SPRING 2019

ENGINEERING PHYSICS

UNIVERSITY OF WISCONSIN-MADISON

PREPARING TOMORROW'S LEADERS WITH HANDS-ON LEARNING

CHAIR'S MESSAGE

Greetings!

There is much to be excited about where we have come as a department and where we are headed in 2019.

Our students continue to gain national recognition for their outstanding achievements. Undergraduate student Jake Quincey was a member of the winning design team at the 2018 Nuclear Innovation Bootcamp at the University of California, Berkeley, earning recognition for his promising concept. We encourage our students to participate in entrepreneurial activities, and it's always exciting to see the innovative projects they come up with.

Recent graduate Emily Jewell was also recognized as a rising star in aeronautics and astronautics by winning a prestigious 20 Twenties award from the American Institute of Aeronautics and Astronautics and Aviation Week Network. Emily was an exceptional student and undergraduate researcher in the department, and we're proud of her remarkable achievements.

This year also brings us the retirement of a longtime member of our faculty, Todd Allen. Over the years, Todd contributed in numerous ways to the growth of the department. His knowledge and insight will be missed, but it also provides us the opportunity to look forward with strategic additions to our faculty.

We are very excited to welcome three new faculty members this spring. Prior to joining the department, Assistant Professor Jennifer Choy worked at Draper Laboratory in Cambridge, Massachusetts, where she developed atomic and optical inertial sensors, and served as technical director on Draper's contribution to DARPA's Chip-scale Combinatorial Atomic Navigator program. Assistant Professor Benedikt Geiger came to us from the Max Planck Institute for Plasma Physics in Germany. Geiger, who conducts research on particle motion in hot fusion plasmas, will augment our leading fusion science research. Curt Allan Bronkhorst joined the department at the rank of full professor, coming from Los Alamos National Laboratory. His research interests include investigating theoretical and computational mechanics of materials. These faculty members bring new energy and expertise and will further enhance the department's standing as one of the best in the country.

As you read about our department's accomplishments in the following pages, remember that many of them would not be possible without the generosity of our amazing alumni and friends. You can give directly to the department at allwaysforward.org/giveto/ep or reach out to our development director, Valerie Chesnik, at Valerie.Chesnik@supportuw.org. She can work with you to ensure that your gift will have the greatest impact on the department.

ON, WISCONSIN!

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ACCELERATING MATERIALS DEVELOPMENT TO ADVANCE CLEAN ENERGY PRODUCTION

A group of UW-Madison researchers has received a $1.8 million grant to develop new materials for multiple uses, including the ability to withstand the corrosive environment within a molten salt nuclear reactor.

The group, led by Assistant Professor Adrien Couet, earned the three-year grant from the Advanced Research Project Agency-Energy, a U.S. Department of Energy agency created to identify and fund promising research that has the potential to disrupt or transform energy technology.

Couet says his group's objective is to develop new metal alloys for use in molten salt technology. For instance, molten salt reactors are nuclear fission reactors that use molten salt as a coolant and as a solvent for uranium fuel. Such reactors were first conceptualized in the 1950s and show promising potential safety and economic advantages over current water-cooled reactors. Still, they pose unique engineering challenges that researchers have been slow to remedy.

> **"We're trying to increase the pace of materials development for molten salt technology. The approach will be to produce, test and characterize a lot of alloys very, very quickly."**

One of those challenges is molten salt's corrosive properties, which require a whole new class of metal alloys that can withstand them. That's where the UW-Madison team enters. "Right now, the lag in alloy development is one of the reasons why molten salt technologies are not impacting the energy industry in the way they should," says Couet, who has assembled a team from across the College of Engineering campus with specialties in materials science, additive manufacturing and machine learning to work on the problem.

Their vision is to not only produce a new alloy by the end of the grant, but to also use 3D printers and machine learning to accelerate the process.

"We're trying to increase the pace of materials development for molten salt technology by two orders of magnitude compared to state-of-the-art technologies," says Couet. "The approach will be to produce, test and characterize a lot of alloys very, very quickly."

