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The Wisconsin Physicist

Volume 24 | 2019

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***The Wisconsin Physicist* is the newsletter for alumni and friends of the:**
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All photos are from the Department of Physics, except:
Page 1: (L) Benjamin Eberhardt, IceCube/NSF, (C) Nature Communications, (R) Jeff Miller, University Communications
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On the Cover

UW–Madison associate professor of physics Brian Rebel's photo submission was one of 12 winners in the 2019 UW–Madison Cool Science Images contest. The container is a prototype for a neutrino detector that would hold more than 3 million gallons of argon in which neutrino collisions with argon atoms could be carefully studied for clues suggesting why our universe is made of matter. The corrugated areas in this stainless steel wall will keep welds from breaking as the vessel is cooled to minus 265 degrees Fahrenheit and filled with 135,000 gallons of liquid argon.

Stay Connected!

Please continue to send us your professional and personal news! We will be happy to include updates from alumni and friends in *The Wisconsin Physicist*. Send updates to: info@physics.wisc.edu

Find us on LinkedIn, Instagram and Twitter:

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Graduate program alumni, please join our new LinkedIn Group:
UW–Madison Physics Graduate Program: Current Students & Alumni

Undergraduate alumni: there will be a group formed soon, please stay tuned!

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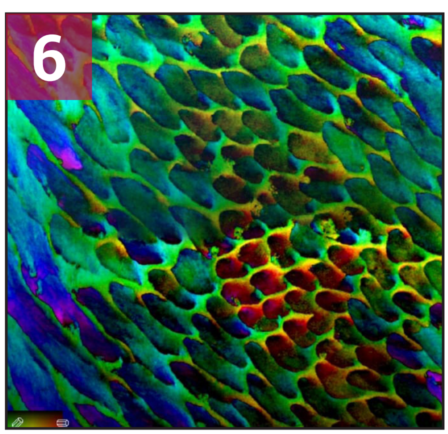
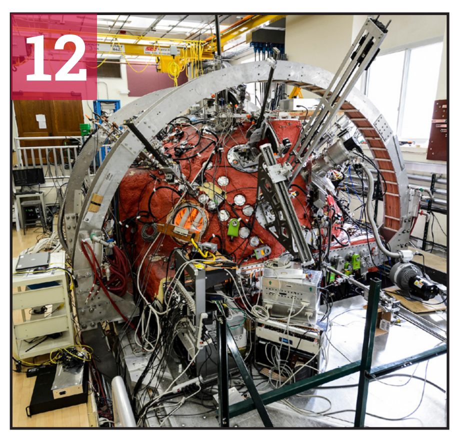




Greetings from the Chair

By Sridhara Dasu, Chair, Department of Physics

Dear Alumni and Friends,

The Physics Department continues to be a vibrant place for education, research and outreach in a wide range of areas. This new edition of the Wisconsin Physicist will give you an opportunity to get a glimpse of our department in 2019.

The administration team for the year remained intact from 2018, namely Associate Chair, Professor Mark Rzchowski, Associate Chair for Alumni Affairs, Professor Robert Joynt, Department Administrator Ms. Aimee Lefkow, Director of Graduate Studies, Dr. Jeffrey Schmidt and Director of Undergraduate Studies, Dr. James Reardon. We welcomed Dr. Sarah Perdue as the Department's first Director of Communications in Fall 2019. We are also pleased to introduce Ms. Mae Saul who recently joined the UW Foundation as a Director for Development working with our department. We continue to share our mutual goals of sustaining the best practices in the department and improve wherever possible.

The department was fortunate to host many members on its faculty and staff who were recognized this year with awards. My colleague and mentor Professor Wesley H. Smith won the prestigious Wolfgang Panofsky award of the American Physical Society. Assistant Professor Shimon Kolkowitz was selected as one of the 22 members of the 2019 class of Packard Fellows for Science and Engineering. Professor Francis Halzen continued to bag in major awards including 2018 Bruno Pontecorvo Prize and 2019 Kanwal & Gaurang Yodh Prize. Professors Maxim Vavilov and Tulika Bose were elected as 2019 APS Fellows.

The faculty of the department continued to play important roles at the national level, for instance with the election of Professor Thad Walker to the chair-line of the Division of Atomic, Molecular and Optical Physics, and Professor Baha Balantekin as the Speaker of the APS Council.

The first intra-departmental Ray MacDonald awards, funded by the $3 million gift from former graduate and returning adult student, the late Mr. Ray MacDonald, were awarded to Professors Yang Bai, Daniel Chung, Alex Levchenko and Deniz Yavuz.

I am happy to announce that Dr. Uwe Bergmann has agreed to join us as the first endowed Martin L. Perl Professor in Physics. He is a world-renowned researcher in the area of ultrafast science exploiting X-ray free electron lasers and related technologies to study physical phenomena at the SLAC National Laboratory.

The department received a generous gift from alumnus Dr. Dunson Cheng to establish its second named professorship, the Dunson K. Cheng Professorship in Physics. We look forward to awarding it in AY2020-21.

The department is currently conducting four faculty searches in the areas of computational/theoretical cosmology, computational/theoretical plasma physics, particle astrophysics and quantum computing.

The department received substantial gifts from Emeritus Professors Clint Sprott and William Haeberli, towards the Wonders of Physics and Ingersoll Physics Museum, respectively. The branding of the Wonders of Physics as the vehicle for outreach of the department and celebration of the Ingersoll Museum as one of the oldest and successful touch-me exploratoria remains a primary goal of the department.

The department welcomed the most diverse graduate class in the recent memory in Fall 2019. The sustained efforts of the new graduate student coordinator Ms. Michelle Holland, the admissions committee, the climate and diversity committee and most importantly the enthusiastic support of the PGSC, the new physics graduate student council, GMaWiP, the gender minorities and women in physics group, and the Board of Visitors had paid off very well. The department also welcomed its first cohort of students in the Quantum Computing professional master's program (MSPQC).

The Physics Department Board of Visitors met twice in 2019, including once at the CERN laboratory, where they were able to hear from the Wisconsin faculty, scientists and students working at the ATLAS and CMS experiments and visit the underground experiment. The Board of Visitors continues to help us in a number of ways, by providing feedback to the Department, recruiting of graduate students, and with fundraising. Our fundraising priority for this year is to take advantage of the Morgridge match to raise funds for the Bernice Durand Professorship (see box below). This fund is set up to honor Emeritus Professor Bernice Durand, the first female professor of the department, and to recognize the need for diversity in physics.

The 18th Annual Awards Banquet was held in May 2019. The continued generosity of our alumni and friends allows us to present many awards to outstanding students. You can read more about the Awards Banquet on pages 17-20.

We are pleased to maintain our tradition to recognize Distinguished Alumni. Awards were presented to distinguished alumni: Dr. Greg Piefer, Founder and CEO of Shine Medical Technologies and Dr. Ted Strait of General Atomics.

Whether you are an alum, friend, employee, or student, we appreciate your interest in, and loyalty to, the University of Wisconsin-Madison Physics Department. All of the awards given out are based on donations. As an example, the Physics Alumni Graduate Support Fund allows us to give fellowships and to supplement stipends of incoming graduate students. The Newton fund helps the Department to help in many. You can donate to the Physics Department online by going to https://wp.physics.wisc.edu/giving or please see pages 23-24 for more ways to give.

I sincerely thank our generous alumni and friends who have financially supported the Department. This support is truly our margin of excellence.

Sridhara Dasu – Department Chair

Priority Fund: The Bernice Durand Endowed Professorship Fund

Prof. Bernice Durand

In last year's issue of *The Wisconsin Physicist*, we announced a new endowed professorship fund to recognize Emeritus Professor Bernice Durand, the first woman professor of Physics at the University of Wisconsin–Madison. Durand has exemplified the role of a gifted researcher and devoted teacher, inspiring physics and non-physics majors across the university. Endowed professorships help the University and the Department to attract and retain the very best thinkers, teachers, and researchers in an increasingly competitive hiring market. We feel that it is most fitting to name the chair in Professor Durand's honor.

