SUMMER 2018

ENGINEERING PHYSICS

UNIVERSITY OF WISCONSIN-MADISON

STUDENT STARS: BRINGING CLEAN, SUSTAINABLE ELECTRICITY TO RURAL AFRICA

CHAIR'S MESSAGE

Douglass Henderson

Greetings!

As we finish another successful academic year, there are many stories to share of our department's accomplishments and the impact our faculty, students and alumni are making around the world.

In May, we celebrated our 2018 graduates with a reception at Union South between the UW-Madison commencement at Camp Randall Stadium and the college's graduate recognition event at the Kohl Center. It was great to have time to share in the excitement with many of our graduates and their families, as well as hear stories of where they'll be heading next on their journeys.

Aaron Olson, who will be graduating this summer with a PhD in engineering mechanics, is featured in this newsletter (pg. 6-7) for the incredible work his company NovoMoto is doing to provide solar lighting systems to off-grid rural communities in sub-Saharan Africa. Olson co-founded NovoMoto with fellow graduate student Mehrdad Arjmand, who recently earned his PhD in engineering mechanics. Their startup has won many awards over the past few years, and NovoMoto most recently received the grand prize in the 15th annual Governor's Business Plan Contest in June 2018 out of 12 finalists. It has been great to see Aaron and Mehrdad build their company while also pursuing their graduate studies, and we're proud of their success and the positive impact their work is having on people's lives.

National organizations have recently honored our faculty for their outstanding work. Assistant Professor Jacob Notbohm received a prestigious NSF CAREER award that he will use to focus more on his research on the mechanics of fibrous materials such as human tissue (see article on back cover). Duane H. and Dorothy M. Bluemke Professor James Blanchard and Grainger Professor of Nuclear Engineering Paul Wilson both received recognition from the American Nuclear Society (ANS) for their contributions to nuclear science and technology. Blanchard was elected a fellow of ANS, the highest member status presented by the society, for the outstanding work he has done advance fusion power through innovative and creative designs of the first wall, blanket and divertor systems in extreme operating heat flux and neutron irradiation conditions. Wilson was elected to the ANS board of directors for 2018-2021, as well as vice chair/chair-elect of the ANS Fusion Energy Division. He also received the 2018 Arthur Holly Compton Award in Education from ANS. The award recognizes his unparalleled contributions to nuclear engineering computing education through innovating locally, volunteering nationally, and advising the next generation of computational nuclear engineering educators.

Our faculty were also recognized within the UW-Madison community for their outstanding research and teaching. This spring, Assistant Professor Raluca Scarlat received a Vilas Faculty Early Career Investigator Award and Professor Oliver Schmitz received a Vilas Faculty Mid-Career Investigator Award. In addition to this recognition, Schmitz was recently promoted to full professor.

I want to thank you for your continued involvement in and support of our department. Through your gifts, you are instrumental in helping enhance our students' educational experience and our department's excellence. You can make a gift online at **allwaysforward.org/giveto/ep** or reach out to our development director, Valerie Chesnik, at Valerie.Chesnik@supportuw.org. She can talk with you about your goals and share examples of the many ways in which your donation can, and does, make a difference.

ON, WISCONSIN!

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UW-MADISON RESEARCH CENTRAL TO NEXT-GEN NUCLEAR INNOVATION

Photo: Renee Meiller

PhD student Francesco Carotti and graduate student Alexandra Delmore shared research from Raluca Scarlat's lab with visiting NuSTEM collaborators.

Raluca Scarlat

Adrien Couet

Kumar Sridharan

NuSTEM is an excellent platform for UW-Madison to continue to exercise and advance its leadership in the area of molten salts

Researchers in the engineering physics department are at the forefront of a nationwide push toward next-generation nuclear power reactors.

Molten salt nuclear reactors are under development by startup companies across the world as a promising next-generation technology. Researchers at UW-Madison support this development by advancing molten salt science and technology.

"Courses and research opportunities on our campus train students in the necessary skills to enter a future workforce for the emerging molten salt reactor (MSRs) industry," says Assistant Professor Raluca Scarlat.

To be viable, these future reactors must be more economical and potentially more efficient than current nuclear power technologies that have changed little in decades, while fulfilling the safety requirements of the U.S. Nuclear Regulatory Commission.

"There needs to be innovation," says Assistant Professor Adrien Couet, who researches environmental degradation of nuclear materials. "We need to change how we build nuclear power plants and we need better technologies to compete with other power sources."