For the team's testing ground, Couet describes 3D-printed blocks that will roughly resemble Legos. Each one of the knobs on those blocks will be made from a different alloy, and the researchers will deposit small molten salt droplets on their surface and monitor the alloy performance. Testing how those many alloys stand up to the molten salt will produce huge amounts of data, which is where the analytical muscle of machine learning will step in. In fact, the team aims to produce two innovations: new alloys fit for molten salt applications and a novel method for high-throughput research.

"It's super-exciting," Couet says, about landing the grant and the prospective research. "It's a very high-risk, high-reward type of research. There is a potential to bring a real benefit to industry."

The ultimate goal, he adds, is to develop energy solutions that can help mitigate greenhouse gas emissions that contribute to global climate change. The college is providing a 10-percent cost-share for the research.

Other College of Engineering faculty involved in the research grant include Dan Thoma, a professor of materials science and engineering and director of the college's Grainger Institute for Engineering; Kumar Sridharan, distinguished research professor in engineering physics; and Dimitris Papailiopoulos, an assistant professor of electrical and computer engineering. The team is partnering with researchers at the Argonne National Laboratory, the National Institute of Standards and Technology, and Ametek.

FOCUS ON NEW FACULTY: JENNIFER CHOY

Taking precision to new levels with quantum systems

Extremely precise quantum sensors promise to be a transformative technology with a variety of potential applications. For example, quantum sensors could advance neuroimaging by allowing researchers to detect nanoscale changes in electromagnetic fields in the brain with incredible precision.

This technology harnesses unique attributes of quantum mechanics, which describes the behavior of atoms and subatomic particles.

"At the heart of how these quantum sensors work is the interaction between discrete electronic energy levels of quantum systems and their environment," says Jennifer Choy, who joined the department as an assistant professor in January 2019. "We're essentially using these interactions to precisely and sensitively measure physical quantities such as electric and magnetic fields, and inertial motion."

Photons play a crucial role in characterizing and manipulating quantum systems, and that is why Choy's research focuses on engineering interactions between light and matter in atoms and atom-like systems.

Choy says developing methods to control photons and their interactions with these atomic systems will enable better understanding and control of quantum properties, and improve the performance and utility of quantum sensors.

"I'm interested in drawing on the wealth of research already happening in nanoscale optics and photonic engineering to enable more efficient measurement and control of quantum systems, and develop more compact and robust atom-based instruments," Choy says.

One type of quantum system Choy studies involves single atomic-scale defects trapped inside of diamonds. "These defects can behave like atoms in the sense that they have isolated electronic energy states that you can probe with spectroscopy," says Choy. "These systems are promising for sensing applications because you can engineer the environment around the defect and use it as a nanoscale probe that can be placed very close to the object that you want to sense, such as a neuron."

Choy earned her PhD in applied physics from Harvard University. Prior to joining UW-Madison, she was a principal member of technical staff at Draper Laboratory, a nonprofit research and development organization in Cambridge, Massachusetts, where she developed atomic and optical inertial sensors for precision navigation, which could be useful for defense applications.

> **"I think there are a lot of quantum technologies that can bear fruit in the near term and can really benefit from an engineering approach."**

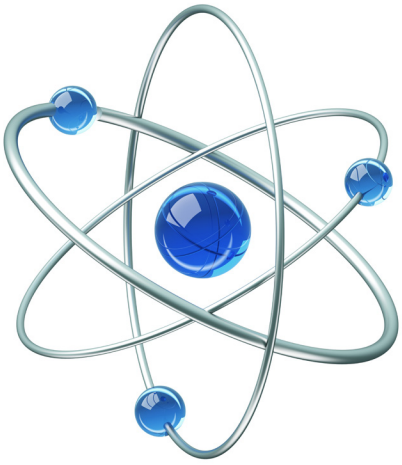
"Working at Draper was a really valuable learning experience for me, but ultimately I'm excited to work with students both in the context of research advising as well as classroom instruction," she says.

While quantum research as a discipline is often based in physics departments, Choy believes the EP department will be a great home for her research.

"I think there are a lot of quantum technologies that can bear fruit in the near term and can really benefit from an engineering approach, and in particular a pan-disciplinary program such as engineering physics at UW-Madison, which has a history through the nuclear engineering track of combining very fundamental research with challenging engineering to assemble fully functional systems," she says.