This year, the Wisconsin Foundation and Alumni Association is pleased to announce that, thanks to the generosity of John Morgridge '55 and Tashia Morgridge '55, a $70 million matching gift is available for endowed faculty positions at UW–Madison. To learn more about this opportunity, please contact the Physics Department's development director, Mae Saul.

For more information, please contact Mae Saul, Associate Director of Development
mae.saul@supportuw.org or (608) 216-6274

IceCube: Antarctic neutrino detector to get $37 million upgrade

By Terry Devitt, University Communications

IceCube, the Antarctic neutrino detector that in July of 2018 helped unravel one of the oldest riddles in physics and astronomy — the origin of high-energy neutrinos and cosmic rays — is getting an upgrade.

In 2019, the National Science Foundation (NSF) approved $23 million in funding to expand the detector and its scientific capabilities. Seven new strings of optical modules will be added to the 86 existing strings, adding more than 700 new, enhanced optical modules to the 5,160 sensors already embedded in the ice beneath the geographic South Pole.

The upgrade, to be installed during the 2022–23 polar season, will receive additional support from international partners in Japan and Germany as well as from Michigan State University and the University of Wisconsin–Madison. Total new investment in the detector will be about $37 million.

"Neutrinos are the last unexplored corner of the Standard Model of physics," explains Kael Hanson, director of the Wisconsin IceCube Particle Astrophysics Center, referencing the best available scientific model to explain the behavior of subatomic particles. "Neutrinos have properties the Standard Model can't account for."

The principal goal of the upgrade, explains Hanson, a UW–Madison professor of physics, is to expand the cubic-kilometer detector in a way that permits more precise studies of the oscillation properties of neutrinos, which as they interact with other particles and transit space can change or oscillate from one type of neutrino to another. A second goal is to better characterize the ice around IceCube sensors and thereby obtain better performance with the existing detector, thus yielding more definitive reconstructions of high-energy neutrinos. In addition, a better understanding of the ice that surrounds the neutrino

The IceCube Neutrino Observatory is located at NSF's Amundsen-Scott South Pole Station. Management and operation of the observatory is through the Wisconsin IceCube Particle Astrophysics Center at UW–Madison.

detector will help bring the neutrino sky into crisper focus, providing opportunities to discover additional sources of high-energy neutrinos and improving scientists' ability to gather more insight into those sources.

The new strings will be deployed below the center of the existing detector, a mile deep in the Antarctic ice. The deep ice in and around the detector is known to be some of the world's clearest, which makes it a nearly ideal medium in which to study the properties of neutrinos, sometimes called "ghost particles" for their ability to breeze through planets and entire galaxies without missing a beat. When neutrinos interact with other particles in or near the detector, they transform into secondary particles such as muons, which give off light that can be sensed by the detector to trace the trajectories of the parent neutrino.

Not only are there different kinds of neutrinos, but their energy levels vary by orders of magnitude. The very high-energy neutrino that was captured by IceCube in September 2017 was critical for resolving where cosmic neutrinos — those created in accelerators like massive black holes — come from. But other low-energy neutrinos such as those created when subatomic particles collide in Earth's atmosphere likely hold clues to how the particles change from one kind to another, says Hanson, and the IceCube Upgrade is intended to capture that kind of physics.

> Neutrinos are the last unexplored corner of the Standard Model of physics. [They] have properties the Standard Model can't account for."
>
> — Kael Hanson

Scientists know there are at least three kinds of neutrinos: tau, muon and electron. They can change from one to another and the changes have known patterns linked to the energy of the neutrinos, their masses, and how far they have traveled in space.

A "sweet spot" for observing neutrino oscillations, according to Hanson, is when muon neutrinos are created in the atmosphere by a cosmic ray interaction with the nucleus of an atom. As the muon neutrino travels through the Earth, it can oscillate into a tau neutrino.

"We can use neutrinos from the atmosphere," he says. "They are almost perfect for understanding these changes. They change from one type of particle to another, but we don't know enough about this morphing."

Understanding how neutrinos change from one to another will help refine the Standard Model, or show scientists why the model, which over time has withstood many experimental and observational tests, may need to be revised to account for new physics.

A prototype of one of the IceCube Upgrade project's new sensor module designs, called the mDOM, which has multiple photomultiplier tubes arranged for uniform sensitivity.

The planned additional IceCube arrays will have two different types of new sensor modules, which will be tested as candidates for an even larger future upgrade of IceCube known as IceCube-Gen2. "The modules to be deployed in the new upgrade will be two to three times more sensitive than the sensors that now make up the detector," notes Hanson.

To watch a video explaining the upgrade, please visit: **go.wisc.edu/huw9hd**

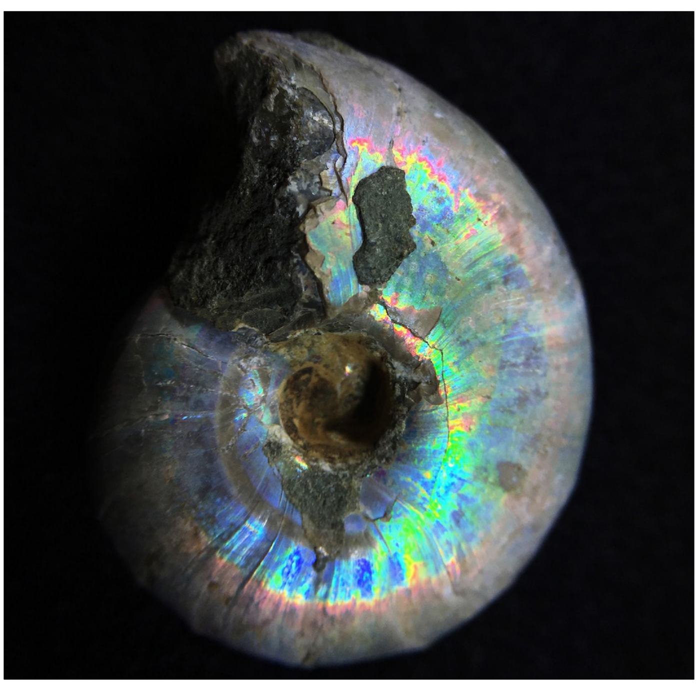
A crystal-clear understanding of biomineral form and development

By Sarah Perdue, Department of Physics ,
& Terry Devitt, University Communications

The materials that animals make from scratch to build protective shells, razor sharp teeth, load-bearing bones and needlelike spines are some of the hardest and most durable structures known. The recipe for making those materials was one of nature's closely held secrets, but powerful new analytical tools and microscopes have peeled back much of the mystery, showing, at the nanoscale, how those structures are organized, and how a wide array of animals use precisely the same mechanisms and starter chemicals to make them.

In 2019, University of Wisconsin–Madison physics professor Pupa Gilbert and colleagues published two studies that answered important questions about the evolution and nanostructures of some of these durable biomaterials. The details of both studies may one day be harnessed by humans to produce harder, lighter, and more durable materials.

The first study, published in the Proceedings of the National Academy of Sciences, shows that the recipe for making these biominerals is ancient — dating back 550 million years — and evolved independently more than once.



A Desmoceras fossil. A cephalopod that thrived in the early Cretaceous, 146 to 100 million years ago. Note the fossilized biomineral nacre, or mother of pearl.

The findings are important because they stitch together an evolutionary narrative of biomineralization. Gilbert used PhotoEmission Electron Microscopy — or PEEM, which employs soft X-rays produced by a synchrotron to observe at the nanoscale how the biominerals form — to reveal the nanoscale structures of the crystals that make up these strong biomaterials.

With PEEM studies, Gilbert showed that diverse animals, ranging from mollusks to echinoderms to cnidaria, have no common ancestor that was already making biominerals, thus they must have evolved biomineralization mechanisms independently.

Therefore, Gilbert says, "it is extremely surprising that when they started biomineralizing in the Cambrian (more than 500 million years ago) these three phyla started doing it in precisely the same way: using attachment of amorphous nanoparticles."

Gilbert and her colleagues have shown that different biominerals form beginning with amorphous calcium carbonate nanoparticles, which are produced in cells and are the critical starter chemical for all of the materials that form in the biomineralization process, be it the nacre, or mother-of-pearl, that lines an abalone shell or the rock-grinding teeth of a sea urchin.

