

MECHANICAL ENGINEERING



UNIVERSITY OF WISCONSIN-MADISON



NEW LIGHTNING-FAST LASER FOR COMBUSTION DIAGNOSTICS

CHAIR'S MESSAGE



Jaal Gandhi

Greetings from Madison as we begin 2018!

This past year has been another successful one for the department, which most likely

does not resemble the one that you left years ago. We have undergone a substantial hiring binge and now by all measures we are a very young faculty. As of January 2018, we will have 11 assistant professors, out of 31 tenured or tenure-track faculty. We are continuing to hire and hope to add a few more to our ranks in the not-to-distant future. This is mirrored by retirements, including the past-Chair Roxann Engelstad, whom you can read about on the back cover of this newsletter.

I want to highlight an event that has grown substantially in the last couple of years: Scholarship Night. This past September we

celebrated the 42nd anniversary of the event by awarding 200 scholarships totaling more than \$250,000 to 104 deserving undergraduates. This year, we also had 25 donors in attendance; the students often bring parents and other family. In order to accommodate such a large group, we needed to hold the event in Varsity Hall at Union South, the largest facility on this end of campus. The growth of this event has been driven by the generosity of alumni, and the students have benefited greatly. The cross-generational interchange at the event is great to experience and exemplifies our shared Badger pride.

Best wishes for 2018, and On, Wisconsin!

Jaal Gandhi

Professor and Chair

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Participants in the Women in Mechanical Engineering program all received scholarships at Scholarship Night. The new mentorship program pairs incoming female freshmen with juniors and seniors to help the incoming women thrive as mechanical engineers at UW-Madison.

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BETTER THAN YOUR AVERAGE BIKE: UW-MADISON ENGINEERS AMONG TOP FINISHERS IN HUMAN POWERED VEHICLE CHALLENGE



With an efficient, highly engineered vehicle, the UW-Madison Human Powered Vehicle team won fourth place overall in the 2017 ASME Human Powered Vehicle Challenge North America East.

The UW-Madison team competed against 45 student teams from around the world in the challenge, which was held April 21-23, 2017, at Tennessee Tech University in Cookeville, Tennessee.

The team also took third place in the innovation category at the competition.

"I'm really happy with how the team did in the competition," says senior Victor Markus, the team's chief engineer and vice president. "The leadership on the team was really solid, and everyone put a lot of hard work into designing and building our vehicle."

"The innovation event is a big part of the competition, and it's a lot of fun coming up with creative new ideas for the vehicle."

ASME's international Human Powered Vehicle Challenge provides an opportunity for students to design and build sustainable and practical transportation alternatives for everyday use, from commuting to work to carrying goods to market.

Each team creates a 30-page design report for its vehicle and gives a presentation at the competition. Then the teams pit their vehicles against each other in two speed events—a drag race and a two-and-a-half hour endurance race. In the endurance race, the teams must maneuver their vehicles around a variety of obstacles.

This year, the team designed and built its vehicle in the form of a recumbent tricycle, with two wheels in the front and one wheel in the back. To make their vehicle aerodynamic and reduce the drag from air, the students designed and constructed a lightweight

carbon-fiber fairing—an aerodynamic outer shell—to enclose their vehicle.

In making the design, the fairing team performed aerodynamic analyses to achieve an optimal design. "Without the fairing on, we got the bike up to 25 mph. With it on, we could get up to 40 mph. So it made a big difference and those students did an awesome job," Markus says.

"The students designed, prototyped and tested their safety system, and the judges really liked it," Markus says. "The innovation event is a big part of the competition, and it's a lot of fun coming up with creative new ideas for the vehicle."

Markus says participating on the team enhances students' engineering education in a number of ways.



Student Victor Markus standing in front of the UW-Madison Human Powered Vehicle team's 2017 bike. Markus is holding a 3D printed model of the team's vehicle. *Photo: Stephanie Precourt.*

The team's entry in the innovation category earned praise from the judges and won third place in that event. The students developed a safety system that consisted of a crumple zone in the front of the vehicle, an airbag, and sonar detectors on the sides of the vehicle to detect objects in blind spots.

"You learn a lot about engineering design—and about how to articulate that design to others or in a report," he says. "We also do nearly all of the fabrication ourselves in the student shop, so everyone on the team gains awesome hands-on manufacturing experience, which employers really like."

SENIOR DESIGN PROJECT WITH GREENHECK INSPIRES CREATIVITY

A team of students participated in a unique kickoff event for their senior design project, thanks to the project's sponsor, Greenheck Fan Corporation.