Choy is excited to collaborate with faculty not only in the College of Engineering but across the university. Opportunities for collaboration are growing as UW-Madison has been making significant investments in quantum science and technology—including joining the Chicago Quantum Exchange in February 2019. The CQE—a partnership anchored at the University of Chicago and which includes the University of Illinois at Urbana-Champaign, the U.S. Department of Energy's Argonne National Laboratory and the Fermi National Accelerator Laboratory—is a hub for the research and development of quantum technology. Choy is among the UW-Madison faculty who will be contributing expertise and collaborating within the CQE.

In spring 2019, Choy is teaching a lab course on nuclear instrumentation (NE 427). "It's exciting because I think lab experience is very critical to any training in science and engineering," she says. "I think lab courses are important because they encourage students to take an active role in learning through hands-on experiences."



NAVY VETERAN BOOSTS CAREER IN NUCLEAR ENERGY WITH 'ENGINEER'S MBA'

After more than 20 years in engineering, Dave Pearson started feeling stagnant in his career. He wanted to advance his education while maintaining work/family balance. Pearson decided to pursue a master of engineering: engineering management (MEM) degree from UW-Madison, and he's glad that he did.

"This online program is geared for the real-world engineer with a relatively busy life," says Pearson, a veteran who served as a nuclear reactor operator and electronics technician for six years with the U.S. Navy. "My career path has changed significantly as a direct result of this program."

Shortly after completing MEM in 2014, Pearson accepted a new position in Dominion Energy's corporate office. He's the course designer, instructor, technologist and administrator for their nuclear training department, responsible for meeting the training needs of 150 engineers.

The MEM program provides an MBA-style education in the business of engineering. It's geared toward engineers ready for leadership positions or leaders looking to strengthen their effectiveness. Working professionals can stay in their jobs while earning the degree online, along with optional, brief residencies on the UW-Madison campus over two summers.

The program offers engaging and applications-focused learning from senior faculty who have broad industry experience and strong academic credentials. Students learn to analyze corporate financial data, build leadership and communications skills, and synthesize information to make sound engineering and business decisions.

Prestigious, practical program

Pearson was already a Badger. He graduated from UW-Madison in 1997 with a degree in nuclear engineering and engineering physics.

"I wanted an excuse to come back to Madison, and more importantly, the UW-Madison online engineering graduate programs were rated very highly," he says. "I was confident they would do it right."

Pearson was impressed with the quality of the program, the faculty, and his fellow students.

"The instructors were second to none. They took time to know the students," Pearson says. "They promoted learning from each other while providing the facilitation required to ensure we did not veer off track."

Pearson says his MEM experience allowed him to keep his job, continue to be engaged with his family, and apply new knowledge to better his career at Dominion Energy. Headquartered in Richmond, Virginia, Dominion is one of the nation's largest producers and transporters of energy. Pearson has been using the tools from MEM to make positive changes to the Dominion training program, to develop a better working relationship with engineering leaders, and to manage various projects across its nuclear fleet.

He has recommended the program to people because of the focus on application of knowledge and the flexibility.

"Because the program tries to make the education part of one's career, it is very possible for work and school to take place at the same time," he says.

Learn more about the master of engineering: engineering management program:
advanceyourcareer.wisc.edu/degrees/engineering-management/

Crone elected president of the Society for Experimental Mechanics

Karen Thompson Medhi Professor Wendy Crone was elected president of the Society for Experimental Mechanics (SEM) for the 2018-2019 term.

Her research is in the area of solid mechanics, and many of the topics she has investigated are connected with nanotechnology and biotechnology. She has applied her technical expertise to improving fundamental understanding of mechanical response of materials, enhancing material behavior through surface modification and nanostructuring, exploring the interplay between cells and the mechanics of their surroundings, and developing new material applications and medical devices.

In addition to more than 60 peer-reviewed journal publications, dozens of explanatory education products, and four patents, she is the author of the book *Survive and Thrive: A Guide for Untenured Faculty*. Her research has been funded by the National Institutes of Health, National Science Foundation, U.S. Department of Energy, U.S. Air Force Office of Scientific Research, and the Whitaker Foundation.

