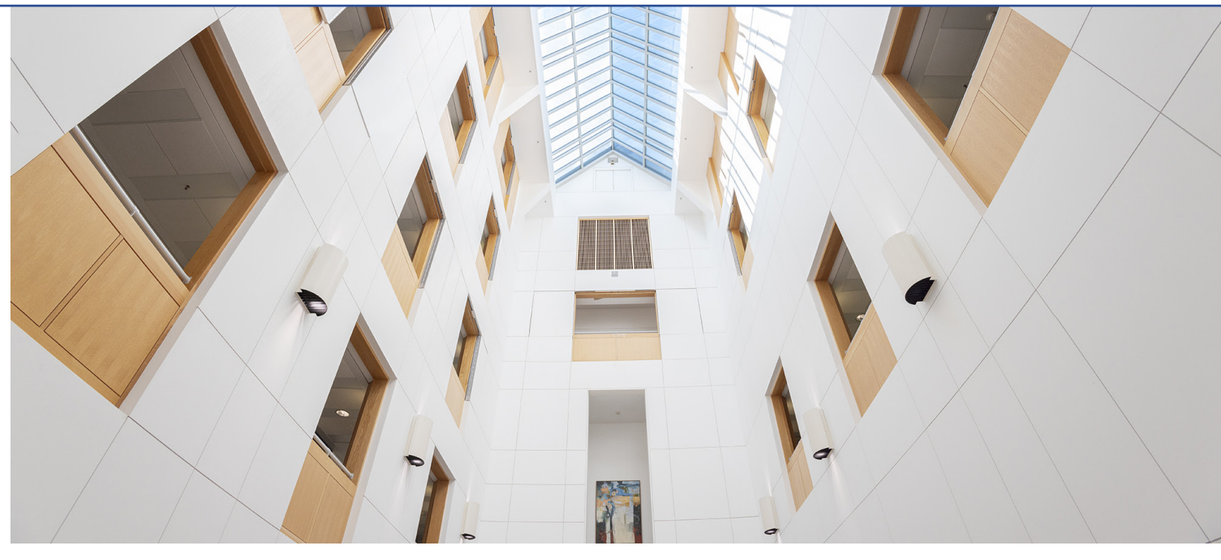
- **Engineering CAReS Workplace Study:** The Competence, Autonomy, Relatedness Survey (CAReS) project seeks to understand how well basic psychological needs of working engineers are met in the engineering workplace. Results are integrated into our "Sex, Gender, and Engineering" course and other professional development opportunities for ECE students.
- **Exploring the Student Experience:** Interviews and surveys are conducted on a rolling basis to better understand equity and inclusion issues in student experiences and strategize improvements accordingly.

For more information about the efforts listed above and to view a complete list of past, present and future initiatives at UW ECE, visit our DEI webpage at www.ece.uw.edu/about/dei or contact Professor Denise Wilson at denisew@ece.uw.edu.

UW ECE WELCOMES TWO NEW FACULTY MEMBERS

UW ECE is proud to welcome two new assistant professors, Jungwon Choi and Hossein Naghavi, who joined the Department this fall. Choi conducts research focused on enabling compact and reliable power conversion systems for electrification, as well as extending these systems to provide wireless power transfer. Her work is applicable to a wide range of technologies, including battery-powered vehicles, biomedical devices, renewable energy systems, and other industrial applications. Naghavi is an expert in millimeter-wave and terahertz integrated circuit design, especially for imaging, spectroscopy, metrology, and communication applications. His research also has the potential to improve high-resolution sensing and imaging and high-speed communication networks.

"I am excited to have Jungwon and Hossein join our Department," said UW ECE Professor and Chair Eric Klavins. "They each bring a high level of expertise and skill to their respective research areas. I am looking forward to seeing what they both will contribute, and I know that our students will greatly benefit from this new addition to our faculty."



UW ECE would like to thank the faculty search committee, which was chaired by UW ECE Professor Georg Seelig. The Department appreciates the committee members' careful reviews, engaged participation and generous welcome toward the candidates.

JUNGWON CHOI

Jungwon Choi joins UW ECE from the University of Minnesota, where she was an assistant professor focused on power electronics, power semiconductor devices, wireless power transfer and magnetics. She received her doctoral degree in electrical engineering from Stanford University in 2019, her master's degree in electrical engineering and computer science from the University of Michigan in 2018, and her bachelor's degree in electrical engineering from Korea University in Seoul, Korea, in 2009.

Choi's research focus at UW ECE is in power electronics and sustainable energy, power semiconductor devices, control systems and magnetic designs. Her research interests include high-frequency power converters, wireless power transfer for battery-powered vehicles, industrial and biomedical applications, controls at high frequencies, energy storage, and wide bandgap devices.

In 2017, Choi was selected to be one of the Rising Stars in EECS at Stanford University. In 2019 and 2020, she received Unlock Ideas awards from Lam Research, and in 2021, she received a National Science Foundation (NSF) CAREER Award. She is the associate editor of the Institute of Electrical and Electronics Engineers (IEEE) Journal of Emerging and Selected Topics in Industrial Electronics, was a member of the organizing committee and vice chair of the 2023 IEEE Energy Conversion Congress & Expo and was on the Technical Program Committee and Organizing Committee of the IEEE Workshop on Control and Modeling for Power Electronics (COMPEL) in 2023 and 2024, respectively.

HOSSEIN NAGHAVI

Prior to joining UW ECE, Hossein Naghavi received his doctoral degree in August 2023 from the University of Michigan, focusing on terahertz integrated circuits. During his doctoral studies, he was a research scholar in the University of Michigan's Radiation Laboratory, where he contributed to the development of the first fully integrated terahertz inverse synthetic aperture radar (ISAR) imaging system. From 2012 to 2016, he was the deputy technical manager of the Antenna Type Approval Laboratory at the University of Tehran, where he implemented several antenna and radio frequency measurement setups based on IEEE, Federal Communications Commission (FCC), and European Telecommunications Standards Institute (ETSI) standards. He received his master's degree in electrical engineering from the University of Tehran, Iran, in 2013 and his bachelor's degree from the Amirkabir University of Technology in 2009.

Hossein's research focuses on millimeter-wave and terahertz integrated circuit design, especially for imaging, spectroscopy, metrology, and communication applications. The terahertz frequencies he investigates have shown promising potential for a wide range of other, unique applications. For example, the short wavelength, see-through capability, and availability of wide bandwidth in the terahertz band makes terahertz frequencies a desirable option for high-resolution sensing and imaging and high-speed communication networks.

Hossein was a co-recipient of the Best Invited Paper award at the 2019 IEEE Custom Integrated Circuits Conference for fully integrated solutions for high-resolution terahertz imaging. He is also a lead contributor to developing traveling-wave energy enhancement devices (TWEED) for the Defense Advanced Research Projects Agency (DARPA).

UW ECE AND THE CHIPS AND SCIENCE ACT

Pictured: A recently designed microchip from the lab of UW ECE Professor Chris Rudell, mounted to a circuit board. This chip is a 2.4 GHz full-duplex transceiver, which employs multiple self-interference cancellation techniques to improve signal fidelity and efficiently use limited bandwidth. The chip has a broad range of applications, including use in satellite communications and radar; shipping, aviation, and space industries; and 5G and 6G technologies. Below, the same chip shown to scale at actual size.

Microchip (center) mounted to circuit board at actual size of 2mm.

(millimeters)

The CHIPS and Science Act is making historic investments in semiconductor research, workforce development and manufacturing. Learn how UW ECE is leveraging these opportunities.

SEMICONDUCTOR DEVICES SUCH AS integrated circuits and microchips have become a necessity for modern life. Long considered to be the brains of modern electronics, these tiny chips can be found in almost every electronic device in use today. And their impact is vast, supporting every sector of the U.S. economy, as well as national security. Currently, all major U.S. defense systems and platforms rely on microchips for their performance, and in many cases, simply to operate.

It is with these things in mind that the White House passed into law the CHIPS and Science Act of 2022, which is making historic investments in semiconductor research, workforce development and manufacturing. The CHIPS Act aims to bolster supply chains and reassert the U.S. as a global leader in semiconductor manufacturing. Over the next couple of years, billions of dollars will be pouring into this effort, and faculty from universities and colleges around the country will be competing for research and development funding, including many from UW ECE.

"At UW ECE, we have top-notch faculty researchers, strong industry partnerships, and we recently redesigned our undergraduate curriculum to offer academic pathways for students interested in pursuing studies and careers related to the semiconductor industry," said UW ECE and Physics Professor Mo Li, who is the Department's associate chair for research. "We also have hired two new faculty members whose research is in chip design, and we plan to add more faculty with semiconductor expertise in the near future."

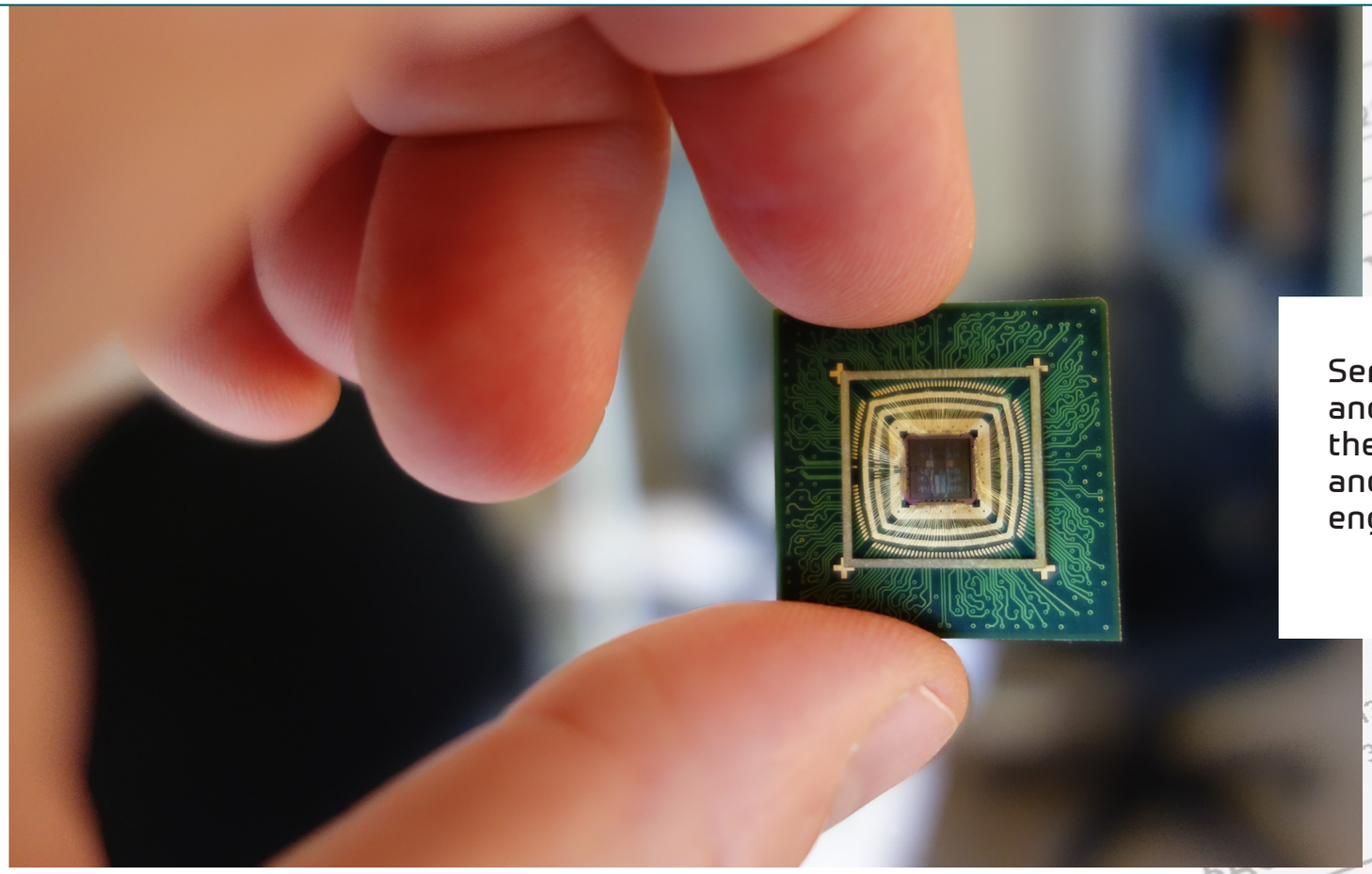
Li, as well as other UW ECE faculty, such as Professor Michael Taylor, who holds a joint appointment in the Paul G. Allen School of Computer Science & Engineering, have contributed to and partnered on several proposals and initiatives that would help to bring CHIPS Act funding into semiconductor research and workforce development at UW ECE. The Department has also spent a significant amount of money over the last two years to upgrade and refurbish its electronics teaching labs.

"Semiconductor design and development is at the heart of electrical and computer engineering, so our Department is well-positioned to leverage funding and support stemming from the CHIPS and Science Act," said UW ECE Professor and Chair Eric Klavins. "I'm especially excited about the opportunities this will provide for our students and faculty, as well as how it will strengthen our existing collaborations and create new industry, government and community partnerships."

UPWARDS FOR THE FUTURE

One of those new partnerships is the U.S.-Japan University Partnership for Workforce Advancement and Research & Development in Semiconductors (UPWARDS) for the Future, which began September 1, 2023. UPWARDS brings together six U.S. universities and five Japanese universities with Micron Technology to provide advanced training and research opportunities that will grow the semiconductor workforce and help the U.S. and Japan build more of the microchips that both nations need. A total of $60 million in funding is available for this collaboration, including a $10 million grant provided by the National Science Foundation's new Directorate for Technology, Innovation and Partnerships, which was authorized by the CHIPS Act. Matching funds were provided by Micron and Tokyo Electron. Li is a principal investigator for the grant, alongside David Bergsman, who is an assistant professor in the chemical engineering department.

"Our nation's success in advanced technologies depends on having a strong workforce," said Washington Senator Maria Cantwell in a press release about UPWARDS, which she had a hand in creating. "This NSF award, led by the University of Washington, will help establish the Pacific Northwest as a leader in training the more than 90,000 students, faculty, and skilled professionals needed to build the most advanced chips right here in the United States. If we want to lead the world tomorrow, we must invest in worker training today."



The Bespoke Silicon Group (BSG) Ten chip from the lab of UW ECE and Allen School Professor Michael Taylor. *Photo courtesy of Michael Taylor*

> "Semiconductor design and development is at the heart of electrical and computer engineering."
>
> — Eric Klavins
> UW ECE Professor and Chair

UW ECE and Physics Professor Mo Li is the Department's associate chair for research and a principal investigator in UPWARDS for the Future. UPWARDS is aimed at providing advanced training and research opportunities that will grow the nation's semiconductor workforce. It will also help the U.S. and Japan build more of the microchips that both nations need.