Greenheck invited the four students on the team to tour the company's facility in Schofield, Wisconsin, in August 2017. Mike Cheadle, senior design program coordinator, says the event was a great opportunity for the students to build their team, meet Greenheck employees and learn about the company's impressive testing and manufacturing capabilities.

For their project, the students are working on the design of a new fan for Greenheck. They're approaching the design from the perspective of developing an ideal fan, rather than a fan that is limited by current manufacturing methods.

"One thing I find very exciting about this project is there's a lot of room for creativity," says student Zach Self. "Our clients at Greenheck really stressed to us that there were no wrong answers, and they wanted us to be as questioning and curious as possible about the HVAC industry."

Cheadle notes that Greenheck, as a dedicated partner for the senior design program, is providing a lot of engineering time for the students and will prototype whatever solution they devise.

He says Greenheck sees a lot of value in working with UW-Madison engineering students and participating in the design program. "Greenheck was interested in working with our students because they know our students are among the best in the country," Cheadle says. "There is a lot of talent here, and they recognize that."



NEW LASER IMAGING SYSTEM IMPROVES COMBUSTION DIAGNOSTICS

Associate Professor David Rothamer has designed and built a pulse-burst laser system that opens the door to new research opportunities for imaging turbulent reacting flows.

A faculty member of UW-Madison's Engine Research Center, Rothamer studies combustion diagnostics and is particularly interested in developing new optical techniques to study combustions flows. Because the flows are dynamic and turbulent, and simultaneously have rapid chemical reactions occurring, typical cameras cannot capture them very well. Instead, researchers use a combination of laser-based imaging techniques and high-speed imaging using natural light emission from the combustion process.

But most conventional laser imaging techniques have a hard time capturing the true nature of a combustions flow. That's because conventional high-pulse energy laser sources used for such imaging are only available with low pulse repetition rates, only allowing researchers to capture images at a rate of usually 10 images per a second. While that may seem fast, it's not ideal for understanding fast-paced turbulent combustion in internal combustion engines where the entire combustion event occurs within the space of a few thousandths of a second.

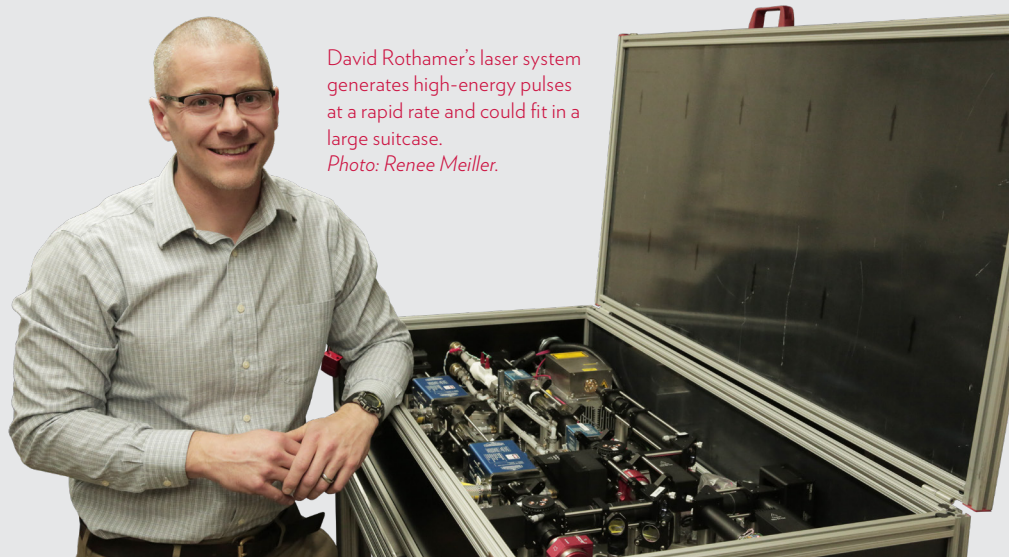
"For a lot of diagnostics that's okay," says Rothamer. "Except that when you're studying flows, generally things are happening much faster than at the rate of 10 times a second. So each image you get is relatively uncorrelated with the previous image."

On the other hand, researchers have more recently developed laser systems that continuously provide pulses at high repetition rates, but the pulses are limited in energy. The idea Rothamer has leveraged combines the advantages of the two types of systems to generate high-energy pulses at a rapid rate.