To that end, in April 2018, Scarlat, Couet, and Distinguished Research Professor Kumar Sridharan hosted a team of collaborating researchers from the University of Texas A&M, University of California Berkeley and U.S. Department of Energy laboratories across the nation. The event served as a multi-institution team meeting six months into a $3 million, three-year DOE-funded research project called Nuclear Science Technology and Education for Molten Salt Reactors, or NuSTEM. It was also an opportunity for Wisconsin researchers to exhibit their highly ranked nuclear engineering research program to visiting colleagues.

NuSTEM comes at a time when renewed interest in nuclear energy is spurring federal investment in basic research to fast-track promising new technologies, MSRs being among them. Researchers are enthusiastic about MSRs because they could provide a more economically competitive way to produce electricity.

Molten salt has been a material of interest for nuclear engineers since the 1950s, though active research on MSRs has been stagnant for decades. But the NuSTEM collaboration is reinvigorating that research.

"This is really exciting for UW-Madison because we have a long history of working in molten salt," says Scarlat. "And I think it's also exciting for the molten salt community to have an integrated research project funded by DOE because it is recognition that MSR technology has evolved and there is a case to be made for MSRs."

NuSTEM is an excellent platform for UW-Madison to continue to exercise and advance its leadership in the area of molten salts, says Sridharan, who was principal investigator for the first molten salt research program at UW-Madison in 2005, and has directed many programs in this area since then.

Together with colleagues at Texas A&M and UC-Berkeley, faculty and graduate students in Madison are already making progress in their research of next-generation nuclear technologies. Couet, Sridharan and Scarlat are investigating how structural materials corrode in nuclear reactors, and Scarlat is developing sensors and probes for measuring the chemical composition of molten salts. The NuSTEM project is also striving to establish active educational collaborations with SAMOFAR, a consortium of molten salt educational and research institutions in Europe, to provide a platform for exchange of young students and scientists.

Read more: www.engr.wisc.edu/uw-madison-research-central-next-gen-nuclear-innovation/

ALUMNUS OPENS DOORS FOR STUDENTS THROUGH INTERNATIONAL INTERNSHIP

Sometimes the gains from a degree go beyond what is learned in the classroom.

That was the case for Tatsuro Kozaki, who enrolled in UW-Madison's master's program in nuclear engineering and engineering physics (NEEP) in 1994. When Kozaki arrived on campus, he was already an established professional. However, even with more than 13 years of experience at Hitachi, Ltd., a Japanese multinational conglomerate company founded in 1910, Kozaki still saw opportunity for growth.

Prior to attending UW-Madison, Kozaki had already built a strong academic background from Tokai University, where he majored in physics, focusing on nuclear fusion and plasma physics. The NEEP program at UW-Madison was not only a way for Kozaki to enhance his professional knowledge, but also to internationalize his experience and give him key insights into how Hitachi could better engage global markets.

"Hitachi is a global company," Kozaki says. "There is a lot to learn about foreign affairs, so it is advantageous for the company to have employees learn abroad."

After receiving his master's degree in 1995, Kozaki returned to Japan and Hitachi, where he eventually became involved in efforts to bring students to Japan to help internationalize the company. As a result, Kozaki has also been instrumental in creating a pipeline for UW-Madison students to gain professional experience at Hitachi and their own global perspective.

Six students from UW-Madison have participated in the internship with Hitachi since it began in 2014. The first two students, both from NEEP, completed the internship at Hitachi-GE Nuclear Energy (HGNE), Ltd. NEEP students took part in the program again in 2016. Students from UW-Madison's mechanical engineering program took part in the program at the Power Business Unit of Hitachi, Ltd. in 2017.

Tatsuro Kozaki continues to be an active member of the Tokyo Chapter of the Wisconsin Alumni Association. *Submitted photo.*

Hitachi's involvement in a wide variety of sectors has given UW-Madison students the opportunity to take part in unique internships aligned closely with their academic and professional interests.

Hitachi's involvement in a wide variety of sectors has given UW-Madison students the opportunity to take part in unique internships aligned closely with their academic and professional interests. Students interning for HGNE focused on equipment design and power plant design. Students interning for the Power Business Unit of Hitachi were involved in wind power projects. Both sites offered opportunities for students to gain practical training, become familiar with Hitachi facilities, tour Japan, and build relationships with Japanese colleagues.