"Diverse biominerals form from these amorphous precursor nanoparticles," Gilbert says. "It doesn't matter if it is a sea urchin spicule, a tooth, a spine, a coral skeleton, or nacre. All of these systems have the same amorphous precursors."

Gilbert's team went back in time to probe the deep fossil record in three distinct phyla, or broad groups of related animals, going as far back as 550 million years to sample the oldest known animal biomineral: the Cloudina skeleton with its characteristic series of funnels nestled into one another.

Gilbert notes that while animal remains undergo significant changes in the process of fossilization, the nanoparticle biomineralization signature remains intact and is observed by cracking open fossils and using a scanning electron microscope to probe the site of the fracture for the telltale signs of nanoparticles during the original crystallization process.

"We stepped back in time as far as possible, to the very first fossils, and biomineralization by particle attachment looked the same as in modern animals. The finding that biomineralization evolved independently multiple times, using the same mechanism, tells us that there is a strong physico-chemical reason for doing so," Gilbert says. "If one organism starts making its biomineral that way, it outcompetes all others that either don't make biominerals or make them differently, it doesn't get eaten, and gets to transmit that good idea down the lineage."

The second study, published in Nature Communications, looked at the crystal structure of human tooth enamel at the nanoscale, and found that individual crystals are not perfectly aligned, as had been previously thought. Additionally, this misorientation likely deflects cracks from chewing, leading to enamel's lifelong strength.

"With a technique that I invented, called polarization-dependent imaging contrast (PIC) mapping, you can measure and visualize in color the orientation of individual nanocrystals and see many millions of them at once," Gilbert says. "The architecture of complex biominerals becomes immediately visible to the naked eye in a PIC map."

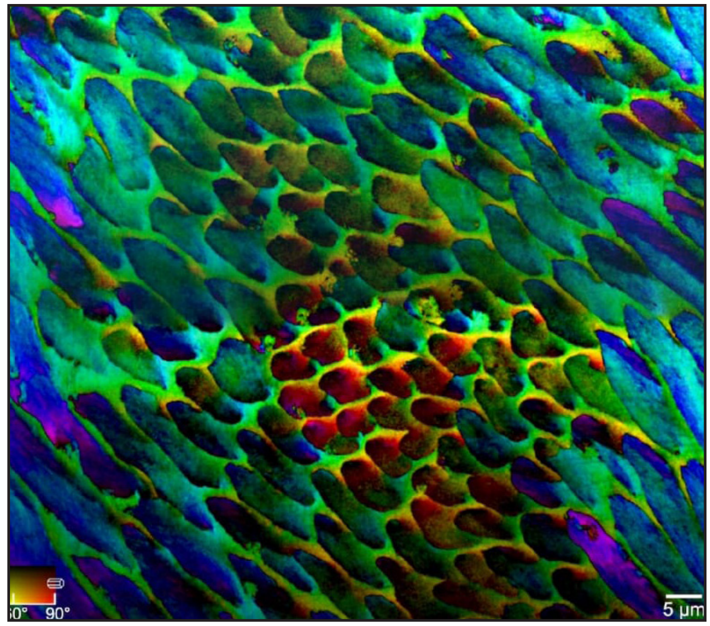
Tooth enamel is made of long and skinny 50-nm-wide crystals of hydroxyapatite, bundled into rods. Gilbert and colleagues applied PIC mapping to several human tooth samples and measured the orientation of each crystal in tooth cross sections.

"We never saw a single orientation in any rod, but always a gradual change in crystal orientations between adjacent nanocrystals," Gilbert says.

Next, Gilbert involved Markus Buehler, an MIT engineering professor who performed computer simulations of chewing-like force to hydroxyapatite crystals. In the simulations, cracks propagated across the interface between either co-oriented or mis-oriented crystals.

When crystals were co-oriented, the crack propagated straight through the interface. When the crystals were mis-oriented 47 degrees from each other, the crack also went straight through the interface. But at 14 degrees, the crack was deflected at the interface.

The simulation results suggested that there might exist an ideal angle of misorientation to deflect cracks. If



PIC mapping, which measures biomineral crystal orientations and assigns different colors to different rotation angles, reveals that the crystals in tooth enamel are not perfectly aligned.

so, it is likely the one that exists in nature. Physics graduate student Cayla Stifler used the PIC mapping data to measure the angular distance between every two adjacent pixels, and found that 1 degree was the most common misorientation angle, and that the angular distance never surpassed 30 degrees, consistent with the modeling result that a small misorientation angle is better than a larger one at deflecting cracks.

"Now we know why cracks are deflected at the nanoscale and don't propagate very far in tooth enamel," says Gilbert. "Slight mis-orientation at the nanoscale is the reason our teeth can last a lifetime."

These two biomineralization stories unraveled by Gilbert and her colleagues, combined with continued research in her group, may well inform the development of novel materials useful for industry.

"We don't know how to make these structures, but nature does," Gilbert explains. "What we learn from them, engineers can reproduce in the lab and in industry, and eventually make materials that are far better than the sum of their parts, as all biominerals are."

A computer modeling video showing the effect of enamel crystal orientation on the deflection of cracks from pressure, such as chewing, can be viewed at **go.wisc.edu/enamelvideo**

Professional Awards and Honors

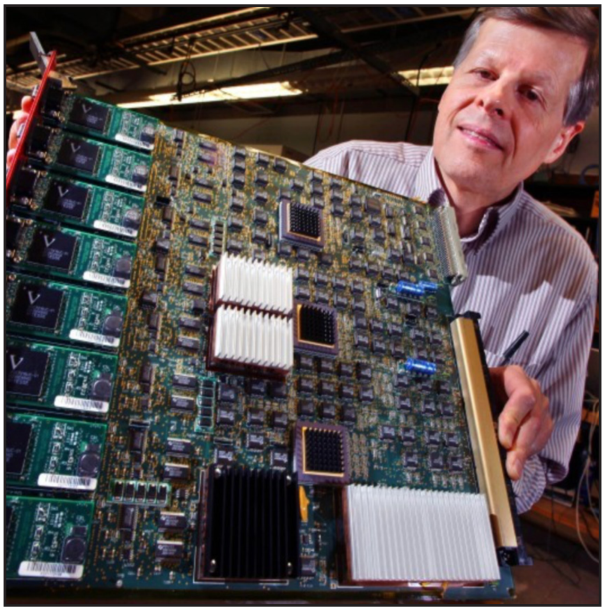
2019 brought many well-deserved accolades for our faculty

Shimon Kolkowitz was selected as one of 22 members of the 2019 class of Packard Fellows for Science and Engineering. The fellowship, awarded to early-career scientists from across the U.S., provides $875,000 of funding over five years. Kolkowitz will use the funds to develop his research program in ultra-precise atomic clocks, which he will use to investigate such fundamental aspects of physics as the relationship between quantum mechanics and gravity and the nature of dark matter.

Frances Halzen was awarded the 2019 Kanwal & Gaurang Yodh Prize at the 2019 International Cosmic Ray Conference and the 2018 Bruno Pontecorvo Prize. For the former, he was honored for his leadership and landmark contributions that cleared the path for the emergence of neutrino astronomy; the latter prize is presented annually by the Joint Institute for Nuclear Research Scientific Council for achievements in elementary particle physics.

Mark Saffman won a 2019 Wisconsin Alumni Research Foundation Innovator Award. He won for developing simplified optical hardware for quantum computing. The technology, recently licensed to ColdQuanta Inc., improves an apparatus for particle trapping, which will reduce the cost and complexity of next-generation quantum computing devices.

American Physical Society Honors



Wesley Smith was awarded the 2019 APS Panofsky Prize. The Panofsky Prize recognizes "outstanding achievements in experimental particle physics," and is the top APS award in that field. Smith developed systems that enabled the discovery of the Higgs boson. Smith led a team of over 100 scientists on the CMS experiment trigger system that captured the data for the Higgs' discovery at the Large Hadron Collider (LHC) in Geneva.

Tulika Bose and Maxim Vavilov were elected 2019 APS Fellows. Each year, no more than one half of one percent of the Society membership is recognized by their peers for election to the status of Fellow. This year, 168 Fellows were selected and recognized for their exceptional contributions to the physics enterprise.