"The limitation is that if you did that continuously, your system would require a huge amount of power," he says.

Instead, Rothamer has devised a system where a train of relatively low-energy laser pulses passes through a series of amplifiers that strengthen them over a limited duration—20 to 40 milliseconds at a time. The system creates high-energy laser pulses over that duration at a high rate, without requiring a huge facility with major energy requirements. In fact, the system could fit in a large suitcase.

"I'm excited about this; it allows for application of laser imaging techniques inside engines at speeds that have never before been achieved," says Rothamer, who spent two years building the system. "I'm particularly excited about the flexibility of the system. In our labs, the system could replace all of our 10-Hertz laser systems. It's much more flexible than those other systems and provides significantly more capability."



David Rothamer's laser system generates high-energy pulses at a rapid rate and could fit in a large suitcase.
Photo: Renee Meiller.



RESEARCHERS BRING 3D PRINTING TO A 'COOL' INDUSTRY

In 2015, UW-Madison engineers received funding from the U.S. Department of Energy Advanced Research Projects Agency-Energy (ARPA-e) program to develop 3D-printed heat exchangers for power plants.

That grant allowed the researchers to design and manufacture proof-of-concept heat exchangers—and now, fueled by their initial success, they have received a \$2.1 million extension to continue the project.

The team of mechanical engineers, led by Professor Greg Nellis, the William A. and Irene Ouwenel-Bascom Professor, who is the heat exchanger design lead, also includes Mead Witter Foundation Consolidated Papers Chair Tim Osswald as manufacturing lead, and Phil and Jean Myers Professor Krishnan Suresh, design for manufacturing lead.

With the extension, the team is now focusing on 3D-printing heat exchangers for refrigerators rather than for power plants. At roughly a square foot with a thickness to be determined, the new exchangers are far larger than most case studies to date.

The shape of and material used to make a heat exchanger dictates its effectiveness. A good heat exchanger shape facilitates heat transfer, and a good heat exchanger material conducts heat well. Metal heat exchangers, like most these days, conduct heat well but



Gregory Nellis



Tim Osswald



Krishnan Suresh

have shape constraints due to the limitations of conventional manufacturing processes.

Given these limitations, the UW-Madison engineers are using 3D printing to create heat exchangers that have finely detailed geometries with internal projections to increase turbulence and facilitate heat transfer. Such intricate shapes are impossible to create with traditional manufacturing.

For its work, the team employs a 3D-printing technique known as fused filament fabrication, in which polymer filaments are deposited in layers to “print” 3D products. And to increase the thermal conductivity of the heat exchangers, they use “highly filled” polymers, which they create by adding small copper particles to the polymer filament to improve the heat-conducting properties of the polymer; polymers have a notoriously low thermal conductivity.

The project extension brings aboard the industrial partners Teel Plastics of Baraboo, Wisconsin; Cosine Additive of Houston, Texas; and Greenheck Corporation of

Schofield, Wisconsin; to implement the heat exchangers in industrial settings.

The partners are helping set competitive performance and cost targets for the project and provide insights on how to feasibly scale

the production of 3D-printed heat exchangers. In return, they are learning about state-of-the-art additive manufacturing techniques used by UW-Madison researchers to help develop better products for their markets.

The impact of the project extends beyond heat exchangers. Because the 3D-printing industry is still relatively young, the project will help advance novel 3D-printing techniques.

In particular, the research will pave the way for emerging applications of highly filled polymers. For example, using these polymers would allow manufacturers to print complex, heterogeneous products such as circuit boards in just one pass. And, down the road, manufacturers could print with polymer filaments made mostly of metal filler, then burn off all of the plastic while fusing the metal into a single piece—an inexpensive technique that allows them to create finely detailed solid-metal products.

“3D printing will find its place among manufacturing technologies,” says Osswald. “It’s only a matter of time.”

CHRISTOPHER MEYER: EARLY CAREER ACHIEVEMENT AWARD RECIPIENT



Christopher Meyer
Director, Sector 67 Inc.
BSME '08, MSME '10

We honored Christopher for his leadership in achieving a unique vision of education, entrepreneurship and community development through Sector 67, which has enabled more than 100 companies and entrepreneurs to turn their ideas and dreams into reality.

How did you choose engineering?