Crone has garnered awards for research, teaching and mentoring, including WEPAN Educator Award and the Doris Slesinger Award for Excellence in Mentoring (2011); WEPAN Educator Award from the Women in Engineering Programs and Advocates Network (2011); as well as fellow (2015) and M.M. Frocht Award (2013) from SEM. She has also served in several leadership roles at UW-Madison, including interim dean and associate dean of the Graduate School (2011-2015).

INTERNATIONAL PLASMA MEETING SPARKS CREATIVE APPROACHES TO FUSION CHALLENGES

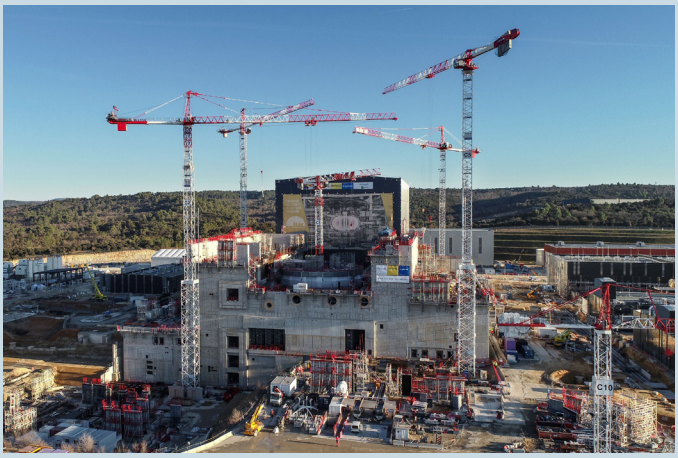
World experts in high-temperature plasma edge physics and plasma-material interaction for fusion energy science gathered at the University of Wisconsin-Madison in December 2018 for the meeting of the International Tokamak Physics Activity Divertor and Plasma Edge section.

Professor Oliver Schmitz organized the meeting of the group, which operates under ITER, the international thermonuclear experimental reactor under construction in southern France. The four-day meeting, which focused on plasma-material interaction, divertor and scrape-off layer physics, drew 79 renowned researchers from 11 countries. The researchers discussed the challenge of integrating high-temperature burning plasmas for fusion energy production with a technically and economically viable material choice for a future reactor.

Schmitz says this highly complex challenge requires expertise from the fields of plasma physics, material science, mechanical and nuclear engineering.

As the largest fusion experiment ever built, the ITER reactor aims to demonstrate a fusion energy output that is 10 times as large as the energy required to heat its plasma. This is an unprecedented challenge, and the heat and particle loads on plasma-facing reactor components require specific attention, says Schmitz.

At the meeting, participants discussed new approaches to solving this challenge. Schmitz's research group works collaboratively with scientists from across the world to study how applying 3D magnetic control fields to the donut-shaped plasma in ITER might tame plasma edge instabilities and reduce material erosion and particle deposition in the device. This topic was a specific focus on the meeting, and participants recognized it as one of the most pressing research challenges in fusion energy science today.



The ITER tokamak building under construction in southern France. *Photo: ITER organization.*

Support from the UW-Madison Office of the Vice Chancellor for Research and Graduate Education also allowed 20 graduate students to participate in the meeting, exposing them to exciting research results and discussions at the forefront of plasma edge and materials research in fusion science.

Scientist honored for innovative fusion research

In February 2019, Dean Ian Robertson honored the contributions of eight outstanding faculty and staff members in the college. Associate Scientist Heinke Frerichs was among those individuals. He received the college's Bollinger Academic Staff Distinguished Achievement Award for Research Excellence.

The EMC3 EIRENE model provides fusion researchers the unique capability to numerically study plasma behavior in multiple dimensions, at the very large scale of a fusion-energy device.

Two researchers in Germany developed this code. However, in Frerichs, the department has an international expert with this model right on the engineering campus.