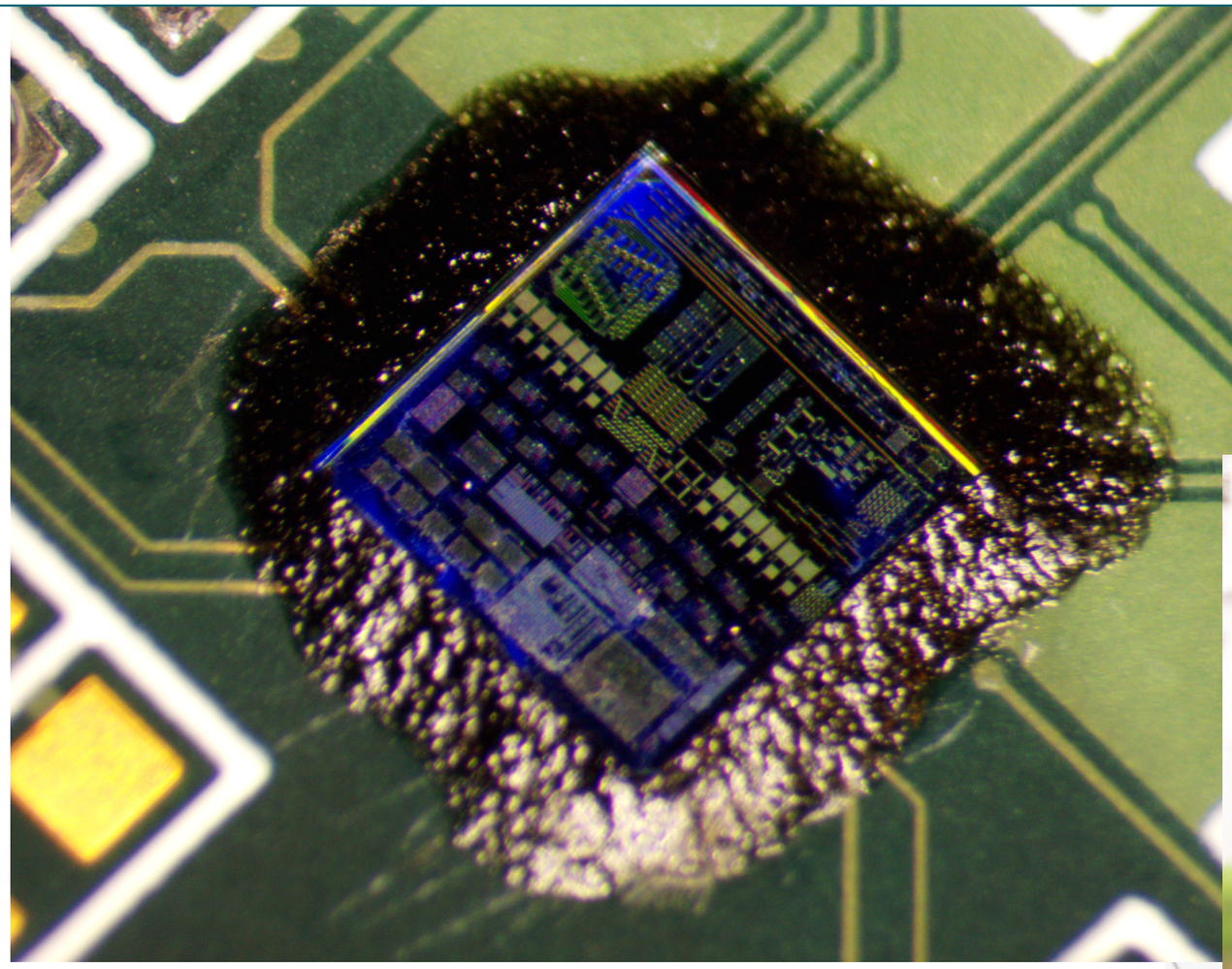
MOVING FORWARD

UW ECE is welcoming two new assistant professors, Ang Li and Hossein Naghavi, who produce research important to semiconductor development. Li has expertise in computer architecture, digital very large-scale integrated (VLSI) design, and reconfigurable integrated systems, and Naghavi is an expert in integrated terahertz electronics. Naghavi began teaching this fall, and Li is slated to join the Department in 2024.

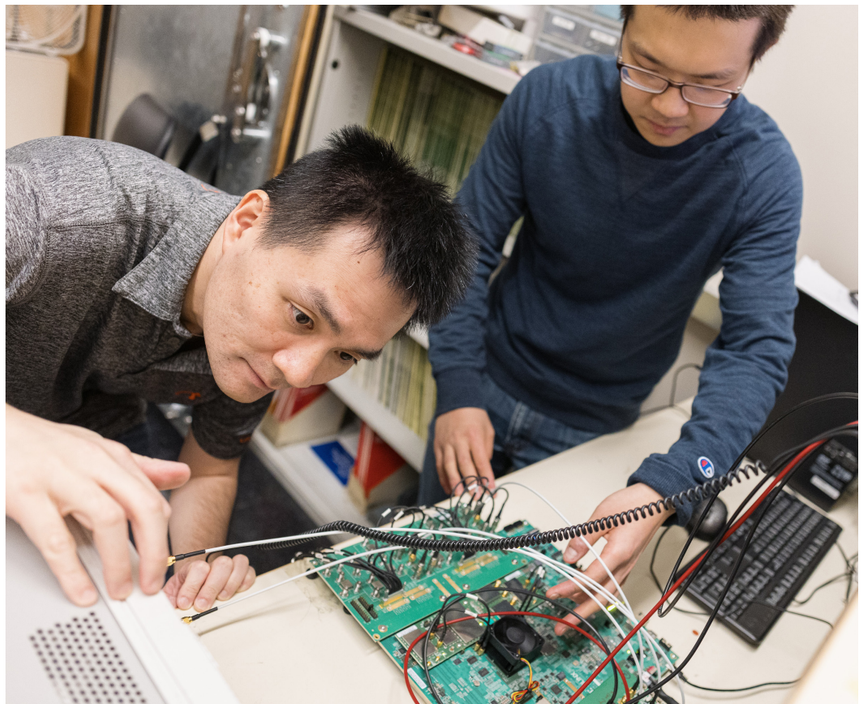
Overall, UW ECE is experiencing rapid growth, partly in response to the CHIPS Act. In addition to Li, the Department plans to add five new faculty members in 2024, including one position at the associate professor level that will be focused on semiconductor design. The number of undergraduate degrees produced annually at UW ECE is also projected to scale up significantly in the next two to three years. This is mostly because of the increasing need for more electrical and computer engineers, but it is also driven by market demand for skilled semiconductor engineers, which is being stimulated by the CHIPS Act.

The UW College of Engineering is designing a plan for an interdepartmental, multidisciplinary curriculum focused on semiconductor technology. This curriculum would provide university-wide, multiple pathways for students and could include offering new undergraduate minors and certificate programs. Professor Mo Li noted the UW's stature as a flagship university for Washington state as well as its proximity to and existing partnerships with Microsoft, Amazon, Boeing, Micron, and Intel — all key players in designing, developing, manufacturing, and distributing microchips.

"Our industry partners tell us what kind of skills they need for particular types of jobs in the semiconductor industry," Li said. "We want the curriculum we develop to match industry needs. So, then we will know that if a student gets this certificate or that minor, they will have the complete skill set for the job they are looking for. That's the benefit for both sides, for our industry partners, future employers, and most importantly, for our students." **w**



The EOS24 Chip is advanced silicon photonic technology developed in the lab of UW ECE Assistant Professor Sajjad Moazeni (pictured below). It contains high-speed optical transmitters and is flip-chip bonded onto a high density printed circuit board. This chip has applications in optical communication and computing. *Photo courtesy of Sajjad Moazeni*



UW ECE graduate students Yi-Hsiang Huang (left) and Xichen Li (right) working in the lab of Professor Chris Rudell.

"IF WE WANT TO LEAD THE WORLD TOMORROW, WE MUST INVEST IN WORKER TRAINING TODAY."

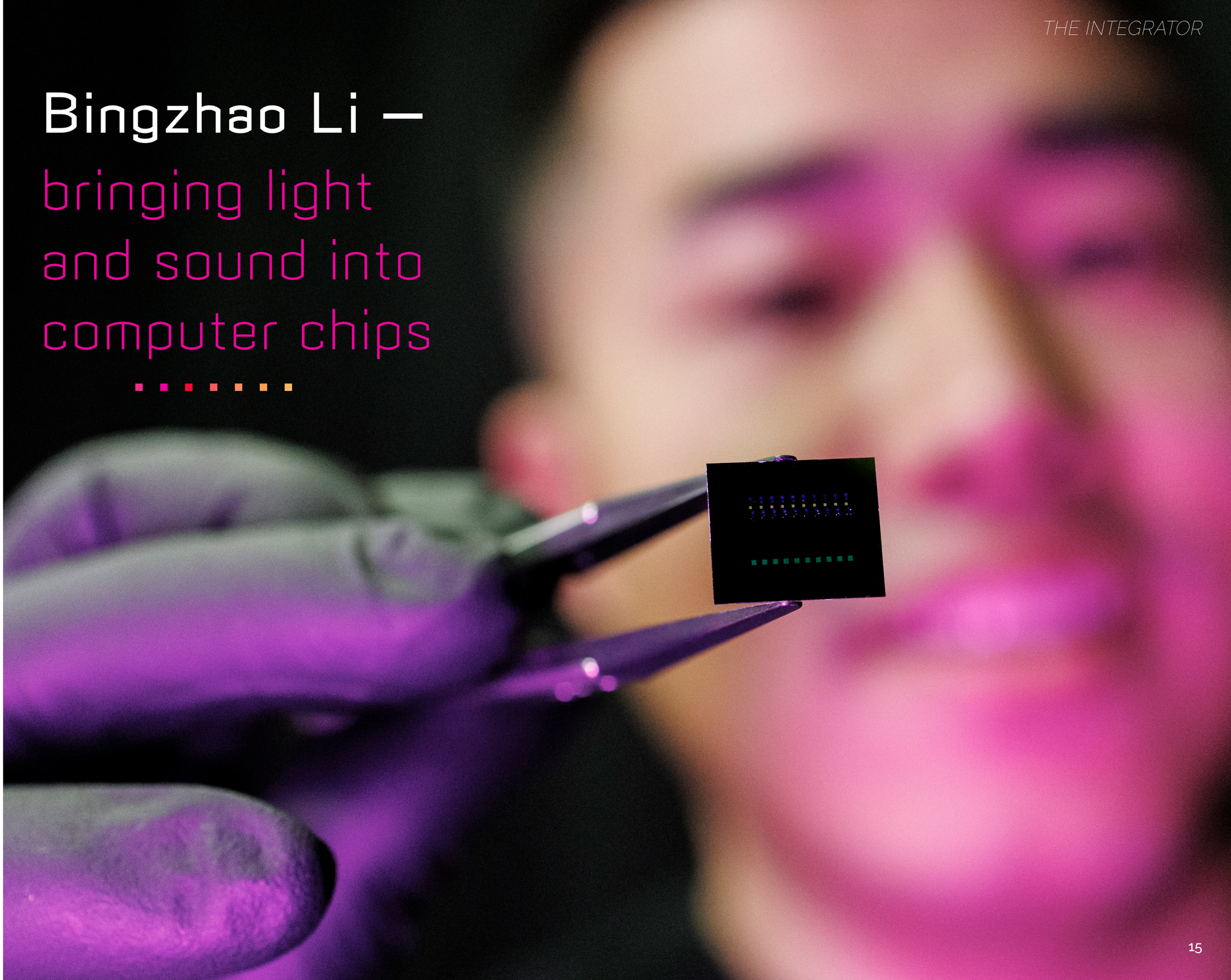
— Maria Cantwell
Washington State Senator

Read more about the latest developments and related CHIPS and Science Act news stories.

www.ece.uw.edu/research/chips-at-uw-ece/chips-news-and-media/

Bingzhao Li — bringing light and sound into computer chips

2023 Yang Award recipient Bingzhao Li is a postdoctoral research fellow in UW ECE and Physics Professor Mo Li's UW Laboratory of Photonic Systems, which conducts research focused on integrated photonic devices, optoelectronic materials, and quantum photonics.



WHEN BINGZHAO LI WAS A CHILD, GROWING UP IN SHIJIAZHUANG, CHINA, HE ENJOYED TAKING APART VIDEO GAME CONSOLES AND FIGURING OUT HOW TO PUT THEM BACK TOGETHER AGAIN. ALTHOUGH HE SELDOM WAS SUCCESSFUL AT FULLY RECONSTRUCTING THE DEVICES – THERE WAS ALMOST ALWAYS A SCREW, OR A SPRING LEFT OVER – THIS CHILDHOOD PASTIME REFLECTED A STRONG INTEREST IN LIGHT, SOUND, AND ELECTRONICS. IT ALSO FORESHADOWED A DETERMINED PURSUIT OF AN ENGINEERING CAREER.

And Bingzhao pursued this interest across the globe, choosing to attend the University of Minnesota to study electrical engineering. It was there that he met UW ECE and Physics Professor Mo Li (not a family relation), who was at the time an associate professor in the University of Minnesota's electrical and computer engineering department. Bingzhao was a student in Professor Li's applied electromagnetics course, where he asked questions that demonstrated a deep level of understanding about the subject and a curiosity to learn more. Professor Li was impressed, so much so that he later brought Bingzhao into his lab as an undergraduate research assistant. In 2016, Bingzhao completed his bachelor's degree in electrical engineering and became a graduate student, continuing to work in Professor Li's lab.

In 2018, Professor Li joined UW ECE and the UW Department of Physics, relocating his lab to the UW campus. So, Bingzhao moved to Seattle as well to maintain continuity in his education and research. In 2022, at the end of the autumn quarter, Bingzhao completed his graduate studies and received a doctoral degree from UW ECE.

Today, Bingzhao is a postdoctoral research fellow in Professor Li's UW Laboratory of Photonic Systems, which conducts research focused on integrated photonic devices, optoelectronic materials, and quantum photonics.

"Over the years, I've realized that Bingzhao is truly talented in turning conceptual ideas to working experiments," Professor Li said. "He can be both analytical and practical, but it's important that he can strike a balance to make things work in the lab. That strength has made all the difference."

YANG AWARD FOR OUTSTANDING DOCTORAL STUDENT

In June 2023, Bingzhao received the Yang Award for Outstanding Doctoral Student at UW ECE for his research in optics and photonics. The Yang Award recognizes a UW ECE doctoral student in their final year of study who has conducted outstanding research in the field of electrical and computer engineering as evidenced by their publications or recognized by outside researchers in the field.