Baha Balantekin was elected APS Speaker of the Council. He will serve as Speaker-elect in 2020, Speaker in 2021, and Speaker Emeritus in 2022. The APS Speaker of the Council presides over the Council, a body of elected leadership within the professional society. The Speaker also serves on the APS Board of Directors as well as presiding over the Council's Steering Committee.

Thad Walker was elected to leadership of the APS Division of Atomic, Molecular and Optical Physics (DAMOP). He will serve as the vice-chair in 2020 and the chair in 2021.

Master's of Science in Physics — Quantum Computing: the First Year

By Sarah Perdue, Department of Physics

As an electrical engineering student in Belgium, Jacques Van Damme was not required to take advanced physics or quantum computing classes.

"But I took one elective course in quantum mechanics, with some applications to electronic devices," he says. "That course really blew my mind. I was very eager to go more into quantum."

After completing his Master's degree, Van Damme was interested in continuing his studies, and he knew he wanted to study abroad. When he received a fellowship from the Belgian American Educational Foundation — essentially an educational exchange program — choosing the U.S became an easy decision. His search for quantum computing-specific programs led him to apply to the University of Wisconsin–Madison, where the first-ever Master's of Science in Physics – Quantum Computing (MSPQC) in the U.S. was being offered for Fall 2019.

This academic year, Van Damme and eight other students enrolled in the MSPQC program. Most of them will complete their degrees in August 2020, and be primed to enter the rapidly-growing field of quantum computing.

The program grew out of a recognized workforce need, says Bob Joynt, professor of physics at UW–Madison and director of the MSPQC program.

"We started graduating Ph.D.'s in the area of quantum computing maybe 10 to 15 years ago, and they did fine, they found jobs," Joynt says. "But then a few years ago, we started noticing that these graduates were in much more demand than our other graduates. Sometimes there were bidding wars, and that had never really happened before."

Joynt and others in the department worked closely with the College of Letters & Sciences and the Graduate School to develop the program and curriculum. The degree is designed to be completed in 12 months, includes lecture and laboratory courses, and offers optional directed research.

Unlike physics Ph.D. programs, which require a strong physics background, Joynt hoped that engineering students like Van Damme would be interested in the MSPQC program.

"The program is specifically designed so that students don't really need a background in quantum physics. Even a person who has never studied quantum but has a degree in computer sciences or electrical engineering should be able to succeed in this program," Joynt says. "The reason we thought we could do that is that to understand the theoretical parts of quantum computing, it's not very much. I'm teaching a course now where we spend the first month going over the quantum mechanics you need to understand quantum computers."

Joynt's Introduction to Quantum Computing course is one of three new courses developed for the degree.

The first-ever class of MSPQC students pose with an inflatable Bucky while on a campus tour during orientation week.

The second course, a spring lecture, focuses on the four main types of quantum computers, how they are made, and how they work. The third new course is an intensive summer laboratory course where students actually build and work with hardware that will eventually be used to make quantum computers.

An optional — but encouraged — part of the MSPQC program is directed research. The curriculum initially did not include a research component, because Joynt and others thought the coursework would take up all the students' time.

"Instead, I found that the students really want to be exposed to at least some research, and when I've talked to employers, they also think it's important," Joynt says. "Separate from their job aspirations, the research is cool, and it's what is exciting to our students."

Van Damme is completing a spring quantum theory research project in physics professor Shimon Kolkowitz's group.

Says Carlos Owens, another MSPQC student who will conduct research under physics professor Mark Saffman in the spring, "Quantum computing is a very active area of research, and there are still a lot of unanswered questions. It's exciting to think that I could play a role in answering some of those questions."

For his research project, Owens will be studying ways to reduce noise and improve the coherence and performance of trapped neutral atom qubits. He says his interest in the MSPQC program stemmed from his exposure to quantum computing as a math-physics double major, and the fact that quantum computing is a relatively new, undersaturated field.

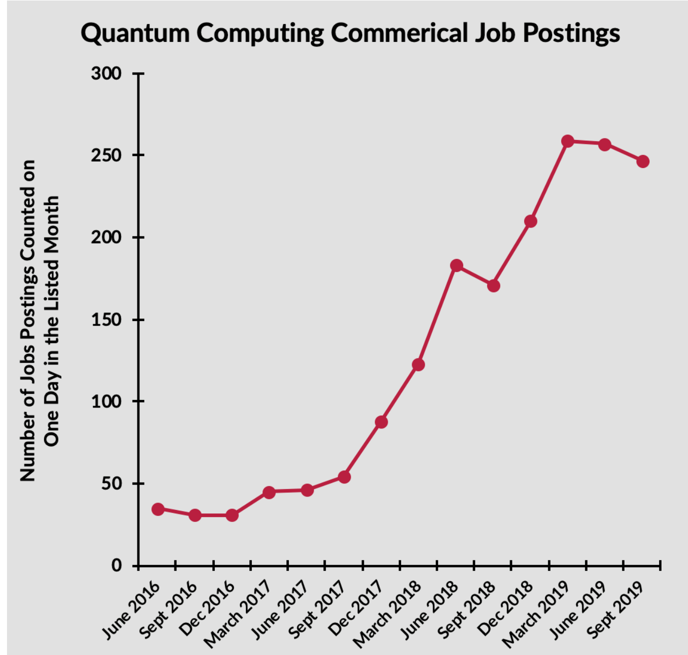
Both Owens and Van Damme plan to join the quantum computing workforce after graduation, though neither has ruled out pursuing a Ph.D. later on. And though the workforce may be in need, Joynt knows it is still important to actively help students land jobs.

"We've been talking to employers, asking, 'What do you want? What are you looking for?' So to a large extent, we're tailoring the program so that students will have the things employers want," Joynt says. "The other thing we're doing is bringing in folks that are hiring in this area, where the students can meet with them one-on-one."

Additionally, Van Damme, Owens and other students are taking advantage of UW–Madison career fairs, which often bring in representatives from companies that are active in quantum computing research.

The first MSPQC class is nine students, and the vision for the program is to enroll 20-25 students each year. It has been a huge achievement to launch the first program of its kind in the country. With the increased workforce demand and the short time-to-entry into the workplace through this accelerated program, Joynt is optimistic the program is on its way up. So are the students.

"Given that we're the first cohort, the program is understandably a work in progress," Owens says. "But I think the program has a bright future ahead of it."



The Quantum Computing Report has tracked commercial job listings in QC on its website every month since June 2016. This graph shows the number of listings on a given day in the month listed. **Source: Quantum Computing Report,** https://quantumcomputingreport.com

Do you know a great candidate for the MSPQC program? Please invite them to visit go.wisc.edu/MSPQC or to contact Michelle Holland, Graduate Programs Coordinator (michelle.holland@wisc.edu) for more information.

A flier for the MSPQC program is available for download to print or share electronically at go.wisc.edu/a5iy50

Plasma physicists recreate the sun's solar wind and plasma "burps" on Earth

By Sarah Perdue, Department of Physics

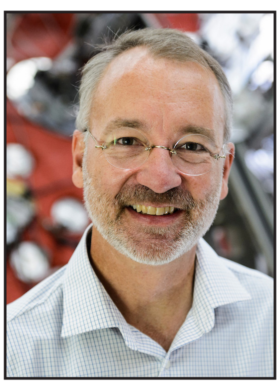
The sun's solar wind affects nearly everything in the solar system. It can disrupt the function of Earth's satellites and creates the lights of the auroras.

A new study by University of Wisconsin–Madison physicists mimicked solar winds in the lab, confirming how they develop and providing an Earth-bound model for the future study of solar physics.

Our sun is essentially a big ball of hot plasma — an energetic state of matter made up of ionized gas. As the sun spins, the plasma spins along, too. This plasma movement in the core of the sun produces a magnetic field that fills the solar atmosphere. At some distance from the sun's surface, known as the Alfvén surface, this magnetic field weakens and plasma breaks away from the sun, creating the solar wind.