I was interested in science and outdoors and stuff like that, so I thought chemistry or biology would be pretty cool. Or I was going to go to Marquette for dental school, which would have been really specific. At SOAR, I went through all of the colleges and never heard chemistry or biology. So, I got to the College of Engineering, for “if you like to work on cars, bicycles, like to build things.” I thought, “This engineering sounds pretty cool.” I worked on dirt bikes and mini bikes and cars and all sorts of stuff when I was in high school, just for fun, in my parents’ garage. And so, it seemed like it’d be something that I was interested in.

How did your experience in the College of Engineering shape your career path?

A friend of mine had seen this innovation-based competition hosted by the College of Engineering. And I thought, “It’s something cool but I thought it was way scary—like no way am I prepared to be in something like that. I’m not an inventor, I’m not a creator.” But at any rate, we showed up to this competition having no idea what we were doing, with just a concept for a computer prototype, and didn’t win anything at all. But the coolest thing was they provided a budget for us to build the prototype. So, every year I competed with different people or different teams with different ideas. And that’s how and why I

ended up doing what I’m doing—because I had an opportunity to do something cool. That competition definitely shaped my career and my entrepreneurial path.

Describe Sector 67 and your role there.

I’m the director of Sector 67. I’m the sole founder of it. I started it in 2010 when I graduated. I actually worked on it for about eight months while I was writing my thesis. Writing a thesis is not very much fun—and so it was more fun for me to play around with this idea of generating a company while I was doing a thesis because it’s a great distraction. The space itself is really an agglomeration of a bunch of different workspaces. We’re called a hackerspace, otherwise called a makerspace. It’s a community workshop. We have a welding shop, machine shop, 3D printers, laser cutters, regular printers, woodshop tools and a car lift area—all the tools that people would be interested in. And then we also do classes for kids and try to provide an entrepreneurial space for somebody who’s trying to start a business.

What do you like most about Sector 67?

The depth and breadth of all of these people coming in. Every day somebody walks in and they have a new thing they want to do.

Of what professional accomplishment are you most proud?

Just managing to build out a nonprofit resource that’s sustainable, building out a company that functions on its own, and then being able to provide a huge breadth of resources to a whole variety of people over the years.

What advice would you give to current students in your discipline today?

I always tell students to never be afraid of doing anything even if they don’t have the background or the degree or the knowledge. Whether you’re a writer who’s writing about engineering topics, whether you’re an engineer trying to write a business plan, or whether you’re a student who has a noble idea, you need to go out and try those things and talk to people about it, because you’ll find other people who are excited about it and happy to help. There are a ton of opportunities on campus. Be willing to step outside of the boundaries of your degree and go do other things.

Any hobbies or interests?

I fly podcopters and first-person helicopters and stuff like that. I had radio-controlled toys when I was a really young kid. And then in college I built robots and robotic stuff, things like that.

ENGINEERS' DAY AWARD RECIPIENTS

CHRISTINE SCHYVINCK: DISTINGUISHED ACHIEVEMENT AWARD RECIPIENT



We honored Christine for her leadership in microphones and the audio electronics industry, which has led to exceptional results in product quality and corporate profitability.



Christine Schyvinck
CEO, Shure

BSME '89 (MBA engineering management '99,
Northwestern University)

How did you choose engineering?

I was a girl who was really good at math and science, and my high school counselor told me to think about doing accounting. But it was my dad who suggested I look into engineering. He was very instrumental in that decision.

Did you have a favorite engineering professor?

Yes, Professor Donald Ermer. I took three of his classes. His engineering economics class was impactful because it helped me understand not just how to create and develop products, but also about cost structures and margins, and what it takes to make a company successful in the long run. He also taught quality and

reliability engineering classes. He was a Juran Institute graduate, teaching Total Quality, the buzzword of the time. Today we call it lean manufacturing. My first job at Shure was as a quality engineer, so the combination of economics and quality was really helpful to me.

What is your fondest memory of your time on campus?

Between my junior and senior year, I took nine credits during the summer. And being on campus during the summer in Madison was pretty awesome. I have a lot of great memories of being outside and looking at the lakes.

Of what professional accomplishment are you most proud?

I joined Shure 28 years ago when we were very much a U.S.-centered company. I think my biggest professional accomplishment has been helping to make the company more global. We now have more than 25 different international locations. Manufacturing was the first place where we really broadened our footprint, then we did the same with the growth of our sales, opening up offices in other parts of the world to establish support for customers throughout Asia, Europe and Latin America.

Who has played the greatest role in your achievements?