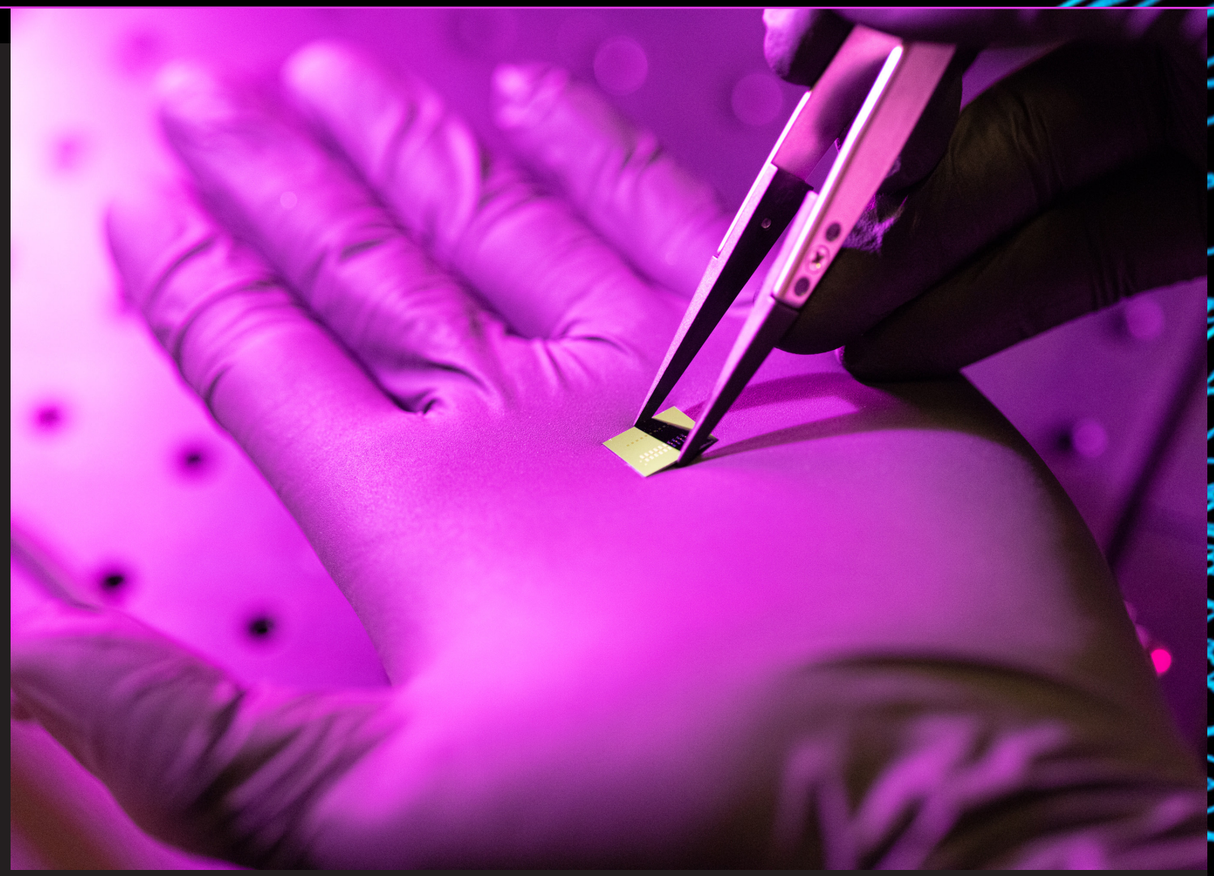
The Yang Award was established by successful entrepreneur and former UW ECE faculty member Andrew T. Yang, who has been one of the most influential people in the electronic design automation industry for nearly three decades. Yang is known for being a visionary in both research and entrepreneurship. The purpose of the award is to recognize and encourage outstanding doctoral student research contributions to the field of electrical engineering. The award goes to one qualifying student per year and is open to all doctoral degree candidates in UW ECE. Receiving the Yang Award is considered a high honor and helps to create career opportunities for the recipient.

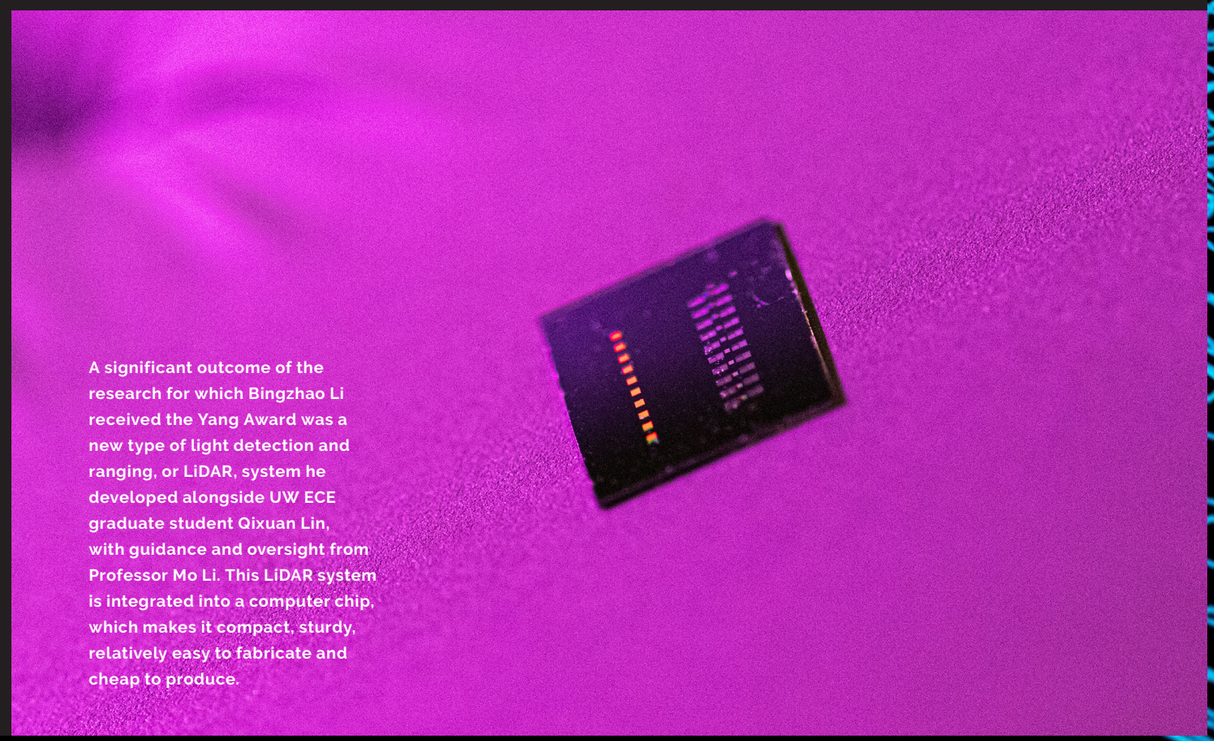
"This award was really important to me in that it recognized my work and what I did during my doctoral studies," Bingzhao said. "It gave me the confidence to realize that I'm doing something that matters. It also helped to expand my vision for what my career could be. Before receiving this award, I was focused solely on a future in academia, but now I'm thinking about building a startup and pursuing other opportunities in industry as well."

INTEGRATED PHOTONICS AND ACOUSTO-OPTICS

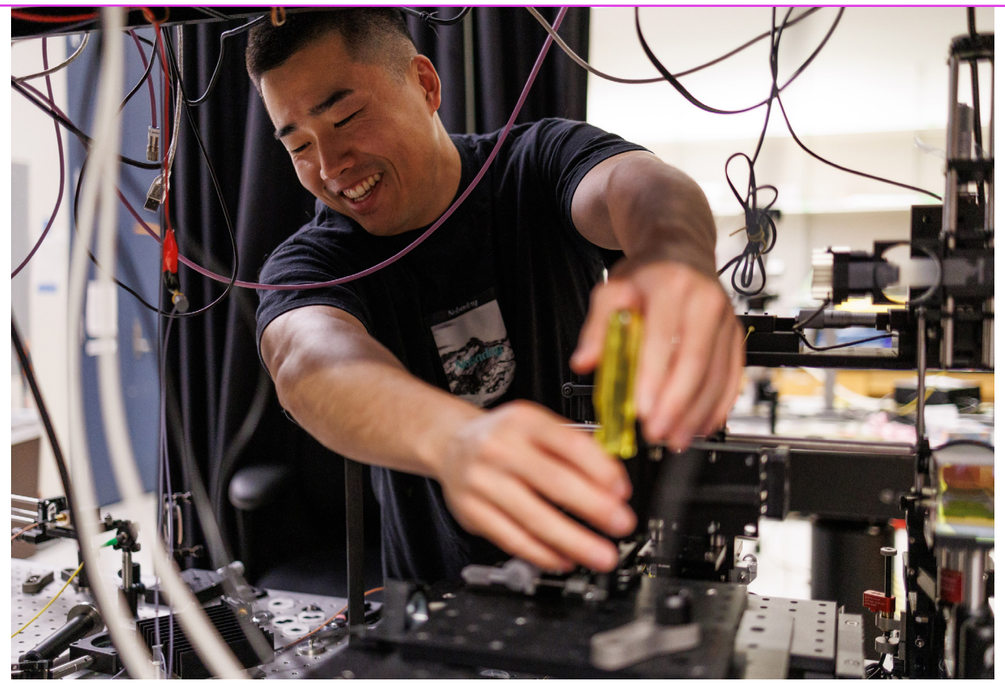
Bingzhao's doctoral work at UW ECE was focused on integrated photonics, which is an emerging area of scientific research that uses light instead of electricity as a medium to transmit and process signals on flat surfaces, such as that of a computer chip. He also builds integrated acousto-optic devices, which use sound waves to manipulate light. And Bingzhao's work in these areas is already having an impact, early on in his career.

For example, a significant outcome of the research for which Bingzhao received the Yang Award was a new type





A significant outcome of the research for which Bingzhao Li received the Yang Award was a new type of light detection and ranging, or LiDAR, system he developed alongside UW ECE graduate student Qixuan Lin, with guidance and oversight from Professor Mo Li. This LiDAR system is integrated into a computer chip, which makes it compact, sturdy, relatively easy to fabricate and cheap to produce.



Bingzhao Li working in UW ECE and Physics Professor Mo Li's Laboratory of Photonic Systems inside the UW ECE building.

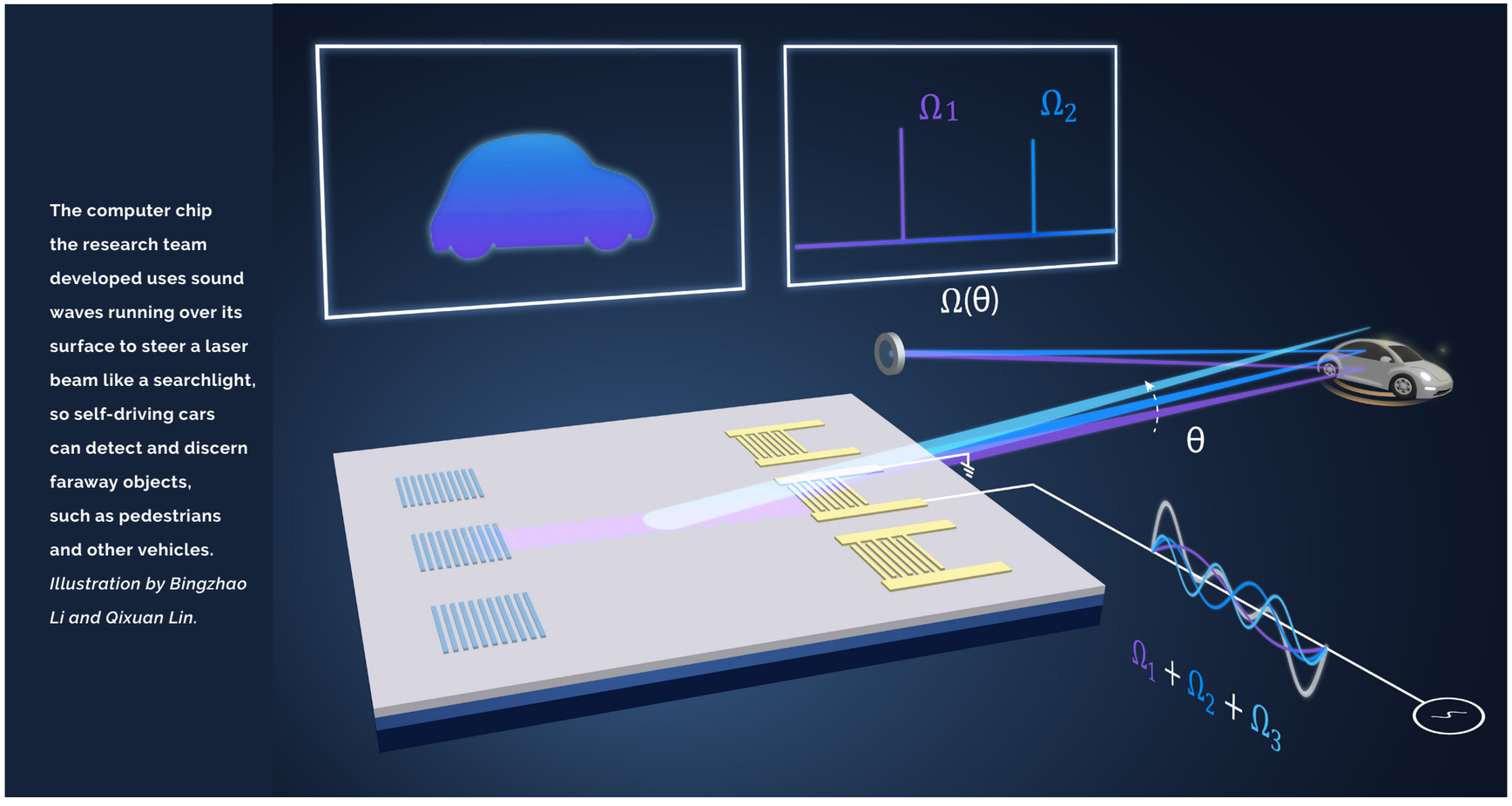
of light detection and ranging, or LiDAR, system he developed alongside UW ECE graduate student Qixuan Lin, with guidance and oversight from Professor Li. LiDAR is a 3D-imaging technology often used in self-driving cars to discern and distinguish objects in their path, including pedestrians and other vehicles. This new type of LiDAR system uses a scanning laser beam, and it could help self-driving cars "see" distant objects with much better clarity and precision. The system can detect and image objects from over 100 meters away.