"The solar wind is highly variable, but there are essentially two types: fast and slow," explains Ethan Peterson, a graduate student in the department of physics at UW–Madison and lead author of the study published in 2019 in Nature Physics. "Satellite missions have documented pretty well where the fast wind comes from, so we were trying to study specifically how the slow solar wind is generated and how it evolves as it travels toward Earth."

Ethan Peterson



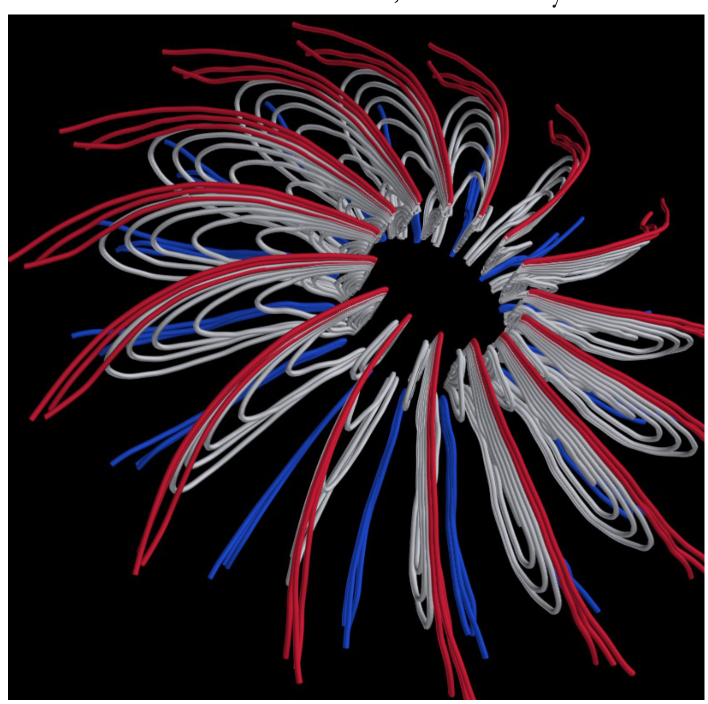
Cary Forest

Peterson and his colleagues, including physics professor Cary Forest, may not have direct access to the big plasma ball of the sun, but they do have access to the next best thing: the Big Red Ball.

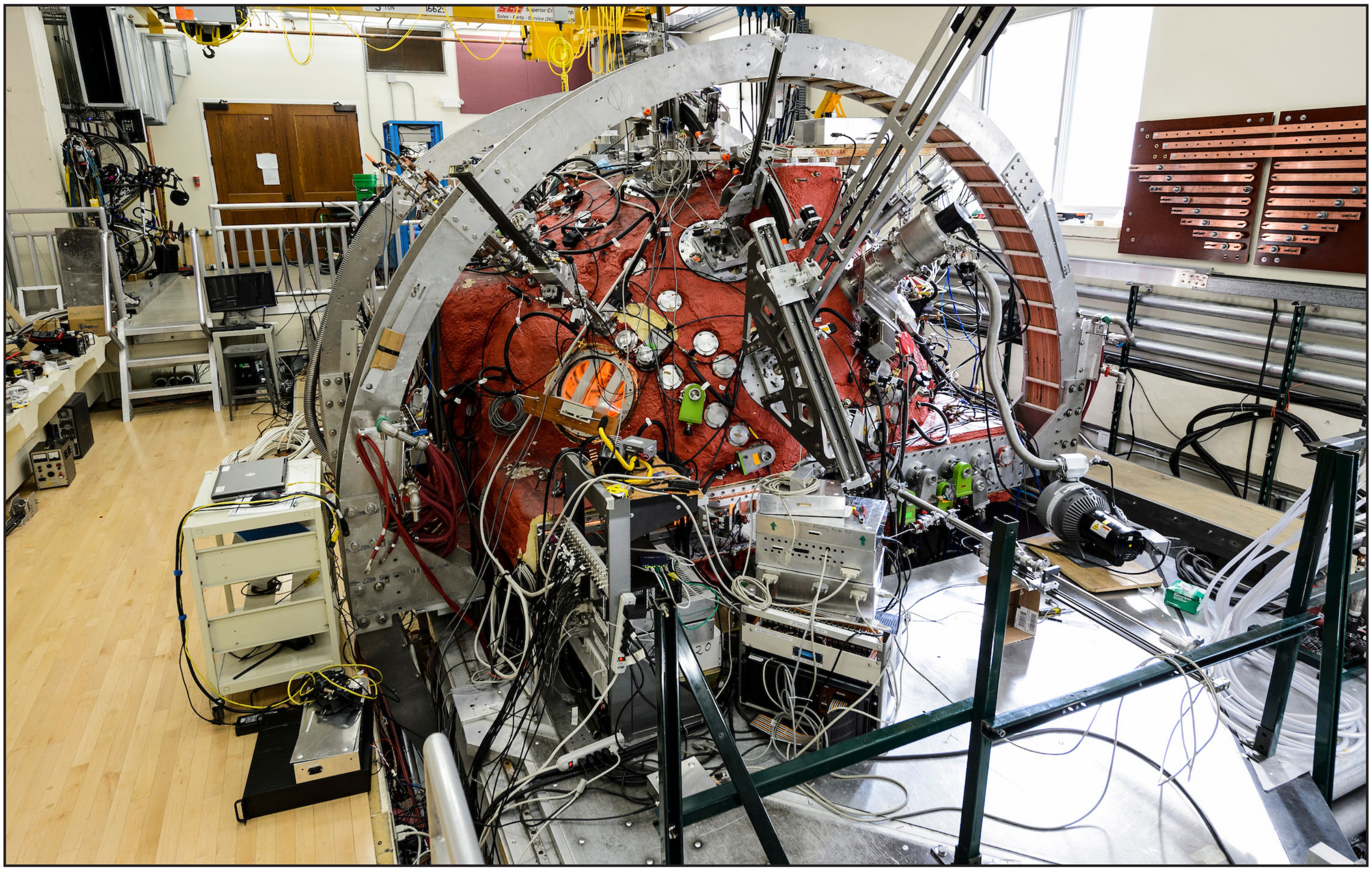
The Big Red Ball is a three-meter-wide hollow sphere, with a strong magnet at its center and various probes inside. The researchers pump helium gas in, ionize it to create a plasma, and then apply an electric current that, along with the magnetic field, stirs the plasma, creating a near-perfect mimic of the spinning plasma and electromagnetic fields of the sun.

With their mini-sun in place, the researchers can take measurements at many points inside the ball, allowing them to study solar phenomena in three dimensions.

First, they were able to recreate the Parker Spiral, a magnetic field that fills the entire solar system named for the scientist who first described its structure. Below the Alfvén surface, the magnetic field radiates straight out from the Sun. But at that surface, solar wind dynamics take



Axisymmetric rendering of the Parker Spiral, as published in the study.



The Big Red Ball is pictured in Sterling Hall. It's one of several pieces of scientific equipment being used to study the fundamental properties of plasma in order to better understand the universe, where the hot gas is abundant.

over, dragging the magnetic field into a spiral.

"Satellite measurements are pretty consistent with the Parker Spiral model, but only at one point at a time, so you'd never be able to make a simultaneous, large-scale map of it like we can in the lab." Peterson says. "Our experimental measurements confirm Parker's theory of how it is created by these plasma flows."

The researchers were also able to identify the source of the Sun's plasma "burps," or small, periodic ejections of plasma that fuel the slow solar wind. With the plasma spinning, they probed the magnetic field and the speed of the plasma. Their data mapped a region where the plasma was moving fast enough and the magnetic field was weak enough that the plasma could break off and eject radially.

"These ejections are observed by satellites, but no one knows what drives them," Peterson says. "We ended up seeing very similar burps in our experiment, and identified how they develop."

The researchers stress that their Earth-bound experiments complement, but don't replace, satellite missions. For example, the Parker Solar Probe, launched in August 2018, is expected to reach and even dip below the Alfvén surface. It will provide direct measurements of solar wind never obtained before.

"Our work shows that laboratory experiments can also get at the fundamental physics of these processes," Peterson says. "And because the Big Red Ball is now funded as a National User Facility, it says to the science community: If you want to study the physics of solar wind, you can do that here."