My family, who has always supported me. My kids and my husband have supported

the travel and all the time I've put into work. My parents and my in-laws have always been there to help when asked. Work-life balance is hard, there is no secret formula. But my family's support has played the biggest role in where I am professionally. Mrs. Shure was also a great mentor for me in terms of understanding the balance between company growth and core values. You can't have one without the other—they are intertwined and she taught me that lesson.

What advice would you give to today's engineering students?

I think in a world that's increasingly focused on technology, it's important to remember the human aspect. I have spent a lot of time with Millennials and Gen Z kids, and despite the negative press they seem to get, I think kids today are 10 times smarter than I was going into college. Technology comes naturally to them—they were born with a mouse or phone in their hands. I have so much confidence in the next generation of leaders. But they do need to remember the human connection.

What interests you outside of your work?

I love music. I play the French horn and piano. Before having children, I did play in a local concert band and I'm thinking about joining that again. I also like to spend time reading—I like fiction (mostly mysteries), but also like to read about all the places I've been able to travel to. What I have determined is that people around the world have many more commonalities than differences. I appreciate the friendships I have been able to establish with people all around the world.

ENGELSTAD RETIRES, CAPPING OFF DISTINGUISHED CAREER



Roxy Engelstad

Over her long and distinguished career at UW-Madison, Professor Roxann Engelstad rose to the top of her field,

achieving an international reputation for her expertise in micro and nanolithography. Engelstad's retirement from the department caps off an extraordinary 29-year career in which she not only made a significant mark in her field but also in the lives of many students.

In addition to being one of the most prolific researchers in the department, Engelstad was recognized as one of the best instructors. Although she was known for her rigorous presentations and high standards, she consistently received glowing teaching evaluations from students, which culminated in her winning the College of Engineering Benjamin Smith Reynolds Award in 2015.

Engelstad's influence on student learning extends far beyond the students she taught and mentored. While serving as department chair from 2007 to 2013, she made a number of significant contributions to enrich students' learning experiences and instruction. These efforts included creating an undergraduate research and development symposium to give students practical experience in presenting their research or design projects to a broader audience. Additionally, Engelstad led the development of a new branch of the curriculum that includes design, innovation and systems engineering to better prepare students to tackle the major engineering challenges of the future.

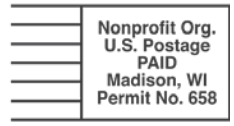
Through her cutting-edge research, Engelstad established herself as the world's foremost authority on mechanical issues associated with designing, fabricating and using advanced masks and processes for next-generation lithographic technologies. Among her many research accomplishments, Engelstad, with her research group, developed a powerful set of numerical tools that not only



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correlates nano-scale models to macro-scale models but also tracks the distortion of the features as a function of the various steps in the lithographic process.

The semiconductor industry consistently turned to Engelstad to address problems in micro and nanolithography, and in response she founded the UW Computational Mechanics Center (CMC) to facilitate this research. Engelstad received significant funding to assess the commercial potential of numerous types of lithography, including X-ray lithography. As a result of these research efforts, a number of agencies and major companies, including the Defense Advanced Research Projects Agency and SEMATECH, an international consortium dedicated to accelerating commercialization of technology innovations in semiconductor manufacturing, have depended on Engelstad and the CMC to conduct early assessments of the major problems in various proposed lithographic solutions.

Engelstad spent her entire academic career at UW-Madison, earning her bachelor's degree in 1977, her master's degree in 1979 and her PhD in 1988, all in engineering mechanics, before joining the mechanical engineering faculty in 1988 as an assistant professor. Throughout her career, Engelstad garnered nearly \$15 million in external funding. As a highly sought-after expert, Engelstad has delivered more than 75 invited lectures and presentations at major conferences, universities, government laboratories and industrial research laboratories around the world.

Engelstad's excellence was recognized by the research community. She was named a fellow of the International Society for Optical Engineering and the American Society of Mechanical Engineers. Engelstad was named the Bernard and Frances Weideman Professor of Mechanical Engineering in 2008, and was recognized by a Wisconsin Alumni Research Foundation professorship also in 2008, one of the highest honors in the university.

"Roxann Engelstad embodies all of the qualities of a faculty member that we look for," says Jaal Ghandhi, Grainger Professor of Sustainable Energy and department chair. "She was a research superstar, a dedicated and beloved teacher, and during her time as chair, a relentless standard-bearer for the department. She has served as an example to me throughout my career here. Her retirement will leave a hole that will, I am afraid, never be filled."