At the core of this innovation is a laser beam-steering device that is roughly 1,000 times smaller than its counterparts currently in the marketplace. It is integrated into a computer chip, which makes it compact, sturdy, relatively easy to fabricate and cheap to produce. It also has a wide range of other potential applications, including use in robotic systems found in agriculture, global supply chains, and medical imaging.

To achieve this tight, on-chip integration, Bingzhao and the research team developed an innovative technique called "acousto-optic beam steering" for guiding the scanning laser beam by sending sound wave pulses across the surface of the computer chip. The sound wave is similar to what is used in filters for wireless communication, and it has a very high frequency of a few gigahertz, which is inaudible to the human ear.

"At a quantum physics level, the particles in the sound waves (phonons) collide with the particles in the laser beam (photons) on the surface of the chip, and their energy combines," Bingzhao explained. "We precisely adjust the frequency of the sound waves to direct the beam into different directions in the free space above the chip and far into the distance."

This new LiDAR system has been reported in a paper in the journal Nature and featured in media outlets such as GeekWire.



The computer chip the research team developed uses sound waves running over its surface to steer a laser beam like a searchlight, so self-driving cars can detect and discern faraway objects, such as pedestrians and other vehicles. *Illustration by Bingzhao Li and Qixuan Lin.*

It also recently made the cover of the September issue of Laser Focus World.

Bingzhao has also made significant contributions to other research areas over the course of his academic career, including creating a new optoelectronic probe for neural engineering and contributing to notable developments in optical computing and quantum computing.

MENTORSHIP AND THE BENEFITS OF DIVERSITY

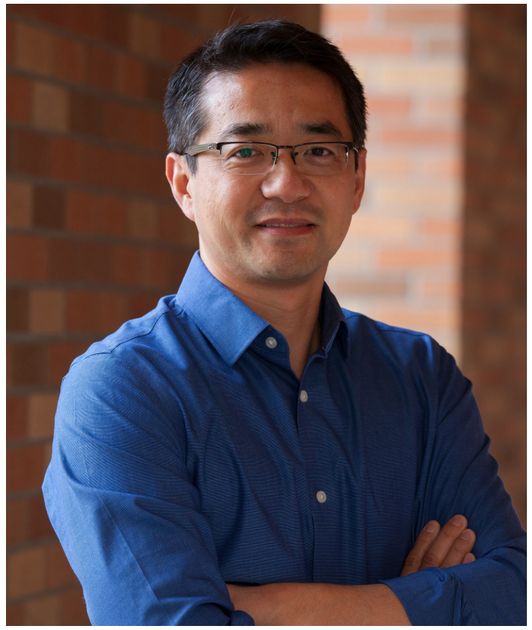
Bingzhao said that Professor Li's guidance and mentorship over the years, from the University of Minnesota to UW ECE, has been crucial to his success.

"Professor Li is really smart and talking to him is easy. He loves sports, so our conversation is not limited to research. And during times when I struggled, he always gave me good advice," Bingzhao said. "I enjoyed my doctoral studies, and he was always there for me, no matter the research or life difficulties I faced. He was there to help."

One important way Professor Li helped Bingzhao was by teaching him better ways to deal with the inevitable and frequent failures that come with research experiments. Instead of letting these failures derail carefully structured plans, Bingzhao learned, under Professor Li's guidance, how to see failure as an integral part of the research process. Bingzhao found that if he simply rethought his approach and tried something new in the moment, rather than considering his experiment a complete failure, he would very often achieve success soon afterwards. This adjustment to his working style made his overall approach to research and his studies much more efficient and productive.

Professor Li also inspired Bingzhao to think about why he began studying engineering in the first place — for the sheer joy of it.

"Professor Li reminded me that science and engineering is about learning. I needed to focus on the experiment I was doing and choose to learn, no matter what might happen," Bingzhao said. "By following his guidance, I found that every time I solved a small problem, I would get excited. This really makes me happy, even though



UW ECE and Physics Professor Mo Li, UW ECE graduate student Quixuan Lin

there are a lot of tasks and difficulties in the research. In the end, publishing in a journal is always good, but I've learned that I gain the most happiness before that, in the day-to-day process."

The breadth of courses and diversity of experiences at UW ECE have also contributed to Bingzhao's personal and professional development. He noted that many of his classmates in China followed an academic path that was very similar to his own. But when he came to America, and, in particular, when he came to UW ECE, he was pleased to find a wide variety of different types of courses offered at the University, as well as people from diverse backgrounds and points of view. Bingzhao said that his experience at UW ECE has enriched his life and informed his research, providing new and different perspectives for him to consider.

Beyond research and academics, Bingzhao enjoys outdoor activities, such as hiking, and sports, especially basketball. He has participated in intramural basketball games at the UW, and tournaments through the Chinese Students and Scholars Association.

LOOKING TOWARD THE FUTURE

Bingzhao plans to continue in his role at the UW Laboratory of Photonic Systems and work with Professor Li on commercializing the LiDAR system they invented. Their research team is already off to a strong start and has garnered support from UW CoMotion and the Washington Research Foundation, as well as major institutions, such as the Defense Advanced Projects Research Agency, or DARPA, and the National Science Foundation. Bingzhao and Professor Li are currently working on creating and field testing an engineering prototype for their LiDAR system, which is a project they estimate will take about one to two years. They are also looking into creating a startup company for the technology.

Beyond work at the lab and the LiDAR project, Bingzhao said that he is looking forward to new developments in augmented reality and virtual reality, where he believes integrated photonics will play an important role in the coming years.

"Light is amazing, and there are lots of things you can do with it, especially in integrated photonics. We can use our on-chip devices to slow it down, manipulate it with sound, play with it in an interesting way, and take it in whatever direction we want," Bingzhao said. "We can also use light for imaging applications and help you to see the world in ways you never could before. We can do a lot of things with light and sound, and they are all interesting. So, I'm curious about where we could go with this. For me, doing research is all about creating happiness, and this subject is something I really enjoy." w

"PROFESSOR LI REMINDED ME THAT SCIENCE AND ENGINEERING IS ABOUT LEARNING. I NEEDED TO FOCUS ON THE EXPERIMENT I WAS DOING AND CHOOSE TO LEARN, NO MATTER WHAT MIGHT HAPPEN."

– BINGZHAO LI

UW ECE SPOTLIGHTS

selected news from UW ECE faculty, students, alumni, and donors

RESEARCH ▪ INDUSTRY ▪ AWARDS

GEORG **SEELIG**

DNA Computer Scientist of the Year

Georg Seelig, a faculty member in UW ECE and the Allen School, received the 2023 Rozenberg Tulip Award from the International Society for Nanoscale Science, Computation and Engineering. The award was in recognition of his original contributions advancing the field of DNA computing.

www.ece.uw.edu/spotlight/georg-seelig-rozenberg-tulip-award-2023

New NSF Center for Soil Technologies

PAYMAN **ARABSHAHI**

Associate Professor Payman Arabshahi was recently named site director and principal investigator at the UW for the new, multi-institutional, NSF-funded Center for Soil Technologies.

www.ece.uw.edu/spotlight/payman-arabshahi-uw-lead-soiltech

SARA **MOURADIAN**

Building quantum technologies for computing, communication and sensing

Assistant Professor Sara Mouradian joined UW ECE in March 2022. Since then, she has established the Scalable Quantum Research Lab at the UW, which is building quantum technologies for real-world applications.

www.ece.uw.edu/spotlight/sara-mouradian-2023

ARKA **MAJUMDAR** & JOHANNES **FRÖCH**

Reimagining optics for smartphone cameras and other devices

UW ECE and Physics Associate Professor Arka Majumdar and UW ECE postdoctoral scholar Johannes Fröch are part of an international research team that has developed an innovative miniature camera, which uses a hybrid optical system over 100 times smaller than its commercial counterpart.

www.ece.uw.edu/spotlight/reimagining-optics

SAJJAD **MOAZENI**

Google Research Scholar Award

Assistant Professor Sajjad Moazeni received a Google Research Scholar Program award to develop faster computer networks for AI and machine learning in the cloud. Moazeni is developing a new type of "smart" computer chip for use in data centers that will help make AI and machine learning applications faster, more powerful and energy efficient.

www.ece.uw.edu/spotlight/sajjad-moazeni-2023-google-research-scholar-program-award

MO **LI**

The 'breath' between atoms — a new building block for quantum technology

A UW research team, led by UW ECE and Physics Professor Mo Li, has found a way to leverage the "breathing," or mechanical vibration, between two layers of atoms, engineering a new building block for quantum technologies.

www.ece.uw.edu/spotlight/the-breath-between-atoms

UW ECE faculty include:

1 **MACARTHUR** FELLOW

5 **NAE** MEMBERS

7 **SLOAN** FELLOWS

18 **FACULTY WITH** RESEARCH PUBLICATIONS CITED OVER 1,000 TIMES

29 **IEEE** FELLOWS

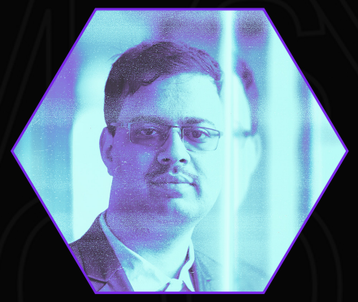
UW ECE SPOTLIGHTS

JAN **SILVA** & DENISE **WILSON**

An IV fluid monitor that could help save the lives of newborns worldwide

A UW ECE student team including recent UW ECE graduate Jan Silva (MSEE '23) and led by Professor Denise Wilson and Dr. Gregory Valentine from the UW School of Medicine, has engineered a low-cost, highly accurate intravenous (IV) fluid monitor aimed at improving infant health outcomes around the globe.

www.ece.uw.edu/spotlight/iv-fluid-monitor-2023



AKSHAY **GADRE**

Long-range wireless networks

Assistant Professor Akshay Gadre is an expert on wireless networks. He is exploring emerging application areas for this technology while helping his students bridge the gap between theory and practice.

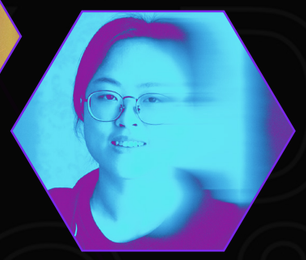
www.ece.uw.edu/spotlight/akshay-gadre-faculty-profile

ARKA **MAJUMDAR,** RAHUL **TRIVEDI,** ABHI **SAXENA**

A new chip for quantum technology

A UW research team led by UW ECE and Physics Associate Professor Arka Majumdar and including UW ECE Assistant Professor Rahul Trivedi and recent UW ECE graduate Abhi Saxena (Ph.D. '23) has moved quantum technology development a significant step ahead. The team has demonstrated a new kind of silicon photonic chip that could work as a solid foundation for building a quantum simulator, one with useful applications in the real world.

www.ece.uw.edu/spotlight/new-chip-for-quantum-technology



MO **LI,** BINGZHAO **LI,** QUIXUAN **LIN**

New 'eyes' for self-driving cars

A UW ECE research team led by UW ECE and Physics Professor Mo Li has invented a new type of light detection and ranging, or LiDAR, technology that helps autonomous vehicles "see" distant objects. This on-chip device also has a wide range of other potential applications, including use in robotic systems found in agriculture, global supply chains, and medical imaging.

www.ece.uw.edu/spotlight/new-eyes-for-self-driving-cars

RADHA **POOVENDRAN**

New NSF-funded ACTION Institute

Poovendran will be the UW lead for a new, multi-university institute, which is developing approaches that leverage AI to defend against cyberthreats that target the security and privacy of computer networks and their users.

www.ece.uw.edu/spotlight/radha-poovendran-action-institute

UW ECE SPOTLIGHTS

SHIMA **ABADI** & JOHN **RAGLAND**

Listening to the ocean to measure the impact of climate change

UW ECE doctoral student John Ragland, who is advised by UW ECE Adjunct Associate Professor Shima Abadi, is finding ways to improve signal-processing and data-driven techniques for listening to ambient noise in the ocean. Their work is providing more powerful tools for measuring ocean temperatures and underwater processes impacted by climate change.

www.ece.uw.edu/spotlight/listening-to-the-ocean-climate-change

DONALD **WUNSCH**

Neural networks used in artificial intelligence

UW ECE alumnus Donald Wunsch II (Ph.D. '91) has been named by IEEE as recipient of the 2023 Computational Intelligence Society Neural Networks Pioneer Award for fundamental contributions to the understanding and development of neural networks.

www.ece.uw.edu/spotlight/donald-wunsch-ieee-pioneer-award

ALANA **DEE**

MARZIYEH **REZAEI**

UW ECE graduate students receive Cadence Diversity in Technology Scholarship

Alana Dee and Marzyeh Rezaei are third-year doctoral students at UW ECE and each was a recipient of a 2022 Cadence Diversity in Technology Scholarship. Both students are advised by UW ECE Assistant Professor Sajjad Moazeni.

www.ece.uw.edu/spotlight/cadence-diversity-scholarship-2022

Recent alumna studying sustainable energy policy at Princeton

MARGOT **ADAM**

Margot Adam (BSEE '23) graduated from UW ECE with a concentration in sustainable energy systems. Now, she is pursuing a doctoral degree at Princeton University, focusing on ways she can help inform public policy applicable to renewable energy.

www.ece.uw.edu/spotlight/margot-adam-policy-for-renewable-energy

UW ECE alumnus Frank Liu leads development of device that enables users to experience liquids in virtual reality

FRANK **LIU**

Liu's device, called Geppetteau, replicates haptic sensations with a string-driven apparatus and is adaptable to an assortment of vessel shapes.

www.ece.uw.edu/spotlight/frank-liu-geppetteau

KYLE **JOHNSON** & ADHYYAN **NARANG**

Kyle Johnson and Adhyyan Narang named UW + Amazon Science Hub inaugural fellows

Recent UW ECE graduate Kyle Johnson and UW ECE doctoral student Adhyyan Narang have been named inaugural Amazon Fellows. They will each receive funding to pursue research projects and participate in summer internships alongside Amazon researchers.

www.ece.uw.edu/spotlight/amazon-fellows

An engineer who sees the world through butterfly eyes

UW ECE affiliate professor and alumnus Gary D. Bernard (BSEE ‘59, MSEE ‘60, Ph.D. ‘64) has had a long, successful engineering career in academia and industry. He has also produced an impressive amount of research exploring how butterflies view and adapt to their environment. Seen here, Bernard at one of the many laboratories in his home in Federal Way, Washington, set up for studying butterflies

UW ECE AFFILIATE PROFESSOR AND ALUMNUS GARY D. BERNARD (BSEE ‘59, MSEE ‘60, Ph.D. ‘64) has had a long and varied engineering career, one that has been full of unexpected twists and turns. Over the years, it was his ability to seek out and embrace unique connections and opportunities, along with a knack for collaborating with people from diverse backgrounds, that has produced a long, successful, and satisfying professional life. And retiring from Boeing in 2007 hasn’t slowed him down, in fact, he has remained incredibly prolific, producing an impressive amount of research related to how insects, and butterflies in particular, see and understand the world. In 2023, with a deep love for his research subject fueling him and a recent paper published in the Journal of Experimental Biology, Bernard, 85, is still going strong and is full of excitement about what he and his collaborators might learn and discover next.