Maybe you've heard about this research already? That could be because it was covered a lot in the popular science press! Media outlets such as Wired, Quanta, Science News and many more all ran stories.

For the original UW–Madison story, please visit **go.wisc.edu/solarwind**

Board of Visitors Update

By Craig Heberer, Board of Visitors Chair

We're about 100 meters under the French countryside looking in awe at the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) at CERN. The sight is incredible.

CMS is immense: 21 meters long, 15 meters in diameter (approximately four and one half stories), and weighs about 15,000 tons. Approximately 3,800 people, representing 199 scientific institutes and 43 countries, form the CMS collaboration that built and now operate the detector.

The importance and history are equally immense: In July 2012, along with ATLAS, CMS tentatively discovered the Higgs boson. By March 2013, existence of the Higgs was confirmed [1]. The goal of the CMS experiment is to investigate a wide range of physics, not only the search for the Higgs boson, but also development of the standard model, the search for extra dimensions, and particles that could make up dark matter.

I break my mesmerized gaze and look at my fellow visitors: colleagues on the Physics Board of Visitors (BOV), friends of UW–Madison Physics and Department Chair, Sridhara Dasu. Effervescent chatter fills the air, rising above the din of crews working on CMS. I reflect and ask — How did this visit happen?

Spearheaded by Bob Joynt, Professor and Associate Chair for Alumni Affairs, the BOV was formed in 2012. Like BOVs of other UW–Madison departments, the sweeping role of the Physics BOV is to collaborate with the department to help define and achieve department goals. Some specific roles are listed above. We meet twice a year, usually on the UW–Madison campus.

The department and BOV have successfully collaborated on: increasing graduate student stipends, supporting Garage Physics, recruiting graduate students, and working with the Foundation on fundraising.

Roles of the Board of Visitors Include:

- Providing a professional network for our graduates
- Helping with outreach efforts
- Assisting in entrepreneurship
- Assisting in Ph.D. and MSPQC recruiting
- Advocating for the department at the campus level and beyond
- Working with UW Foundation for fundraising, including fund establishment

BOV members and others who attended the meeting at CERN in Geneva, Switzerland, show their "W" pride.

Dasu, a principal investigator at CMS, invited the BOV to visit at this particular point in time. Since LHC was down for scheduled upgrades, it allows visitors a unique opportunity to get up close to the various experiments, which is impossible when LHC is operational. Our visit included talks by UW–Madison Physics investigators Sridhara Dasu and Sau Lan Wu. Postdoc Muhammad Alhroob gave us a tour of the LHC control center. Postdocs Varun Sharma and Isabelle De Bruyn gave us tours of CMS. Sylvie Padlewski and Aimee Lefkow took care of countless details that made our trip delightful.

While trips like these are extraordinarily enjoyable, they also serve some important functions. They help establish and strengthen relationships between Faculty, Board members, alums, friends and the broader community. They help us gain a deeper understanding and appreciation of current research in physics and UW Physics in particular. They also help transform abstraction to physical reality — bridging the abstractions of theoretical physics and the physical reality of experimental physics. We hope to have the opportunity to do other visits like this in the future.

For more information, please contact
Bob Joynt | rjjoynt@wisc.edu | 608.263.4169
Craig Heberer | craig.heberer@gmail.com
Or visit physics.wisc.edu/people/bov

[1] Wikipedia: https://en.wikipedia.org/wiki/Compact_Muon_Solenoid

Get to know the new BOV members

Fatima Ebrahimi, PhD '03

Current role:
Principal research physicist at the Princeton Plasma Physics Laboratory, affiliate research scholar at Princeton.

Why join the Board?
I believe plasma physics should be treated as a unifying field of space, astrophysical, fusion and plasma laboratory research, and should be one of the strong thrusts of research and education in physics departments. The physics department at UW has been exemplary in the US to foster all aspects of plasma physics research. I wish to contribute to further strengthening of the plasma physics program, in particular to fully support the next generation of fusion experiments at the department, and to encourage the right scientific atmosphere of close collaboration between theory/computation and experiment, as I experienced during my graduate studies at the UW physics department.

What is your favorite physics concept to explain to others?
The sun as a natural laboratory for plasma physics provides inspiring as well as challenging problems, including rapid dynamical processes, magnetic explosions on its surface, and the replication of its core reaction, fusion energy, on earth in a lab. One of the intriguing physics topics to me is understanding the generation and topological rearrangement of magnetic field in both natural and laboratory plasmas. This basic physics has also inspired some innovative techniques in magnetically confined fusion plasmas.

What else should we know about you?
I enjoy walking and hiking in nature with my husband, these days also with my eight year old son. I have a daily habit of reading at least one poem by the Persian poet Hafez.

Joshua Friess '02, PhD

Current role:
Founder and Consultant, Two Point Strategic Consulting

Why join the Board?
I was interested in joining the Board of Visitors first and foremost out of gratitude and appreciation for the opportunities I've had as a result of my time spent in the UW Physics department. Hopefully I am able to give back to the department in some way through participation on the Board. Without question, UW Physics positioned me well for success in graduate school and beyond by further developing my skills as a quantitative thinker. As far as how I might contribute, to the extent that the department may seek feedback on or even assistance with its strategic planning efforts from the Board, my prior experience in this area could be helpful.

What is your favorite physics concept to explain to others?
There are so many ideas in physics that are fascinating to non-physicists. Many of the ideas that come to mind tend to be highly speculative, maybe even verging on the philosophical rather than the physical, but nevertheless intriguing. "Many world" quantum mechanics tends to come to mind, even though I'm personally not a fan of the idea. But, it's a pretty simple concept that requires very little prior knowledge of physics, and yet people can really latch onto it. It's a similar story with anything involving "extra dimensions". It seems that whenever some idea posits that reality is pretty fundamentally different than what we naively observe it to be, people tend to take notice!

What else should we know about you?
I enjoy learning languages, and I am still a little sad that Game of Thrones has ended. In addition to the Board of Visitors, I also serve on the boards of the National Association for Urban Debate Leagues, the Association of Princeton Graduate Alumni, and Princeton's Alumni Council Executive Committee.

Giving Matters: Scholarship helps a student get the most out of their Physics education

By Sarah Perdue, Department of Physics

Roger Hagengruber '66, Ph.D. '72 and Josh Cherek '16 may have completed their undergraduate physics degrees at UW–Madison 50 years apart, but they have much in common.

Both hail from smaller towns in Wisconsin. Both were interested in areas of physics including nuclear and plasma (Hagengruber earned his doctorate with Heinz Barschall; Cherek met with Cary Forest on his first day on campus and went on to work with him). And both know how difficult it can be to be a student while worrying about paying for their educations.

As an undergraduate, Hagengruber worked as an hourly worker for Barschall's nuclear physics group. Barschall then offered to take Hagengruber as a graduate student, but Hagengruber was unsure how he would be able to afford it while also needing to help support his wife and two small children. Cherek says his financial situation was tight, and being able to fund his schooling was limiting his ability to fully participate as a student.

Hagengruber recalls that he was able to start and complete his doctorate because the department offered him a departmental NSF traineeship and allowed him to work as a quarter-time teaching assistant.

"If it hadn't been for the department's generosity and support of me, I probably wouldn't have been able to go to graduate school and finish with my doctorate in nuclear physics without substantial debt," Hagengruber says. "By the time I finished my Ph.D., I had three kids and a wife, and my wife was able to stay home because of the traineeship and take care of the kids."

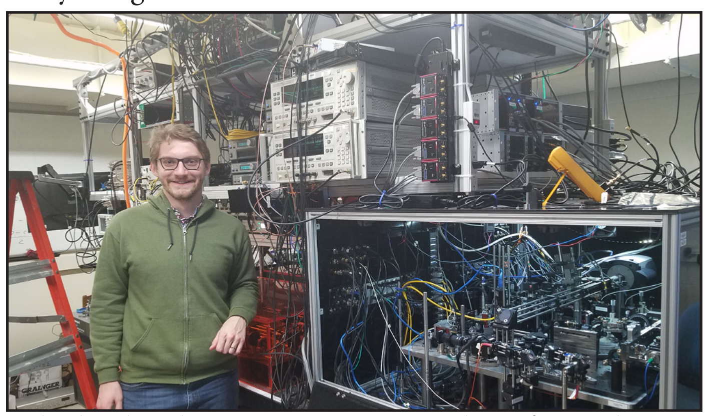
Hagengruber went on to have a 31-year career at Sandia National Laboratories, from which he retired as senior vice president for national security. He served on national and international nuclear security and non-proliferation committees, and was a member of the management of Los Alamos National Laboratories for several years. He taught at Western Michigan University and the University of New Mexico.