Over the course of his career, Heinke has not only become an expert at applying the code, but he also has become one of its lead developers. His adaptations and improvements have expanded its capabilities and applications—so much, in fact, that one of the code's original authors has said, "Heinke's innovation capacity with the model and its numerical implementation have grown the capability of the code so substantially that the most pressing challenges in our field can now be addressed."

One of those adaptations allows researchers to apply the code to both of the leading concepts in magnetic-confinement fusion research. Another enables it to be useful in future development of ITER, an international fusion experiment involving countries that represent almost half the earth's population.

Through his work, Heinke has enriched the scientific community, enhanced the visibility of the college on an international level, and greatly enhanced the training opportunities the college is able to provide its students.

Alumna recognized as aerospace rising star with 20 Twenties award

Emily Jewell has received a prestigious 2019 20 Twenties award from the American Institute of Aeronautics and Astronautics (AIAA) and Aviation Week Network.

The awards program, "Tomorrow's Technology Leaders: The 20 Twenties," recognizes students earning STEM degrees who are nominated by their universities on the basis of their academic performance, civic contribution and research or design project. It was established in 2013 to recognize and cultivate the next generation of aerospace and defense leaders.

The 20 award recipients selected in 2019 were chosen from a group of qualified nominees from 42 different universities representing nine countries.

Jewell graduated from UW-Madison in May 2018 with bachelor's degrees in engineering mechanics and mathematics.

"I feel extremely humbled and grateful to win this award," she says. "I knew I would be up against some stiff international competition, and my receipt of this award is not without much support and guidance from various professors and engineers in my life, especially those in the engineering physics department at UW-Madison."

She is currently a graduate student in aeronautics and astronautics at Stanford University.

"Being named one of AIAA's 20 Twenties affords me an amazing launching pad for my dreams, namely to continue pioneering research in computational aerosciences and to lead in the commercial space industry," she says.

At UW-Madison, Jewell was heavily involved with research in Associate Professor Matt Allen's structural dynamics research group. In addition, she was an officer for Tau Beta Pi Engineering Honor Society, a STEM outreach volunteer, and a member of the nationally competitive UW women's club ultimate frisbee team. During her time at UW-Madison, Jewell garnered a number of academic awards, including the esteemed Barry Goldwater Scholarship in 2017 for undergraduate excellence in the sciences.

BAKER, MCCARTHY ELECTED TO NATIONAL ACADEMY OF ENGINEERING

Mary Baker

Kathryn McCarthy

In February 2019, Mary Baker (BSEMA '66) and Kathryn A. McCarthy, both members of the UW-Madison EP department advisory board, were among the 86 new members and 18 foreign members elected to the National Academy of Engineering.

The designation is among the highest professional distinctions accorded to an engineer, and membership honors those who have made outstanding contributions to engineering research, practice or education.

The NAE recognized Baker for computer simulation methods for structural mechanics problems and engineering leadership.

Baker is president, chair and one of the founders of San Diego-based ATA Engineering Inc., the leading independent company in modal and dynamic testing of aerospace structures in the United States. She is an expert in the application of computer methods to structural dynamics and continuum mechanics with particular experience in liquid rocket development, satellite system engineering, launch vehicle and road vehicle dynamics, and simulation and testing of electronic equipment and consumer products for shock and vibration environments.

Prior to founding ATA, Baker served as vice president and general manager of SDRC's advanced test and analysis division and guided this group for most of its 24-year history. She earned her master's degree and PhD in applied mechanics from the California Institute of Technology.

The NAE recognized McCarthy, vice president of research and development at Canadian Nuclear Laboratories (CNL), Chalk River, Ontario, Canada, for leadership in research and data analysis in support of licensing extensions for light water nuclear reactors. McCarthy is leading the effort to develop a nuclear reactor park at CNL for siting and demonstrating advanced reactor technology.

Prior to joining CNL, McCarthy worked at the Idaho National Laboratory (INL) for 25 years. From 2012 to 2017, she served as the director of nuclear science and technology and was responsible for oversight and coordination of the major domestic programs at the INL. She directed advanced reactors and advanced fuel research, as well as the delivery of lab-directed research programming, commercial projects and international collaborations. In that time, McCarthy was also the director and technical integrator of the U.S. Department of Energy Light Water Reactor Sustainability Program. Her team, made up of more than three dozen scientists and engineers from across the United States, conducted research on key issues that enabled nuclear power plant owner-operators to make informed decisions on long-term power plant operation and move forward with subsequent license renewal for their operating nuclear power plants. She received her bachelor's degree in nuclear engineering at the University of Arizona, and her master's degree and PhD in nuclear engineering at UCLA.