“After my postdoc, I was an engineer that wanted to take principles from life sciences and apply them in a technological way to making devices,” Bernard said. “But later, I became more interested in what insects actually do and how they do it. How does a small butterfly eye behave so beautifully and do such amazing things? You can’t imagine what flying insects can do and how capable they are. So, I became much more interested in that, and I still am. But the technological fallout from our work has been absolutely amazing.”

The impact from Bernard’s research has been broad and wide ranging. For example, he has applied fundamental principles learned from his studies of insect vision to improving machine vision and real-time monitoring of manufacturing processes at Boeing. And together with UW ECE Professor Les Atlas and his students, Bernard applied neural network technology to the real-time monitoring of hard-metal machining, work that was later supported by the Office of Naval Research. Bernard has also collaborated and co-authored a paper on Saharan silver ants with a professor of applied physics at Columbia University and a professor of zoology at the University of Zurich to better understand how desert ants are able to survive extreme midday heat. This paper has been widely cited by many groups applying its principles to create materials with optical and thermal radiative properties for passive cooling of diverse objects such as buildings, vehicles, clothing, and even microcircuits. The graduate students Bernard has taught and advised over the years have gone on to make their marks in the field as well. For example, Mandyam Srinivasan, who was Bernard’s doctoral student at Yale University, focused his research on the flight of the worker honeybee. Srinivasan discovered principles of this insect’s flight control that were later applied by the Australian Air Force to ground-following flight control of helicopters and other low-flying aircraft.

Today, as a UW ECE affiliate professor, Bernard continues his research on intracellular optical physiology, rhodopsin photochemistry, and retinal densitometry in the compound eyes of living butterflies. To that end, he conducts experiments and takes measurements of the spectral and polarization properties of these flying insects’ unique and fascinating eyes.

FLYING FULL CIRCLE — FROM UW ECE TO MIT, YALE AND BACK AGAIN

In 1959, Bernard received his bachelor’s degree from UW ECE. He then went on to earn his master’s and doctoral degrees from the Department in 1960 and 1964, respectively. As a graduate student in the early 1960s, Bernard was one of the first to be advised by Professor Akira Ishimaru, who was the Department’s first doctoral degree recipient and one of the world’s top experts in the study of electromagnetic wave propagation and scattering. Ishimaru has since received numerous awards and honors for his work and today is a UW ECE Professor Emeritus.

Under Ishimaru, Bernard focused his doctoral research on frequency-independent guided and radiated electromagnetic waves. He also taught undergraduate courses on transmission lines, pulse circuits, and electronic circuits. According to Bernard, his first love was theoretical work, but Ishimaru insisted that he conduct experiments as well, so Bernard worked on two research contracts and had a Boeing fellowship during this time. He also tested the frequency-independent surface-mounted antennas he designed on a Boeing antenna range.

Bernard said that skills he gained at UW ECE included analysis, useful mathematics, and being able to test things and understand phenomena from both a theoretical and a physical standpoint. He also learned how to collaborate on research and work well with people in teams, which was a skill he believes was crucial to success in both his career and insect research.

“Butterfly vision is so complicated that there is no way you can master all the techniques for studying it. Teaming is necessary,” Bernard said. “By working together, you can accomplish things that no one person could do by themselves. This type of collaboration has happened often in my career, and I have Ishimaru to thank for helping me to build my skills for that.”

In the late 1950s and early 60s, Professor Walter Rogers taught the Department’s undergraduate course in electromagnetic fields and waves, and he pointed Bernard toward this subject

Many butterfly species can see polarized light — light oscillating in only one planar direction. Bernard and his colleagues have recently discovered that some species, such as the Australian imperial blue butterfly, can use visual information gathered from polarized light to detect and assess the health of each other and choose mates. Here, Bernard demonstrates a phenomenon of polarized light, “birefringent interference,” which he uses in his butterfly eye research.

Bernard holding a Painted Lady butterfly that was raised for scientific research. Its wings are waxed prior to a microscopic eye exam with incident white light. The color of reflected light from the butterfly’s eye is a measure of the quantity of visual pigment (rhodopsin) it contains, and among other things, it reveals the health of the eye.

On the computer screen is one of a series of depolarized butterfly eyeshine photos, taken from the completely intact eye of a living Hairstreak butterfly. Bernard examines the facets of different areas of the eye, which enables him to learn how arrays of lenses within the butterfly's compound eye are organized for competing requirements of motion detection and polarization vision.

for further study. Later, while considering what to do after receiving his doctoral degree, Rogers told Bernard about a new Ford Foundation postdoctoral program at MIT. Bernard applied, and in 1965, he moved to the East Coast to join MIT as a postdoctoral scholar. The Ford Foundation recognized that new engineering postdocs were not necessarily equipped for teaching, so Bernard spent half of his working hours team-teaching electromagnetic theory and the other half on electron-beam and plasma experiments.

About a year after joining MIT, Bernard received a phone call from William Miller, a physiologist at Yale, who was looking for an expert in electromagnetic fields, waves and antenna design. Miller was conducting experiments to better understand insect vision, specifically, how moth eyes adapted to different lighting conditions, such as between day and night. Miller discovered an array of tiny bumps on moth eye lenses and thought that they might be optical dielectric rod antennas. He asked Bernard to theoretically model how these structures interacted with light.

"Bill was examining an electron microscope picture of a moth eye lens, and he noticed that the surface of the lens wasn't smooth as expected," Bernard said. "He discovered the lens was covered with 2,000-angstrom hexagonally-packed nipples that functioned as a broadband reflection coating. He also showed me electron microscope images of other structures, such as dielectric waveguides. Well, I just got hooked! So, I started working with him."

Bernard feeding Vanessa butterflies in his Yale laboratory, 1987.
Photo courtesy of Gary Bernard

Bernard was "bitten by the bug" of studying insect vision, so much so that he dove headfirst into the field, and, in 1966, he made a notable scientific discovery. While in the process of examining moths and other insects with a microscope loaned by Miller, Bernard caught a butterfly and placed it under the microscope. What he saw through the lens was a small, green reflection from the butterfly eye, but that reflection disappeared before he could photograph it. The next time he looked, it mysteriously changed from green to red. Tests by Miller under an electron microscope confirmed that Bernard had discovered butterfly eyeshine, a phenomenon caused by a reflector behind the retina that makes the eye more sensitive. Eyeshine is most often found in nocturnal animals, and it can often be seen in the eyes of deer or raccoons caught in the glare of an oncoming car's headlights. Why butterflies, who are only active during the day, have eyeshine is still an open question, but this discovery prompted Bernard to think that light could perhaps be used as an optical probe to learn what butterflies can see. He found this idea exciting, and it set him on the research path he still follows today.

In 1968, Bernard joined Yale as an assistant professor with an interdisciplinary appointment that spanned the ophthalmology and visual science department as well as the engineering and applied science department. He also received a five-year research career development award and a grant from the National Eye Institute. His work at Yale focused on the optical physiology and photochemistry of insect visual sensors and, later in his career, on the evolutionary ecology of butterfly color vision. This appointment lasted quite a bit longer than Bernard had expected.

"I thought I would go to Yale for five years, learn some biology and then move on," Bernard said. "I ended up staying for 21 years. My wife and I had four kids during that time and raised our family in Hamden, Connecticut."

At Yale, Bernard continued his work with Miller, using electromagnetic waves to study insect vision. He also taught and lectured on a wide range of topics. In his role as an assistant professor in the medical school, he lectured to residents on principles of color vision, physiological optics, corneal and lens transparency, photoreceptor waveguide optics, principles and practice of optical microscopy, use of polarization to reduce glare in ophthalmoscopy and the use of color-contrast filters in ophthalmoscopy. In the biology department, he lectured and gave seminars and tutorials to graduate students on the optics of compound eyes, the principles and practice of optical microscopy, optical physiology, retinal densitometry, and the use of laboratory computers. And in the engineering and applied sciences department, he taught a graduate-level course on electromagnetic theory and undergraduate courses on the application of engineering to living systems. While at Yale, he advised graduate and doctoral students, some of whom went on to make significant impacts in their respective fields.

Bernard and his wife both were from the Puget Sound area, so in 1989, after their children were grown, they decided to move back to Seattle. Bernard secured a position at Boeing as an engineer in the company's commercial airplanes' advanced sensors and machining research and development groups. He also accepted a concurrent appointment at UW ECE, then UW EE, as an affiliate faculty member. This allowed him to move his lab equipment, which could not be transferred to a private company like Boeing, from Yale to the UW.

At Boeing, Bernard looked for innovative ways to detect wear and tear on industrial cutting tools used to machine airplane parts from hard metals. One of his ideas was to apply speech recognition technology to real-time monitoring of manufacturing equipment. This idea sparked a Boeing research contract with the UW and Professor Atlas, whose graduate students Bernard co-advised as a UW graduate faculty member. Later, when this work was funded by the Office of Naval Research, UW ECE Professor Mari Ostendorf also became involved, developing an important method for predicting the remaining life of the monitored cutter.

Bernard worked at Boeing for 18 years, and from 1998 to 2007, he served as the Boeing collaborator with the UW, the University of Maryland, Boston University and the University of Zurich on a multi-university initiative funded by the Office of Naval Research. Bernard's birth-to-death machining cutter dataset was used by this collaboration to develop and evaluate new methods for real-time monitoring of dynamic faults in machining spindles and cutters. The partnership also established the Center for Acoustic and

Bernard is holding Yale physiologist William Miller's electron micrograph, which shows the fine structure of a birefringent photoreceptor waveguide inside a butterfly eye. Bernard exploits the phenomenon of birefringent depolarization to determine the degree of alignment or misalignment of the photoreceptor waveguides of the neighboring "little eyes" that make up the butterfly's compound eye. Each butterfly compound eye contains thousands of these little eyes, which enable butterflies to see many different things in multiple directions, all at the same time.

Auditory Research at the UW. During this collaboration and all his time at Boeing, Bernard continued his butterfly research after hours.

"Gary was a tremendous collaborator and point of contact for me and my students. He also remained passionate about studying butterflies and insects," Atlas said. "I remember some scientific meetings where Gary came early to wander off outside with his butterfly net in hand."

LOOKING AHEAD

Bernard retired from Boeing in 2007, but he continues to hold his UW ECE affiliate faculty appointment to this day. After retiring, Bernard arranged to transfer his UW equipment to a laboratory he set up in his home in Federal Way, Washington. He has since been collaborating with colleagues at the University of California, Irvine; Harvard University; Columbia University; and Lund University in Sweden on the visual ecology and evolution of butterfly vision. More specifically, Bernard is studying the relationship of butterfly eye design as it relates to the colorful patterns found on butterfly wings and host plants.

Human eyes have three photoreceptor types for color vision, but butterflies, like many other insects and birds, have four or more types of photoreceptors. This enables them to see a much wider spectrum of light in greater detail than humans can. Many butterfly species can also see polarized light — light oscillating in only one planar direction. What Bernard and his colleagues have recently discovered is that some species, such as the Australian imperial blue butterfly, can use visual information gathered from polarized light to detect and assess the health of each other and choose mates. This ability to see polarized light, along with a capacity to see into the ultraviolet and far-red bands of the visual spectrum through compound eyes, which are made up of thousands of tiny lenses, provides these small insects with high visual acuity at close range. It endows them with an awareness of the world that is well beyond what human beings are capable of seeing.

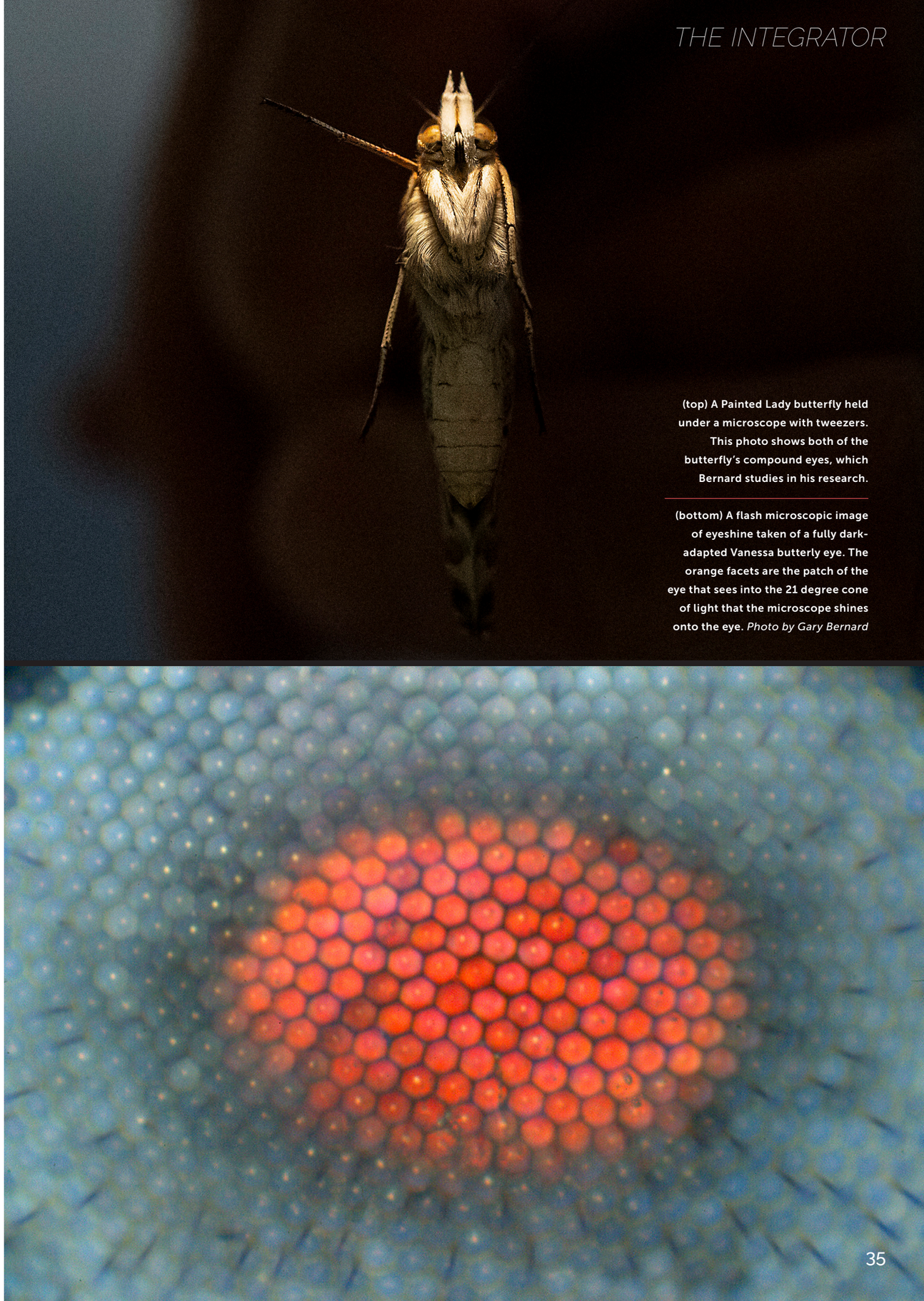
"The photoreceptor waveguides in butterflies are composed of many tiny, parallel tubes of membrane, packed with molecules of visual pigment, but because of that linear structure, they are more sensitive to polarized light that is parallel to the tubes, than light that is perpendicular. That is the basis for their polarization sensitivity," Bernard said. "So, what I'm working on now is how they manage the alignment of neighboring units of the compound eye for polarization detection in a way that allows them to still do flight control and image processing that is not disturbed by polarization."