In 2013, he decided he wanted to help physics students at UW–Madison who, like he did previously, could use a financial boost to complete their studies. Already giving to the department and College of Letters & Sciences, he spoke with a UW Foundation development officer and decided to additionally fund a scholarship.

"I wanted the department to have a tool that they could use to award to students from Wisconsin that showed promise in physics," Hagengruber says. "It was intended for the department to send a signal to a student that the department was optimistic about their future. The award was intended to be an encouragement."

In 2014, Cherek received the first Hagengruber Scholarship.

"That award really helped me get through school," Cherek says. "It also allowed me to not just stress about trying to fund my education, but to spend time on campus really being more involved."



Josh Cherek with a quantum computer in the Saffman Lab.

After graduation, Cherek first accepted a research and development job with an insurance company, and now works in software engineering at the Madison office of ColdQuanta, Inc., a quantum computing company at which physics professor Mark Saffman is the Chief Scientist for Quantum Information. Cherek, who also worked in Saffman's group as an undergrad, was employee number one at the Madison office.

"This degree from UW–Madison and getting to know people at the cutting edge of the field — those things combined, I think, are what really helped me get these jobs," Cherek says. "The scholarship allowed me to spend more time going to seminars and talking to people, to learn what else was going on. It was a huge help."

2019 Physics Award Banquet

The 2019 Physics Banquet & Awards Ceremony, which honors the department award recipients and alumni fellows, was held on Friday, May 3, 2019 at Memorial Union. We honored our award winners with a reception, dinner, and an awards ceremony for their family and friends.

UNDERGRADUATE AWARDS


Fay Ajzenberg-Selove Award

Lauren Laufman (left) and Ariana Blair (right)

This award is presented to undergraduate women majoring in Physics, Astronomy, or Physics/Astronomy to encourage them to continue their careers in science. The late Dr. Ajzenberg-Selove was a distinguished nuclear physicist who received her Ph.D. in Physics at UW in 1952 and spent most of her career as Professor at the University of Pennsylvania.

Dr. Maritza Irene Stapanian Crabtree Award

Mari McPheron

This fund was established by William Crabtree to honor his wife, Dr. Maritza Crabtree, who graduated with a Physics degree in 2917. This annual award benefits undergraduate students in Physics based equally on merit and need.

No Photo Available

Bernice Durand Research Scholarship

Arianna Ranabhat

This award was established by Emerita Physics Professor Bernice Durand to promote meaningful undergraduate research and to support and encourage women and ethnic minorities as undergraduate majors in Physics and Astronomy.

UNDERGRADUATE AWARDS

Albert Agustus Radtke Scholarship

No Photo Available

Luquant Singh

This award stems from a bequest by the late Mrs. Elizabeth Radtke to the University of Wisconsin–Madison to recognize outstanding junior and senior undergraduate students majoring in Physics or AMEP.

Hagengruber Scholarship

Keegan Downham

This scholarship was established by Roger Hagengruber, for a Wisconsin resident undergraduate Physics student who shows exceptional promise for a future in Physics.

Henry & Eleanor Firminhac Scholarship

Gage Siebert

The Fund was established by former University of Wisconsin–Madison graduate, the late Ralph Firminhac (BS '41, MS '42). He created this scholarship in memory of his parents, Henry and Eleanor Firminhac.

Liebenberg Family Scholarship

Brandon Radzom

This scholarship is awarded to Physics, AMEP or Astronomy/Physics majors. This scholarship opportunity was initiated by the Liebenberg family for the purpose of promoting undergraduate summer research opportunities.

GRADUATE AWARDS

Charles Elwood Mendenhall Award

Susan Sorensen

This award was made possible through the generosity of the Charles Elwood Mendenhall estate. Mendenhall received his Ph.D from Johns Hopkins in 1898. He was a faculty member in the Department of Physics from 1901 until his passing in 1935.

Allan M. and Arline B. Paul Physics Award

Ping-Yu Li

The late Mrs. Arline Borer Paul (1914-2012) created this endowment fund for graduate students in memory of Walter Max Borer. Walter was Arline's brother and received an MS degree in 1937.

GRADUATE AWARDS

Emanuel R. Piore Award

Qinrui Liu
This award is made possible through the generosity of the Piore family. It is awarded to the graduate student with the highest score on the qualifier exam.

Hallet H. and Mary F. Germond Award

Leah Tom
This award provides support for graduate students in the Department. Hallet Hung Germond received his Ph.D. in mathematical physics from UW in 1927.

James Nelson Humphrey Award

Barış Özgüler
This award supports graduate students in physics. James Nelson Humphrey was born in Whitewater, WI, and played the French Horn in the UW Marching Band while pursuing his Master's Degree in physics.

Karl Guthe Jansky & Alice Knapp Jansky Award

Adrian Fraser
This award alternates annually between an outstanding graduate student in Physics and one in Astronomy. Karl Guthe Jansky received a BA and MA in physics in 1927 and 1936, respectively.

Elizabeth Hirschfelder Scholarship

Emily Lichko
This award is to assist women graduate students in physics at UW–Madison

Cornelius P. and Cynthia C. Browne Award

Zachary Buckholtz
This award is established to support graduate students pursuing experimental degrees, in honor of Cornelius Browne.

Van Vleck Award

David Gold
This award provides support to graduate students in the department.

DEPARTMENT TA AWARDS

Joseph R. Dillinger Award for Teaching Excellence

Ben Lemberger

Best Teaching Assistant (Spring 2018)

Josh Karpel

Best Teaching Assistant (Fall 2018)

Mitch McNanna

Rookie of the Year

Benjamin Harpt

DISTINGUISHED ALUMNI AWARDS

Greg Piefer

Ted Strait

UW–Madison Physics Degrees Awarded

Undergraduate Degrees

Fall 2018

Adam Berthiaume
Tylor Adkins
Shuo Wei

Spring 2019

Alexandra Borukhovetskaya
Sara Branson
Roman Nathaniel Burridge
Nicholas Christensen
Serkan Comu
Aniket Dalvi
Phillip Edward Flinchum
Nicholas Thomas Friedl
Kevin Gayley
Nicholas Orion Girdis
Dylan Hatch
Alec Helfenbein
Molly Hetzel
Robert Jacob Houillon
Alexander Hryciuk
Li Jin
Genevieve Angeline Kearns
Evan Koenig
Patrick LaChance
Kevin Langhoff
Lauren Laufman
Patrick James Leonard
Alphonse Marra
Jose Maria Martin de Oliva Carranza
Christopher Marzouki
Chandler Purcell
Gretchen Shirley Quade
Wangping Ren
Joseph Schwartz
Lucas Stiemann
Marc Tost
Niklas Kieran Vakil
Zachary Way
Aaron John Wildenborg
Tim Winfree
Moses Cheng Qing Wong
Jerry Zhang
Xinning Zhao
Huaxia Zhou