"The Hitachi-GE Nuclear Energy internship was a great way to offer nuclear engineering students a cross-cultural experience relevant to their studies," says Michelle Kern Hall, interim director of UW-Madison's International Internship Program, who worked with Kozaki to make the program available to UW-Madison students. "A passionate alumnus like Tatsuro Kozaki can help open doors to companies and opportunities abroad that would not otherwise be readily available to Badgers. His commitment to engaging with UW-Madison students during their time at Hitachi has been invaluable."

Though Kozaki transitioned into a role as an engineering manager at Mitsubishi Hitachi Power Systems, Ltd. in 2014, he remains a strong advocate of the program and a resource for UW-Madison students during their time in Japan. He has been a key asset for students who can rely on his local and professional knowledge to succeed in the program.

"When I was staying in Madison, I was supported by the local community," Kozaki says. "Offering this opportunity and assisting students is a way to return this support."

UNIQUE FELLOWSHIP HONORS UNDERGRAD WHO AIMS BEYOND THE SKY

Photo: Renee Meiller

When she first arrived at UW-Madison five years ago, Madeline Kothe had never considered pursuing engineering mechanics and astronautics. In fact, she only started to consider the major at the recommendation of a roommate. But now her passion for space is unquestionable.

"Something people don't always realize about aerospace is how much it affects everyday life," she says. "It's not just something futuristic and out there; it's changing how we live every day."

In 2018, Kothe received the Brooke Owens Fellowship, an opportunity that encourages women pursuing careers in aerospace by matching them with internships and mentorships. Kothe was placed with the space manufacturing company Made in Space, a California-based company that designs and manufactures 3D printers for use in space. Kothe is working at the Made in Space Jacksonville, Florida, location and is excited by the opportunity to observe and learn from the company's many research and development projects. Through the program, she was also connected with a mentor—Pam Melroy, a former NASA astronaut and U.S. Air Force officer.

Kothe is one of the 41 women who were chosen for the fellowship, which is now in its second year. She was drawn to the program in part because of its interesting, thought-provoking application process. For one part of the application, Kothe displayed her entrepreneurial, creative spirit by including a sample of bracelets she designs and creates. They're thin bands with beads, each adorned with a morse code symbol, creating a meaningful message. The take-away from this particular bracelet? "The sky is not the limit."

This space-savvy metaphor seems to perfectly illustrate Kothe's endless pursuits—both within and outside of the field of engineering. She has worked in both co-op and part-time roles at the Sierra Nevada Corporation, an engineering firm that focuses on innovation in aerospace and defense technology. During her time there, she was able to work on flight hardware that traveled to the International Space Station. Here on earth, she has been a member of the UW-Madison Waterski Team and led the Mad-City Waterski Team's ballet line.

Kothe is also working on earning her pilot's license, a pursuit borne mostly out of a desire to push herself intellectually and to apply the technical knowledge of coursework to an immediate, high-pressure experience. "When I go to pre-flight on the plane, I get to see the actual shapes of the airfoils we learned about in aerodynamics, and know how the plane flies with pressure differences," Kothe says. "So it's connecting it to my schoolwork, but also having it be a personal challenge and goal for myself."

For her senior design project, the 23-year-old worked on an electric plane that will help researchers survey wildlife in national parks without noisily disrupting the ecosystem. Kothe and her group drafted a computerized design of a quieter, lighter plane made of composite materials. After graduating in May 2018, she is living in Florida for the summer, after which she'll move cross-country to California where, in fall 2018, she'll begin graduate studies in aerospace engineering at Stanford University.

"It's exciting, but definitely scary; it's the next step and there are so many changes," she says. "I'm grateful to have been given so many amazing opportunities at UW-Madison. I've been given the kick-start to an exciting career path where the sky is no longer the limit."

STARTUP COMPLETING 100 SOLAR SETUPS IN RURAL AFRICA

Aaron Olson

Mehrdad Arjmand

NovoMoto, a spinoff from UW–Madison, is finishing its first 100 solar lighting installations in the Democratic Republic of Congo.

The company distributes the systems on a rent-to-own basis on a plateau about 80 kilometers from the capital, Kinshasa. After a $10 down payment and three years of paying $2.15 a week, the customer owns the system.

If you take electric lighting for granted, you have not lived in the Democratic Republic of Congo, says company co-founder Aaron Olson. In rural villages, he says, lighting options come down to kerosene (dim and dangerous), candles (dim and short-lived) or flashlights with single-use batteries (dim, short-lived and expensive).