He already has lined up partnerships to further investigate this topic with leading experts on insect vision and intracellular physiology in Europe and Australia, where a few months from now, he plans to participate in a field research study via Zoom.

Bernard credits the UW for laying the foundation of his long, successful and interesting career. And when asked what he thought about his many years spent at UW ECE, both as a student and later as a faculty member, he had many complimentary things to say.

"When I was a student, I didn't really understand until much later in my career just how very good our faculty, such as Rogers and Ishimaru, are. Since then, I've been at MIT, Harvard, Yale, Princeton, and worked with faculty and students all around the world," Bernard said. "Looking back at my education, I realized that the quality of both students and faculty at UW ECE is second to none. And the quality of education in the Department compared to what I've seen at other universities throughout the years? It's absolutely top notch. I was so fortunate to have started my professional life here." **w**

Read Professor Bernard's latest research paper, ***"A hypothesis for robust polarization vision: an example from the Australian imperial blue butterfly, Jalmenus evagoras"*** in the Journal of Experimental Biology.



(top) A Painted Lady butterfly held under a microscope with tweezers. This photo shows both of the butterfly's compound eyes, which Bernard studies in his research.

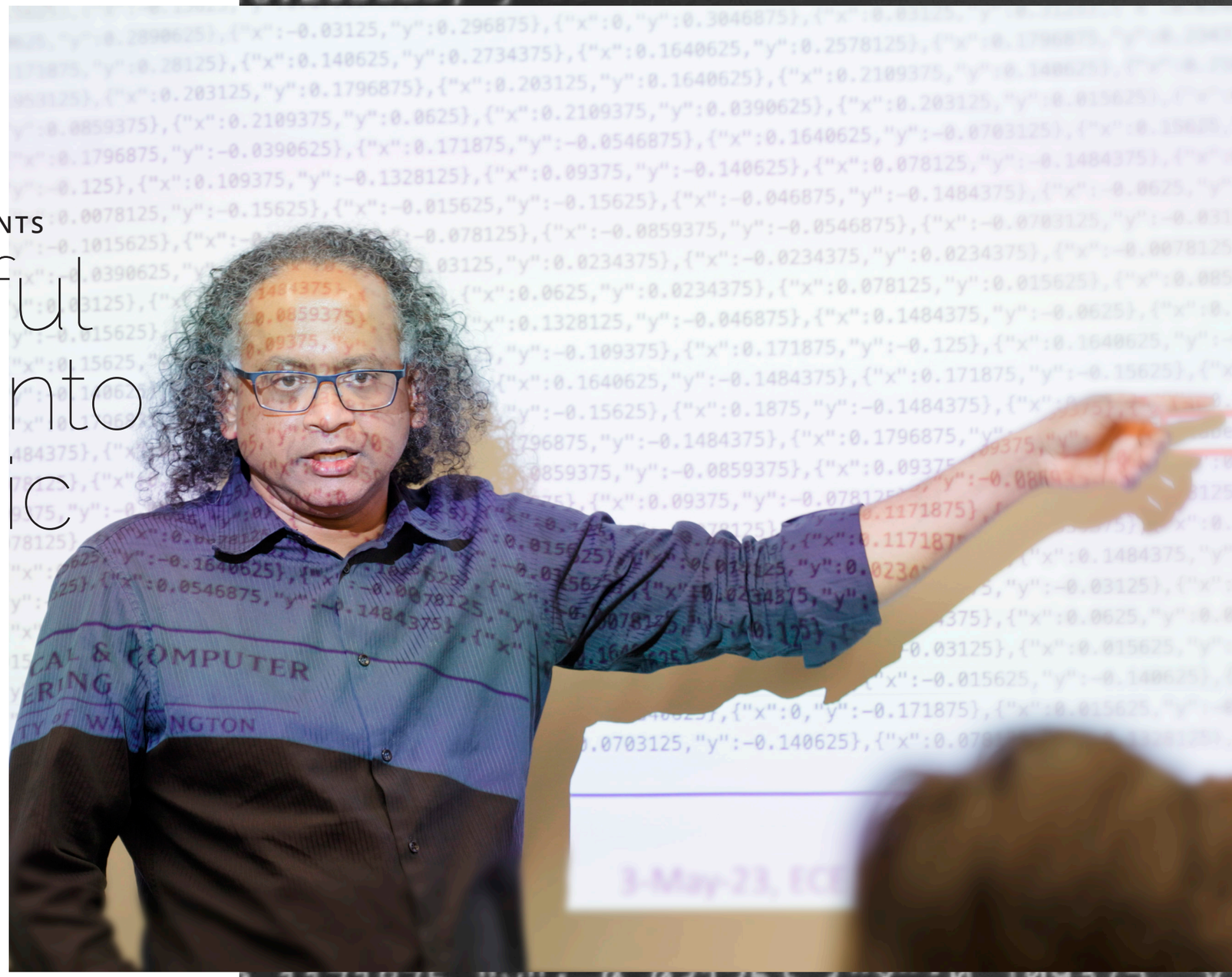
(bottom) A flash microscopic image of eyeshine taken of a fully dark-adapted Vanessa butterly eye. The orange facets are the patch of the eye that sees into the 21 degree cone of light that the microscope shines onto the eye. *Photo by Gary Bernard*

Graduate students in Professor Radha Poovendran's TinyML course are learning how to squeeze sophisticated machine learning networks into small, resource-constrained devices.

UW ECE PROFESSIONAL MASTER'S STUDENTS

pack powerful technology into tiny electronic devices

OUR DAYS ARE FILLED WITH electronic devices that we depend on to perform tasks and stay connected with one another. Whether it's the computers we use at work, our smartphones, or personal assistants such as Siri or Alexa, these gadgets have become indispensable to modern life. A wide range of "smart home" devices considered to be part of the Internet of Things (IoT), such as thermostats, lighting fixtures, and security systems, are also steadily making their way into people's daily routines. And as billions of IoT devices are adopted worldwide, the demand for increased performance from low-power, small electronic devices is growing. →



The TinyML course is taught by UW ECE Professor Radha Poovendran, a former Department chair and an expert on the intersection of machine learning, cyber-physical systems, large-scale network systems and cybersecurity.

Now, UW ECE graduate students taking the TinyML course through the Professional Master's Program are learning how to pack powerful technology into tiny electronic devices and help to meet this emerging demand. TinyML is a type of machine learning that allows sophisticated machine learning models often used in natural language processing, computer vision, and artificial intelligence to run on smaller, resource-constrained electronic devices, such as a microcontroller. This emerging field of study began to flourish in 2020, and it is considered to be an important technology enabler for ultra-low power machine learning in edge devices.

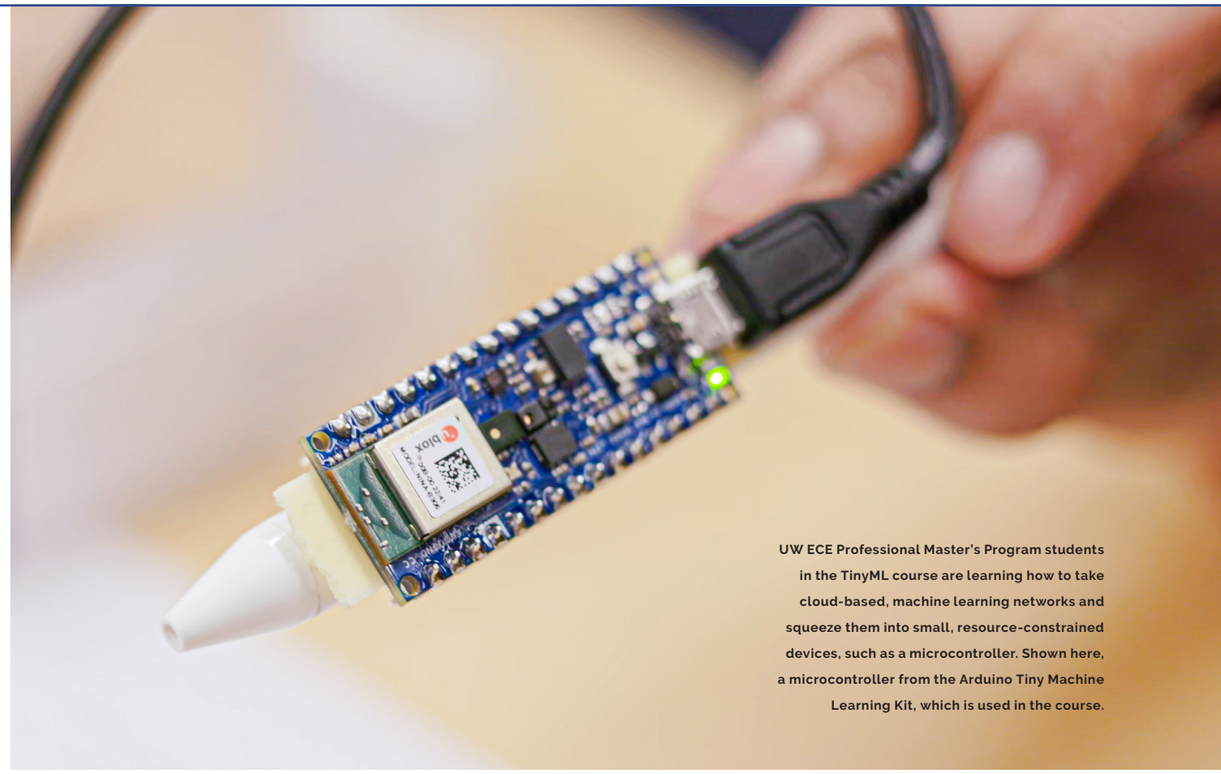
The TinyML course at UW ECE provides training in cutting-edge machine learning concepts and then asks students to apply those concepts to building small electronic devices in hands-on, team-based projects. The course got its start during the 2023 spring quarter, and it is among only a few such offerings at schools nationwide that bring machine learning, embedded systems and the IoT together at the lower end of device capabilities. The course also covers privacy and security for TinyML devices, emphasizing the importance of engineering with device vulnerabilities in mind.

The course is taught by UW ECE Professor Radha Poovendran, a former UW ECE chair and an expert on the intersection of machine learning, cyber-physical systems, large-scale network systems and cybersecurity. Poovendran is also the UW lead for the National Science Foundation's AI Institute for Agent-based Cyber Threat Intelligence and Operation, which is known as the ACTION Institute.

"This course helps students understand how to take cloud-based, machine learning networks and squeeze them into resource-constrained, tiny devices that are left unattended and often operate for long periods of time," Poovendran said. "This is a hands-on course, and the students learn how to formulate and state a problem, use sensors to collect data, and convert the data into a format that the machine can start processing."

UW ECE Professional Master's Program students in the TinyML course.

In addition to being part of the PMP curriculum, the TinyML course is also offered through a PMP Certificate Program in Machine Learning and Deep Learning and the recently launched PMP Certificate Program in Applied Cybersecurity Engineering (ACE), which will be welcoming its first student cohort in winter quarter.



UW ECE Professional Master's Program students in the TinyML course are learning how to take cloud-based, machine learning networks and squeeze them into small, resource-constrained devices, such as a microcontroller. Shown here, a microcontroller from the Arduino Tiny Machine Learning Kit, which is used in the course.

Adithya Gowda Baragur is a full-time PMP student focusing on embedded systems and machine learning. Baragur said that the TinyML course helped him to improve his machine learning skills as well as his collaborative abilities working in diverse teams.

Learn more about the TinyML course from two UW ECE PMP students who took the course during spring quarter 2023:

ADITHYA GOWDA BARAGUR

Adithya Gowda Baragur is a full-time PMP student who is focusing on embedded systems and machine learning. He has a strong background in software engineering, having previously worked with the research and development team at Hewlett Packard Enterprise, Aruba Networks. He was a graduate research assistant last summer in Poovendran's Network Security Lab, and he recently started an internship with Nokia. Baragur said that he chose the PMP at UW ECE because of its industry orientation and flexibility with work schedules. He anticipates graduating with his master's degree at the end of spring quarter 2024.

WHAT INTERESTED YOU IN THE TINYML COURSE?

I was interested in discovering how to apply machine learning to a small microcontroller — a very tiny device. This is a very niche topic, even in machine learning. In engineering, you want to optimize everything as much as possible. When you deploy machine learning to a tiny device, you must move to a higher level of optimization to do that. I wanted to learn what techniques were used to do this, so I could apply them elsewhere.

CAN YOU DESCRIBE ONE OF THE PROJECTS YOU DID?

Sure, one of the projects I and my group came up with was called "Song Bird: Automatic Identification of Bird Species using Bird Calls." It's like the Shazam app for your phone, where you have a button that records what song is playing in the background, and it tells you what song it is. Here, we applied the same idea, creating an app for your phone, but we did it for bird calls. When the user hears a bird call, they can record it through the app, and then the app identifies what the bird is. We had this huge data set, which was available for free through the internet and included people across the world who recorded all kinds of different bird calls. So, we thought: Why not use this data and build an application using TinyML? We targeted hikers and bird lovers as the intended users for the app. The advantages of this app being created through TinyML is that it requires much less memory space and battery power, and no internet connectivity from your phone, which is of utmost importance, especially for people in remote locations, such as hikers in the wilderness.

OVERALL, WHAT DID YOU LEARN IN THE COURSE?

I gained the incredible ability to empower tiny devices with the intelligence to change the world – it's the future of artificial intelligence at your fingertips! Furthermore, when I worked in

Professor Poovendran's lab, I was able to apply the techniques learned in this course to a research problem focused on the security of a Controller Area Network (CAN bus).