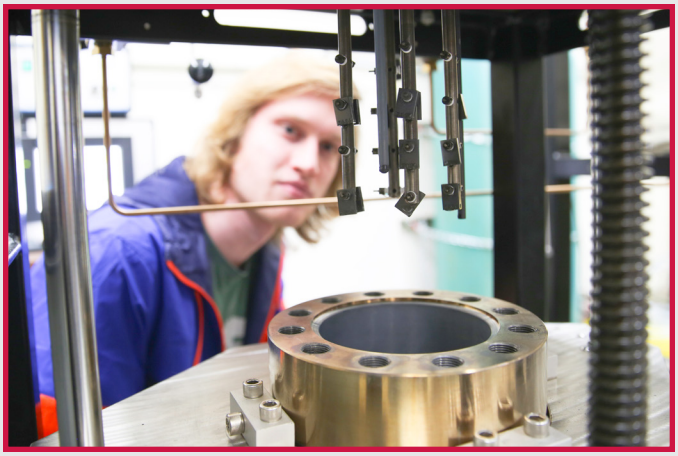
LEARNING BY DOING

Undergrad embraces entrepreneurial approach

Fast-moving startups are shaking up the nuclear industry with new energy and ideas, and their innovations are inspiring the next generation of nuclear leaders to embrace an entrepreneurial mindset.

"Startups are a very new development in the nuclear industry," says senior Jake Quincey. "It's only within the past decade that these startups have really popped up, and some are now getting to the point where they're actually implementing their technology."

Excited by the bold ideas these startups are developing, Quincey was motivated to gain entrepreneurial and business skills that will give him an edge in the evolving nuclear industry. That led him to participate in the Nuclear Innovation Bootcamp at the University of California, Berkeley, in summer 2018. The two-week event, which was co-organized by Assistant Professor Adrien Couet, trained students and professionals in skills essential to innovation in nuclear energy.



During the bootcamp, experts led sessions covering many aspects of entrepreneurship and the nuclear industry. The participants, which included undergraduates, graduate students and early-career professionals from around the world, also spent a significant amount of time working in small teams to execute design projects.

At the end of the two weeks, the teams pitched their design projects to a panel of judges and an audience of company representatives, potential private investors, technical experts, relevant non-governmental organizations, and U.S. Department of Energy program managers.

Quincey's team impressed the judges, who selected the team's project as most likely to succeed. Quincey came up with the team's winning idea—a device that would enable faster and less costly testing and licensing of new materials for nuclear reactors.

The device, a sub-critical irradiator, would allow companies to test their materials and get some initial data to prove their design before taking the next step in the licensing process. To get government approval, companies need to test their materials at a test reactor—an expensive and time-consuming endeavor.

"By the time a startup company is conducting experiments in a test reactor, it has already invested millions of dollars into its design, so it's not ideal to wait until that point to learn if it will work," Quincey says. "We wanted to help startups in that intermediate step, and we saw there wasn't currently a solution for addressing this need."

Quincey says the bootcamp provided a highly valuable experience, and he's interested in continuing to develop the idea. He has committed to a graduate program in nuclear engineering at Oregon State and wants to pursue a career in research and development for nuclear technology.

The bootcamp was just the latest opportunity Quincey has sought to enhance his education. He has worked as a reactor operator at the UW-Madison nuclear reactor and, since the beginning of his sophomore year, he has also been a researcher in Couet's lab, where he studies materials that could better withstand corrosion in advanced reactors.

"Doing research in Professor Couet's lab has given me experiences that go beyond what I can get in classes, and I've gained a deeper knowledge of nuclear materials," Quincey says. "I get to work with cool instruments like electron microscopes, and I enjoy all the hands-on opportunities. It's been a really valuable experience."

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