None of these sources are adequate, he says, yet they cost about one-third of the average family's income.

Olson and his fellow co-founder, Mehrdad Arjmand, have a better idea: small electric systems equipped with a solar panel, battery and controller.

The company's secret sauce is a digital code that unlocks the system, sent via text message after it receives each weekly payment. After the last payment, the final code unlocks it permanently.

Another 100 NovoMoto systems recently reached the capital. NovoMoto has obtained financing for another 450 systems to be assembled and shipped later this year.

NovoMoto would not exist without UW-Madison, says Olson, who completed a PhD in engineering mechanics. Arjmand also recently earned a PhD in engineering mechanics.

The germ of the idea arose in 2015 as Olson and Arjmand prepared for the Weinert Applied Venture in Entrepreneurship class in the school of business. Talking with Selam Zewdie, a native of Ethiopia, they narrowed their focus to a business involving solar electricity for underserved third world locations.

"As we started the class, we were thinking about Sub-Saharan Africa and India, where people were starting to sell pay-as-you-go solar electricity kits," Olson says.

Congo was a natural focus, he adds, since he was born there and a cousin of his was trained in solar installation in Kinshasa. Rural parts of the nation of about 80 million were also severely underserved with electricity.

Olson left Congo with his parents shortly after his second birthday and returned to his father's native Wisconsin. In January 2015, Olson made his first visit as an adult. His father, a UW-Madison alum who had been in Congo in the Peace Corps and then worked in international agriculture, had passed away by then, so Aaron traveled for several weeks with his mother, Agnes, and brothers Amisi and Alvin.

"Visiting gave me a different perspective," he says, and lighting seemed a particularly acute need—and business opportunity. "I knew that people were succeeding in the rent-to-own model for solar lighting in other places, and I had just seen a place that could benefit, a place where I had family ties. All of this molded how I thought about what we'd been talking about in class, and made it seem much more realistic."

The original idea, designing their own equipment, was quickly pushed aside when they looked at existing equipment. "Do we spend money on product development at this point or work with an established solar kit supplier?" Olson says. "It was a matter of funds and time."

Above: This school for orphans in Mboka Paul now has a solar lighting system, donated by NovoMoto LLC. In blue shirts are founder Aaron Olson (center-left) and his brother, Alex Olson. *All photos courtesy of NovoMoto.*

The rent-to-own solar lighting system was greeted with a smile recently in the Democratic Republic of Congo.

Raising money is always difficult for startups, but by mid-2016 NovoMoto had raised $110,000 from two U.S. Department of Energy grants, and an investment from the Clean Energy Trust of Chicago.

By May 17, 2017, NovoMoto was serving eight pilot customers in Mboka Paul, a village northeast of Kinshasa. Building on lessons from the pilot, they began planning the first 100 installations.

The company's entry-level package can store 20 watt-hours even on a cloudy day. That is enough to charge a mobile phone, and power six hours each on two indoor lamps, plus 12 hours for one outdoor lamp.

Combined, these three bulbs emit as much light as a 40-watt incandescent bulb. "This may not sound like much to those in a developed country, who get electricity from a utility, but it's a stellar improvement over candles, batteries or kerosene. The response in Mboka Paul confirms this," says Olson.

The larger package adds several hours of television usage to the mix.

Although homeowners are the primary market, NovoMoto has done free installations in a school and a clinic in each village it serves, Olson says. NovoMoto is also developing packages tailored to larger business needs like refrigeration and electric bike charging.

NovoMoto is prepared for rapid growth, and is aiming for 2,000 customers at the end 2018 and 20,000 by the end of 2019. That expansion includes a gradual transition —already under way—to a "mobile money payment system that can eliminate the problem of having to go out and collect cash," Olson says.

ADVANCE COULD ENABLE NOVEL HIGH-PERFORMANCE MATERIALS

Roderic Lakes

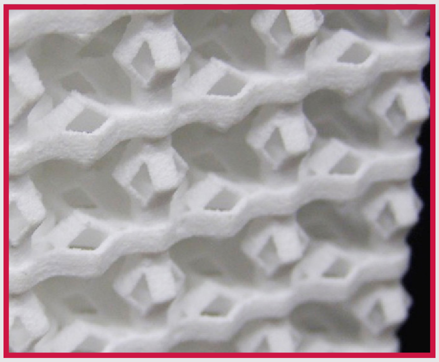
When engineers design things like buildings, airplanes, bridges and electronic devices, they perform calculations to ensure these structures can withstand mechanical forces without breaking or deforming too much.