HOW WILL YOU USE THIS KNOWLEDGE GOING FORWARD?

In my previous industry experience, I felt lacking in my collaborative abilities when working with diverse teams, and my machine learning skills had room for growth. This course helped me with upskilling in both of these areas. Overall, my journey in the PMP at UW ECE has been an upskilling adventure, where I've harnessed the machine learning and analytical skills needed to lead and conquer the ever-evolving industry with unwavering confidence!

MICHELLE ELIZABETH CHUANG

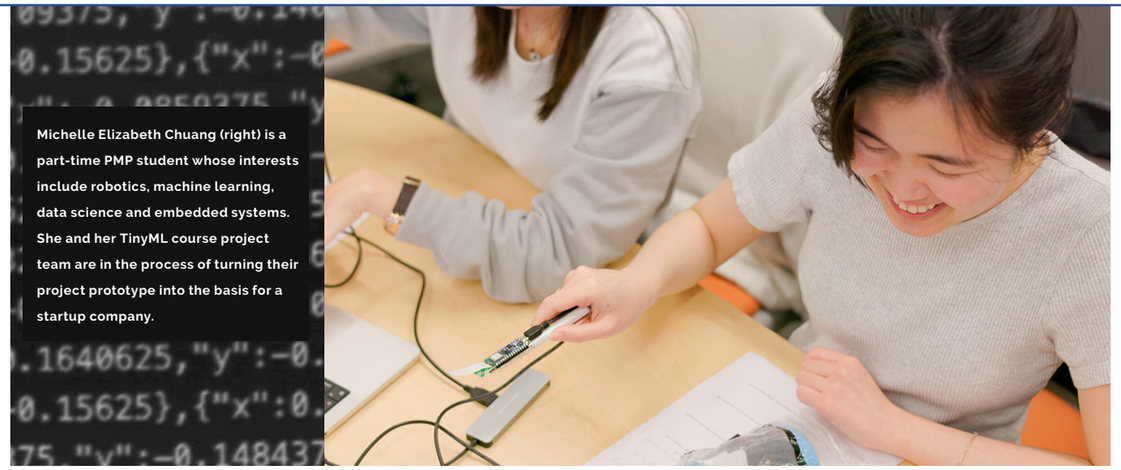
Michelle Elizabeth Chuang received her bachelor's degree from UW ECE in June 2021. She currently works full-time at Microsoft as an Azure Cloud and AI Consultant and is pursuing her master's degree part-time through the PMP. She has developed a strong data engineering skill set, having specialized in numerous Microsoft products used to build end-to-end data pipelines. She also enjoys sharing about her work through hosting and speaking at sessions for large technical conferences. Chuang is passionate about using creativity and technology to invent new experiences for people. Her interests include robotics, machine learning, data science and embedded systems. Like Baragur, Chuang said that she chose the PMP at UW ECE because of its industry focus and scheduling flexibility. She anticipates graduating with her master's degree at the end of spring quarter 2025.

WHAT INTERESTED YOU IN THE TINYML COURSE?

I've always been interested in robotics and the integration of hardware and software. I mentioned this to my mentor at my internship during my undergraduate career, and he recommended to me this TinyML book, which turned out to be the book Professor Poovendran used in class. So, I had the book even before the course started, but I got a little overwhelmed with the new concepts. When I saw that the TinyML course was being offered through the PMP, and that it was using the book I already had, I was like, "It's a sign!" So, that is how I came to take the course, because of the influence of my mentor and my interest.

CAN YOU DESCRIBE ONE OF THE PROJECTS YOU DID?

Our project, "FacePace," tries to solve the problem of inaccurately estimated wait times in theme parks. I grew up going to many theme parks in Southern California, such as Disneyland, Six Flags, and Universal Studios, so our project included a problem statement that came from the heart. Right now, there are some methods that depend heavily on human involvement to estimate wait times, which leaves room for human error and large, inconvenient inaccuracies for the public. To address this problem, we designed a TinyML prototype that runs machine learning algorithms on edge devices to provide a real-time wait time estimate for a queue. This solution aims to be much more efficient and accurate than most systems currently in use today.



Michelle Elizabeth Chuang (right) is a part-time PMP student whose interests include robotics, machine learning, data science and embedded systems. She and her TinyML course project team are in the process of turning their project prototype into the basis for a startup company.

We found that there was a lot of support for the project we developed. I talked about the idea with the Executive Vice President and Chief Information Officer at the Walt Disney Company, Diane Jurgens, who is a UW ECE alumna and someone I consider to be my mentor. I also brought the project into an entrepreneurship course I took over the summer from UW ECE Assistant Teaching Professor Sep Makhsous. There, I practiced my pitching and Professor Makhsous provided more guidance for me and my TinyML team, who I remained in touch with after the course was over. Today, my TinyML team and I are working on turning this project into a startup company. It's very exciting!

OVERALL, WHAT DID YOU LEARN IN THE COURSE?

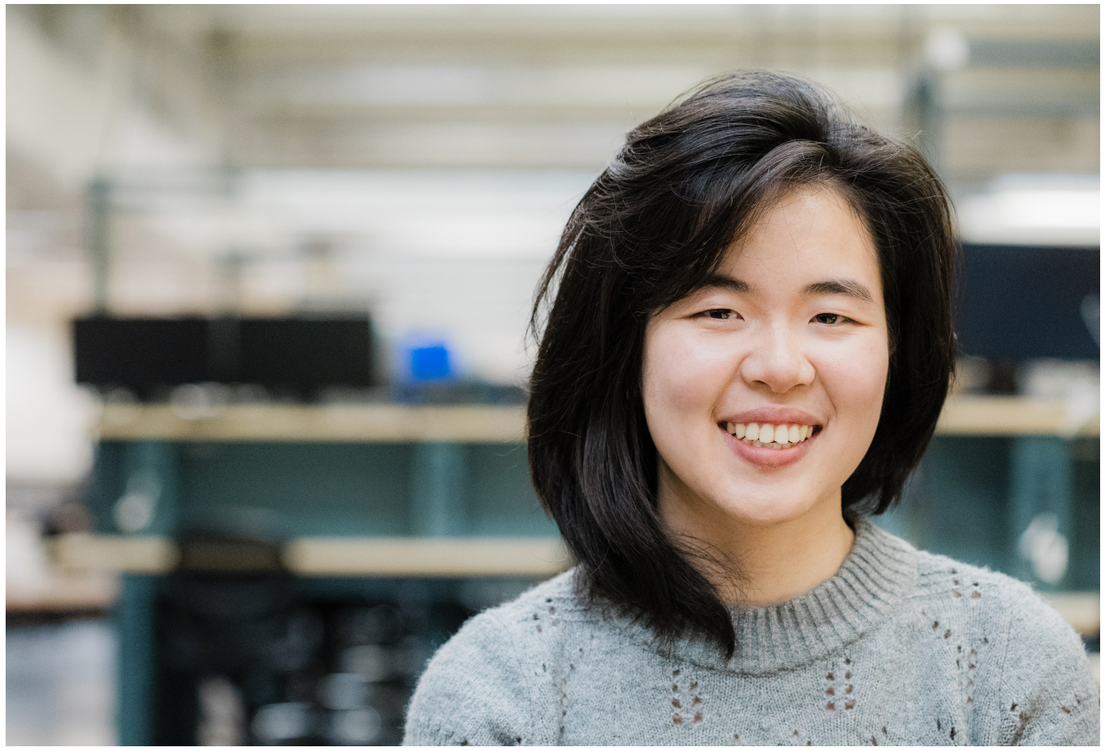
I wasn't very well-versed in machine learning before I took this course. As an undergraduate, I was interested in robotics and electrical engineering, and I heard all the AI/ML buzzwords, but this was the first course where I was able to learn about and experience not only machine learning as a concept (how to program, train models, work with the data), but also to take that big concept and put it into hardware as tiny as this.

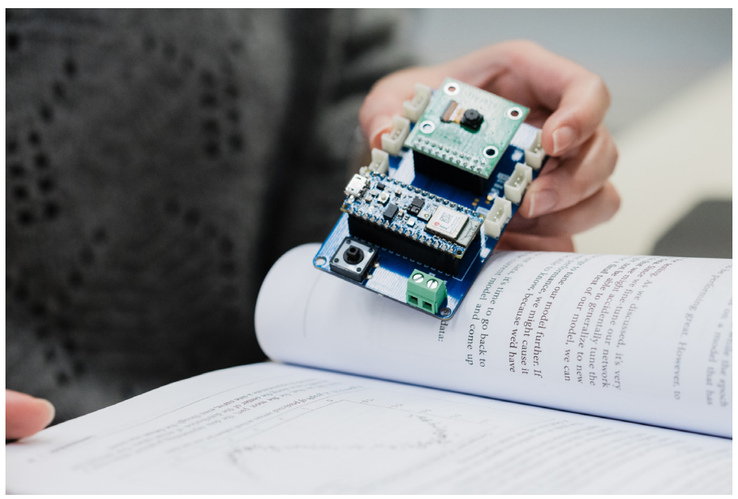
HOW WILL YOU USE THIS KNOWLEDGE GOING FORWARD?

A lot of things that are exciting in my life have stemmed from this course. We'll see by 2025 if FacePace has turned into a product in the real world. It would be very exciting if it does, but there is still a lot of progress to be made. We have had a lot of guidance from professors Makhsous and Poovendran along the way, so I'm optimistic.

I came into the TinyML course with expectations of pretty much just learning about the technology, but I got a whole lot more than that. I've gotten a team together, we've made an actual project (FacePace), and now we're taking it even further, aiming for the marketplace, which the entrepreneurship class has helped with.

Tying that into the PMP, people can really form their own journey based on their needs. Because there are no specific concentrations in the PMP, people can really pick and choose which classes they want to take. It is student created, based on your needs. Having the availability of the TinyML course and then the entrepreneurship course right after it was an amazing way to keep the momentum of our project going. So, I'm excited to see what the future holds! **w**





The TinyML device shown here is composed of three different components. The Arduino Nano 33 BLE Sense Lite (small blue board) and OV7675 Camera Module (small green board) are plugged into the larger Tiny Machine Learning Shield. This device came with the Arduino Tiny Machine Learning Kit that students used for a majority of their coursework.

Watch Professor Poovendran talk about the TinyML course in more detail in the video below:

Congrats, CLASS OF 2023!

THE UW DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING honored the graduating class of 2023 at a celebration held on Wednesday, June 7, in the Alaska Airlines Arena at Hec Edmundson Pavilion. The event was presided over by UW ECE Professor and Chair Eric Klavins. Congratulations to all!

Check out more Graduation 2023 photos below!

Class of '23

415
TOTAL GRADUATES

26
DOCTORAL DEGREES EARNED

162
MASTER'S DEGREES EARNED

227
BACHELOR'S DEGREES EARNED

2023 **GRADUATION SPEAKER**

Dr. Gabriela A. González

(BSEE '92)

UW ECE was proud to have alumna Dr. Gabriela A. González (BSEE '92) as its honored guest speaker for the Department's 2023 graduation ceremony. *Photo by Tara Brown*

> "Gaby is a truly outstanding UW ECE alum who demonstrates by example the kind of positive social impact an engineering career can have."
>
> — ERIC KLAVINS
> UW ECE PROFESSOR AND CHAIR

UW ECE alumna Dr. Gabriela A. González (BSEE '92) was the honored guest speaker for the Department's 2023 graduation ceremony. Dr. González is the founder and CEO of CihuaTEC Connect LLC and the former director of Intel Corporation's Science, Technology, Engineering and Mathematics (STEM) Education Research Office. Dr. González remains committed to improving diversity, equity, and inclusion in technology, engineering, and computing (TEC) education across the U.S. and around the world.

"We were very excited to have Gaby as our guest speaker for Graduation," Klavins said. "She is the current CEO of a new business, a former executive at Intel, a valuable member of our UW ECE Advisory Board, and her tireless work over decades expanding STEM education quality and access for those from underrepresented groups is well known. Gaby is a truly outstanding UW ECE alum who demonstrates by example the kind of positive social impact an engineering career can have."

Dr. González' distinguished career at Intel spanned over 20 years. In her former role, she directed and influenced global STEM education research, policy, governance, initiatives and thought leadership across the enterprise. Dr. González engaged and collaborated with multiple stakeholders across Intel, as well as external partners and collaborators in academia, government, industry, and non-profit agencies to drive and influence inclusive and equitable STEM education outcomes. Prior to this role, she was the deputy director and operations manager of the Intel Foundation, where she led global strategies for STEM outreach and engagement for K–12 students, with particular emphasis on women and girls in STEM.

Earlier in her career, Dr. González served as a program manager for Intel Labs, leading Intel's strategic corporate relationships and academic programs with top American, European and Latin American research universities. She held several engineering roles during her time at Intel, including the transfer of the latest microprocessor technologies from development to high-volume manufacturing and management of equipment capacity, labor, and operational productivity. Dr. González began her professional career at Xerox Corporation, where she held various manufacturing, engineering, and management leadership positions.

Dr. González is the former chair of the National Science Foundation STEM Education Advisory Panel, where she served from 2018 to 2022. In addition to the UW ECE Advisory Board, she serves on the board of directors for Project Lead the Way and the National Girls Collaborative Project. She is an active member of several professional, social, and cultural communities as a leader and role model, driving impact for underrepresented students and professionals in STEM around the globe. Besides her bachelor's degree from UW ECE, she holds a master's degree in engineering and manufacturing management from Clarkson University, and a doctoral degree in human and social dimensions of science and technology from Arizona State University. **w**

On June 1, UW ECE and the UW College of Engineering hosted its eighth annual ENGineering INnovation and Entrepreneurship (ENGINE) Showcase event at the University of Washington wəɬəbʔaltxʷ – Intellectual House. It was a delight to invite our industry and campus colleagues to join us as we featured and celebrated the hard work of our students, who soon after graduated to become the next generation of electrical and computer engineers. This year's Showcase featured 59 team projects representing 280 students and covered topics as diverse as digital health, cybersecurity, power systems, machine learning, energy, communications, quantum computing, and robotics.

The projects here arise from ENGINE — our engineering entrepreneurial capstone program. ENGINE was created to enable students to work in teams on industry-sponsored projects, and it is the culmination of a student's electrical and computer engineering education. This program, generously endowed by our alums Milton and Delia Zeutschel, is designed to develop students' skills in collaborative system engineering, innovation, entrepreneurship, project management and product development. It is also a way for our industry partners to benefit from the rich culture of innovation at UW ECE.

Congratulations to all students on the completion of your incredible final capstone projects!

Josh Smith, the Milton and Delia Zeutschel Professor in Entrepreneurial Excellence, speaking with Milton Zeutschel, a UW ECE alumnus (BSEE '60) and UW ECE and founding ENGINE program donor.