Master's Degrees

Fall 2018

Dylan Adams

Spring 2019

Tim Gu
Alex Loving

Summer 2019

Alex Scherer

Doctoral Degrees

Fall 2018

James Buchanan
Advisor: Dasu

Adam Frees
Advisor: Coppersmith, Friesen

Kevin Ghorbani
Advisor: Halzen

Zhenyi Qi
Advisor: Vavilov

Nicholas Smith
Advisor: Smith

Dallas Wulf
Advisor: McCammon

Spring 2019

John Boguski
Advisor: Sarff

James Bourbeau
Advisor: Vandenbroucke

Kyle Bunkers
Advisor: Sovinec

Samuel Fahey
Advisor: Vandenbroucke

Konstantinos Horaites
Advisor: Boldyrev

Cameron King
Advisor: Coppersmith

Minho Kwon
Advisor: Saffman

Benjamin Lemberger
Advisor: Yavuz

Sida Lu
Advisor: Bai

Matthew Meehan
Advisor: Vandenbroucke

Gandhari Wattal
Advisor: Heinz

Logan Wille
Advisor: Halzen

Zichuan Anthony Xing
Advisor: Den Hartog

Edward Leonard, Jr
Advisor: McDermott

Kenneth Long
Advisor: Herndon

Andrew Loveridge
Advisor: Hashimoto

Brandur Thorgrimsson
Advisor: Eriksson

Garth Whelan
Advisor: Terry

Zach Williams
Advisor: Terry

Yuan-chi Yang
Advisor: Coppersmith, Friesen

Summer 2019

Phillip Bonofiglo
Advisor: Egedal

Zachary Griffith
Advisor: Halzen

Graduate Class of 2019

PhD Program

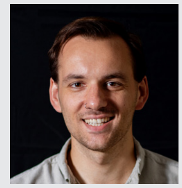

Sohair Abdullah

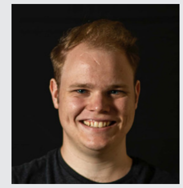

Ryan Albosta


Anagha Aravind


Vedant Basu

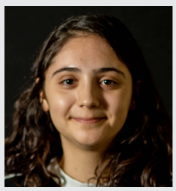

Abby Bishop


Matt Cambria


Jack Dolde

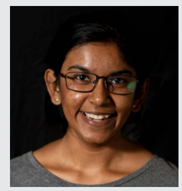

Ricardo Dos Santos Ximenes

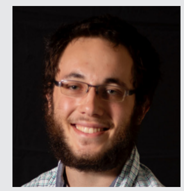

Joey Duff


Daniela Girotti-Hernandez


Jaglul Hasan


Joon Suk Huh


Nidhi Kandathpatinharuveetil

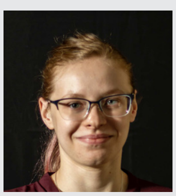

Cameron Kuchta


Sarah McCarthy

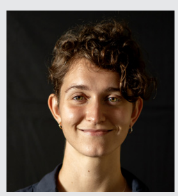

Susmita Mondal


Soren Ormseth

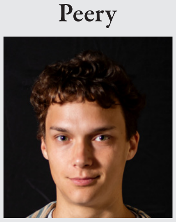

Ganesh Parida

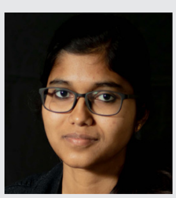

Jill Peery

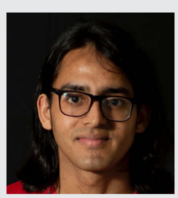

Josh Peterson


Rachel Sassella


Jacob Scott

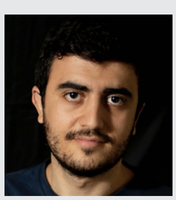

Keenan Smith

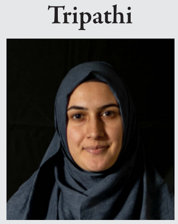

Lekshmi Thulasidharan


Bindesh Tripathi

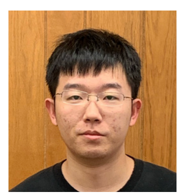

Justin White

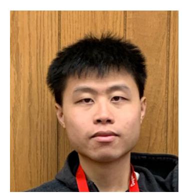

Tian Xie


Emre Yildizci


Zaynab Yildizci

MSPQC Program


Yi Feng


Ryan Leong


David Morser


Carlos Owens


Josh Ramer


Paul Totzke


Jacques Van Damme


Reid Vorbach


Delano Yoder

GIFT GIVING GUIDE

The department's greatest need continues to be the ability to fill gaps in funding between extramural research support ("grants") and university-supplied funds to support faculty, students, and staff in research, professional development, travel, and to remain on the cutting edge of research and teaching.

PRIORITY FUNDS

Physics Newton Fund

Administered by the Department Chair, this general, unrestricted fund aids the department in its research, teaching, and public service roles

Physics Alumni Graduate Award Fund

Provides support to incoming graduate students who hold Teaching Assistant appointments in the department

Physics Board of Visitors Undergraduate Research Fund

Provides funding for awards that will assist directed study projects in pure and applied physics; multidisciplinary projects linking physics to such fields as biology, engineering, business, and creative expression; and participation in related conferences

OTHER DEPARTMENT FUNDS

UNDERGRADUATE

Fay Ajzenberg-Selove Scholarship Fund

Dr. Maritza Irene Stapanian Crabtree Undergraduate Scholarship Fund

Bernice Durand Undergraduate Research Scholarship Fund

Henry & Eleanor Firminhac Physics Scholarship Fund

Liebenberg Family Scholarship in Physics Fund

Hagengruber Fund

GRADUATE

Allan M. and Arline B. Paul Physics Fund

Carl and Brynn Anderson Graduate Physics Fund

Cornelius P. and Cynthia C. Browne Endowed Fellowship Fund

Joseph R. Dillinger Teaching Award

Albert R. Erwin, Jr. — Casey M. Durandet Graduate Student Fund

Elizabeth S. Hirschfelder Endowment for Graduate Women in Physics

Karl Guthe Jansky & Alice Knapp Jansky Fellowship Fund

Van Vleck Fellowship

E. R. Piore Award Fund

Phyllis Jane Fleming Graduate Student Support Fund

Gerald W. and Tui G. Hedstrom Physics Fund for Graduate Support

Roberston Leach Graduate Student Fund

Graduate Student Recruiting Fund

L. Wilmer Anderson & Dave Huber Graduate Support Fund

Robert M. St. John Graduate Support Fund

Jeff and Lily Chen Wisconsin Distinguished Graduate Fellowship

Raymond G. and Anne W. Herb Wisconsin Distinguished Graduate Fellowship

GENERAL

Barschall Enterprise Fund

Ray Macdonald Fund for Excellence in Physics

Friends of the L.R. Ingersoll Museum Fund

Willy Haeberli Fund for the L.R. Ingersoll Physics Museum

David Grainger Physics Library Energy Sources College Fund

Physics Community Building Fund

Jane and Clarence Clay Fund for Chaos and Complex Systems

Raymond G. and Anne W. Herb Endowment Fund in Physics

L.R. Ingersoll Physics Fund

Dalton D. Schnack Memorial Fund

Wonders of Physics Outreach Fund

Atomic Collision Research Fund

Elementary Particle Physics Institute Fund

Quantum Computing Research Center Fund

Thomas G. Rosenmeyer Cosmology Fund

John H. Van Vleck Physics Endowment Fund

ENDOWED CHAIRS

Bernice Durand Endowed Chair in Physics Fund

Martin L. Perl Chair Fund

Emanuel Piore Professorship Fund

Please visit https://wp.physics.wisc.edu/giving/funds/ for fund descriptions or to make a secure gift with your credit card. **A mail-in donation form may be found on page 24 of this newsletter.**

Support Physics

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P.O. Box 78807
Milwaukee, WI 53278-0807

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Cardholder Signature: _________________________________ Date: __________________

Your name (if different from cardholder): ____________________ Home phone: _____________

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City, State, ZIP: ____

MY GIFT

I wish to designate my Gift to the following fund(s) (please see Page 23 for fund details)

☐ **Physics Newton Fund**

☐ **Physics Alumni Graduate Award Fund**

☐ **Physics Board of Visitors Undergraduate Research Fund**

☐ **Other fund (please write in fund name):** _____________________________________

Should you prefer to make your donation electronically by credit card on a secure server, please go to https://wp.physics.wisc.edu/giving/funds. Click on the fund in which you are interested for more information, and then complete the UW Foundation secure site form.

If you wish to consult with a UW Foundation Development Officer on your gift or other options including estates, trusts, gifts in kind, or planned giving, please contact Mae Saul, Development Director for Physics, by phone at (608) 216-6274 or by email at mae.saul@supportuw.org

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

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Madison, WI 53706-1390