The classical elasticity theory works well for predicting the behavior of most ordinary materials, including steel, aluminum and concrete. But for some materials, this theory is too limiting.

Wisconsin Distinguished Professor Roderic Lakes and graduate student Zachariah Rueger have recently made new materials that behave in an unusual way that defies the standard theory of elasticity.

It's an advance that could open the door to designing novel materials for applications that require high toughness.

Lakes and Rueger used 3D printing to make their new polymer lattice materials. Their lattice design—in other words, the regular pattern in which the materials' polymer strips are arranged—is a repeating crisscross structure. And when it's twisted or bent, a bar of this polymer lattice is about 30 times stiffer than would be expected based on classical elasticity theory.



Professor Roderic Lakes created a new polymer lattice material that defies classical elasticity theory. This advance could open the door to designing novel materials with improved toughness. *Photo: Roderic Lakes and Zachariah Rueger.*

Performing measurements in the lab, Lakes determined that the materials' behavior was consistent with Cosserat elasticity, a more descriptive theory of elasticity that takes into consideration the size of the underlying structure in a material.

"When you have a material with substructure in it, such as some foams, lattices and fiber-reinforced materials, there's more freedom in it than classical elasticity theory can handle," Lakes says. "So we're studying the freedom of materials to behave in ways not anticipated by the standard theory."

This increased freedom offers a potential path to creating novel materials that are immune to stress concentration; in other words, materials with improved toughness. Such materials would be useful for a variety of applications—for example, airplane wings that are more fracture resistant.

If a crack forms in an airplane wing, stress is concentrated around the crack, making the wing weaker. "You need a certain amount of stress to break something, but if there's a crack in it, you can break it with less stress," Lakes says.

Using the Cosserat theory of elasticity to inform materials design will yield tougher materials in which stresses are distributed throughout the materials differently, according to Lakes.

JACOB NOTBOHM RECEIVES NSF CAREER AWARD

Jacob Notbohm

In his research, Assistant Professor Jacob Notbohm takes a closer look at human diseases and injuries—studying cellular and material properties on the scale of a micron.

And, one of nine College of Engineering faculty to receive an NSF CAREER Award in 2018, Notbohm will use funding from his award to more thoroughly study the mechanics of fibrous materials such as human tissue.

His research is unique in how it zooms in on these materials—deforming, stretching and contracting them at a cellular scale. Such experiments can increase understanding of how mechanical properties of these materials can be altered by changing the fibrous structure.

"The big picture is to relate the structure of fibers—their density, alignment and size—to the mechanical properties of the whole network," he says. "And because there are so many different ways you can change fiber properties, there are a wide array of mechanical properties you can get as a result."

Notbohm and his research group are particularly interested in properties such as stiffness at small size scales. For many biological materials, the more you stretch them, the stiffer they get. This fact has been known for decades, and now Notbohm aims to apply it to his research of materials at the length scale of a biological cell.

Notbohm's group tests fibrous materials by applying forces to them and observing their reactions under a microscope. By adding microscopic active particles that contract when heated, he and his students can observe the material's reactions to force.

Because Notbohm's research intersects disciplines, he recognizes the importance of integrating different topics in the classroom. Among those are mechanics and biology.

Jacob Notbohm is using his award to study the mechanics of fibrous materials. *Photo: Renee Meiller*

"There's this notion that students take a class in physics or mechanics, and then they take a class in biology and math, and then separate all these topics without integrating them," he says. "So one educational objective of my award is to help students integrate concepts among disciplines."

The CAREER award will enable Notbohm to apply this objective to not only undergraduate classrooms, but at area high schools as well. Through Research Experience for Teachers—a National Science Foundation program that promotes collaboration between higher education and K12 instructors—he'll be working with high school teachers to create modules for students, whether on the mechanics of biomaterials or the structure of human tissue. Teachers will be able to bring these ideas back to their classrooms and lead lab units, helping students gain an early understanding of the broad scope of science and engineering.

Although his CAREER award will allow Notbohm to focus more on fibrous materials, he also studies cellular interactions. He received another NSF grant in July 2017 that funds a study of the physics of collective cell migration—for example, what kind of forces cause a cell to heal wounds, or in the case of cancerous cells, what causes them to invade the body.

Notbohm's CAREER award is $500,000 over five years.

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