THE UW DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

THURSDAY, JUNE 1, 2023

ENGINE Showcase

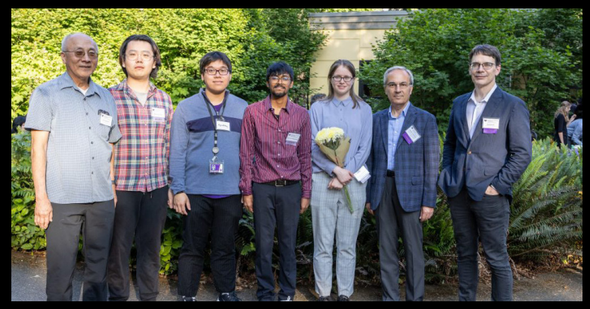
at

wəɬəbʔaltxʷ

– INTELLECTUAL HOUSE

ENGINE 2023 1st Place Teams

Teams are pictured with ENGINE donor Ray Kanemori; UW ECE Associate Professor, Associate Chair for Education, and Industry Liaison Payman Arabshahi; and UW ECE Professor and Chair Eric Klavins.



An Optoelectronic Closed-Loop Control System for RF Amplifiers

Sponsored by Access Laser

Students (listed alphabetically): Raymond Huang, Anastasiya Makarevich, Hongming Ping, John Velpugonda

Faculty Adviser: Sajjad Moazeni

Industry Advisers: Christopher Mau, Shahab Shahdoost, Iris Tsai

Digital Companion for Chronic Disease Patients

Sponsored by Novo Nordisk

Students (listed alphabetically): Sajjad Atabi, Valerie Chan, Ishan Dane, Zongjin Li, Mark Long, Evan O'Neill, Jin White

Faculty Adviser: Kim Ingraham

Industry Adviser: John Cavenari

Find out more about the ENGINE program and see additional team project photos, videos and posters:

ENGINE

59
ENGINE TEAM PROJECTS

40
INDUSTRY SPONSORS

280
ENGINE PROGRAM STUDENTS

ENGINE program industry mentor, Dave Laning (Insitu, a Boeing Company), discusses student team projects with longtime ENGINE mentor and supporter, John Reece.

Our 7TH annual UW ECE Research Showcase featured cutting-edge research projects from several of our electrical and computer engineering graduate students. Visitors had a chance to review their posters, speak with the students and their advisers and learn more about the exciting projects underway across the various labs in the Department. The Research Showcase was also a perfect opportunity for visiting prospective students to learn more about the Department's research.

Research Showcase is UW ECE's premier event for students to showcase the exciting research projects they are working on in labs and groups across all areas of ECE. This event allows our students to present top research in a variety of areas with societal impact. The topics covered include AI, medical device technologies, power and energy, transportation, the environment, wireless communications and many more.

▲ UW ECE Ph.D. student Francisco Luquin Monroy presenting his research project.

▼ UW ECE Ph.D. students Ahmed Aboulsaad (left) and Deniz Dosluoglu (right).

32
RESEARCH PROJECTS

34
PARTICIPATING STUDENTS

Research

THURSDAY, MARCH 9, 2023

Showcase

UW HUSKY UNION BUILDING

THE UW DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

Research Showcase 2023 1st Place Teams

Best Overall Research

Liban Hussein and Marziyeh Rezaei

The pair won a UW ECE Cash Prize for their research on **"Secure FMCW LiDAR Systems with Frequency Encryption — EMiT Lab."**

Faculty adviser: **Sajjad Moazeni**
Awarded by **Payman Arabshahi**

Best Applied Research

Alvin Cao and Ken Christofferson

The team won a Boeing tour for their research on **"EarSteth: Phonocardiogram Reconstruction using Earbuds."**

Faculty adviser: **Shwetak Patel**
Awarded by **Angela Li, Boeing**

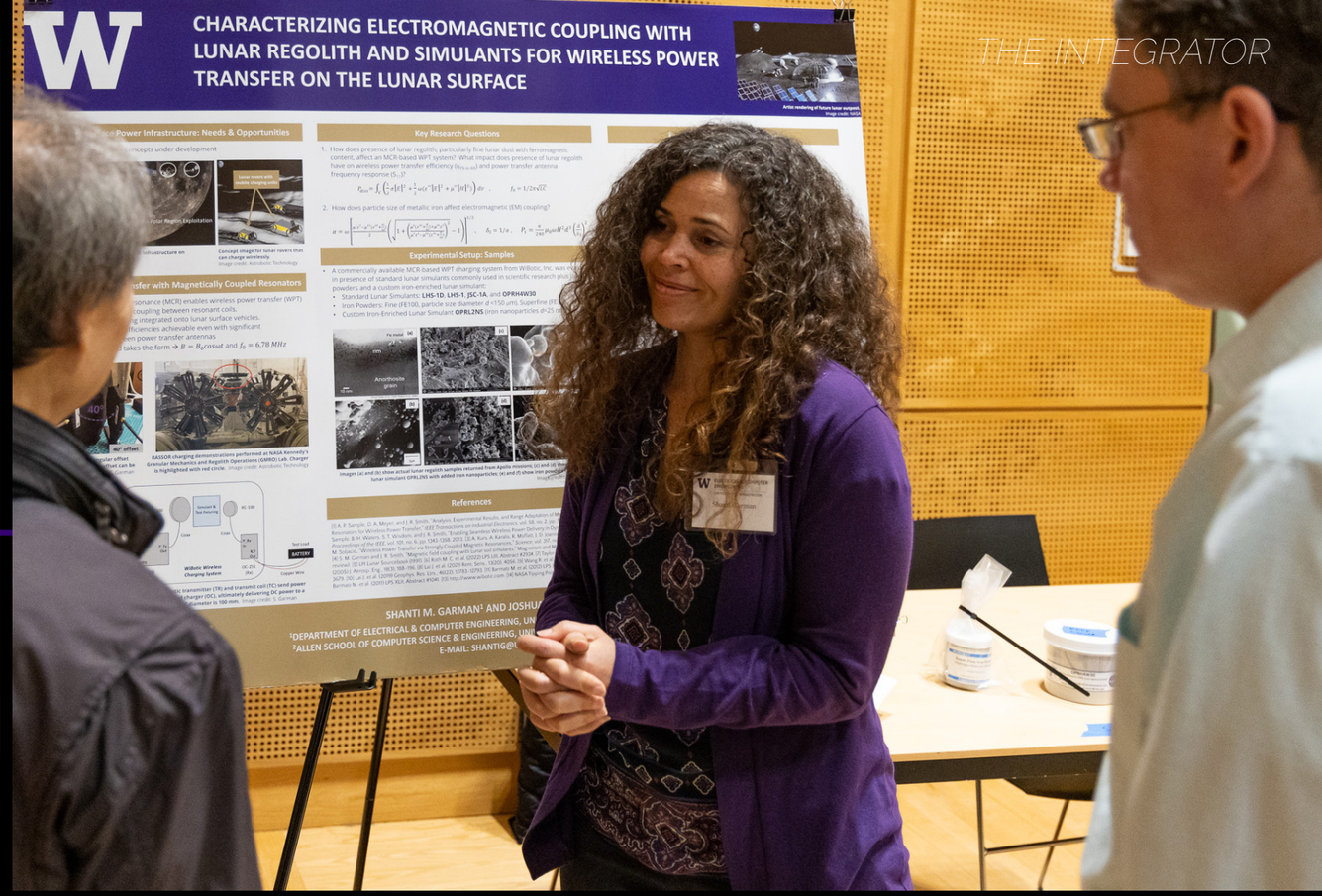
Best Foundational Research

Joaquin Santecchia, Kai Luo, Alex Sklar and Rodriguez Pham

The team won Amazon Frames for their research on **"Evaluation of Indoor Localization Methodologies: A Comparative Study of Trilateration, LSTM, and Random Forest Regression."**

Faculty adviser: **Sep Makhsous**
Awarded by **Mo Li**

PMP alumnus and winning team member Joaquin Santecchia with his LocSense prototype, a customizable sensor platform with indoor localization technology that can provide real-time information on environmental metrics.



This page, UW ECE Ph.D. students:

Joaquin Santecchia

Austin Oursland

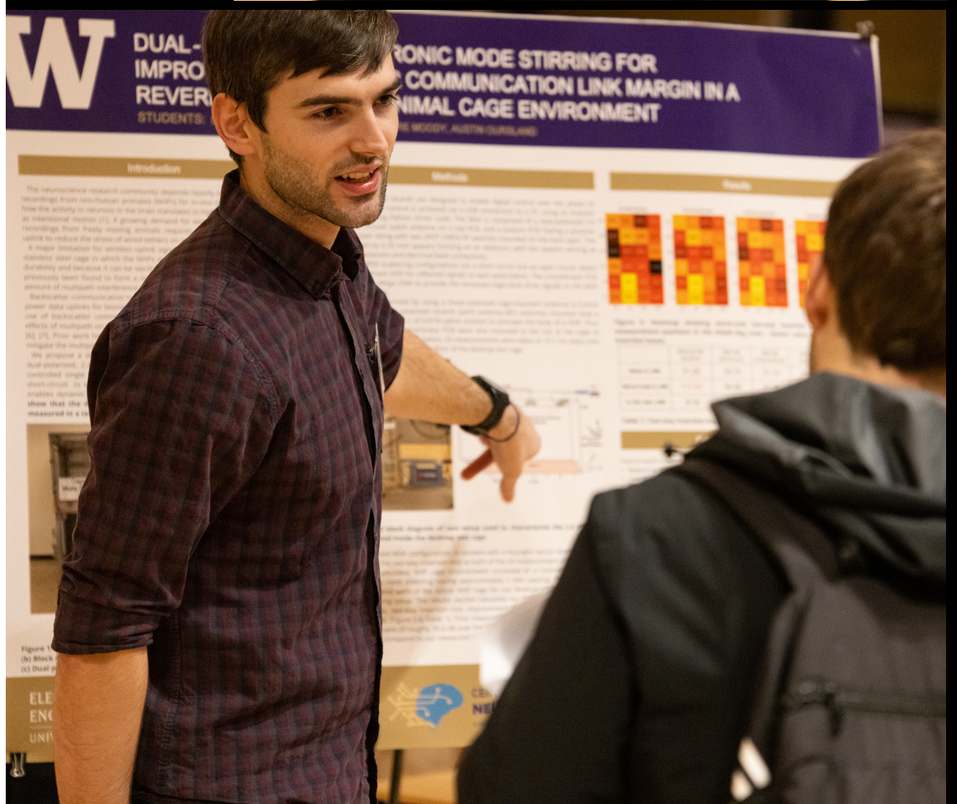
This page, UW ECE Ph.D. students:

Shanti Garman

Elpida Karapepera

I-Tung Chen

Alvin Cao



THE UW DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

FIND OUT MORE ABOUT THE RESEARCH SHOWCASE, CHECK OUT ALL OF THE PROJECT POSTERS AND SEE MORE PHOTOS!

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ENGINE PROJECT MENTORSHIP

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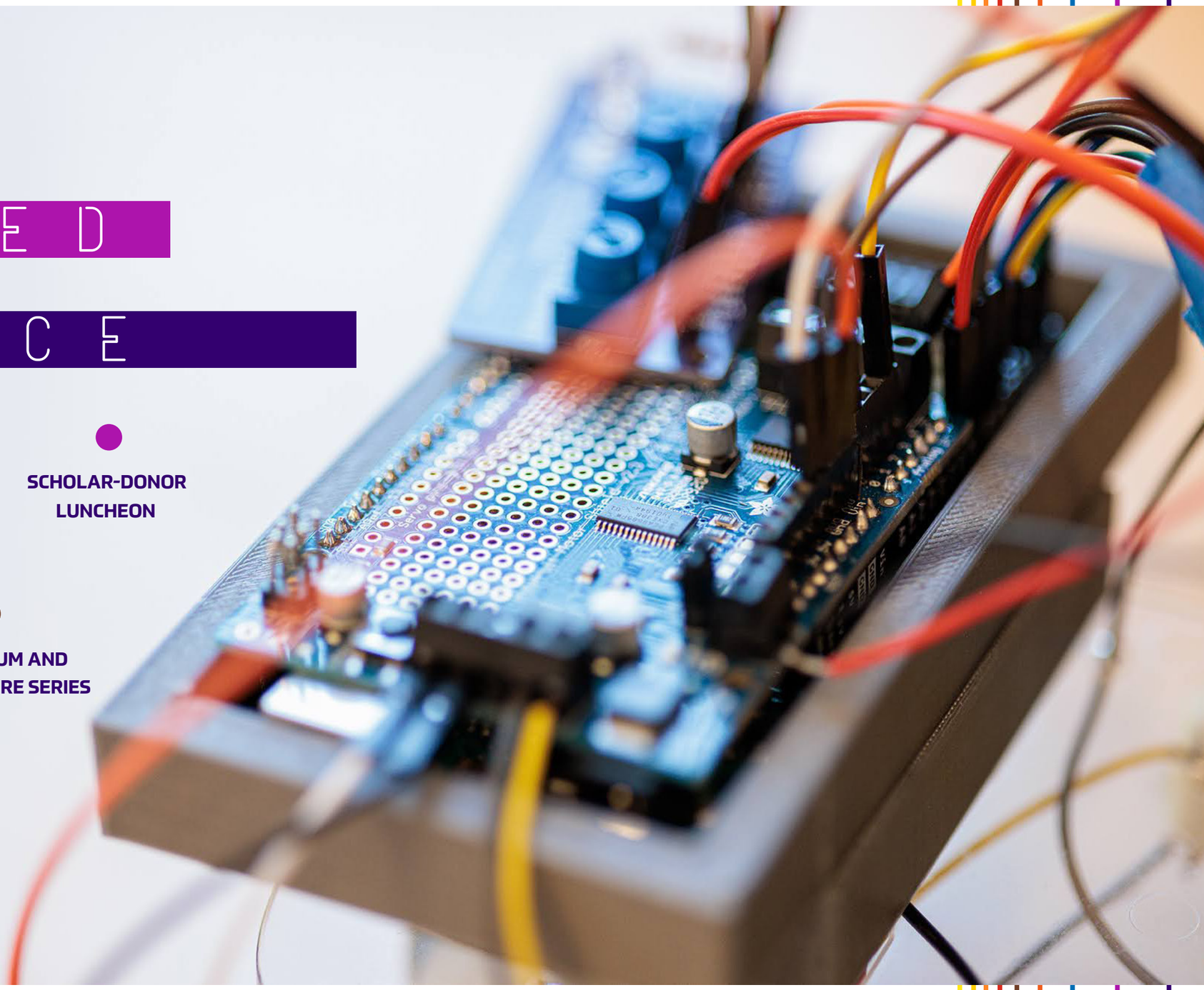

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