Physics@UVM

SPOTLIGHT ON PHYSICS

Physics research, faculty/student profiles and a message from the Chair, Dr. Dennis Clougherty, are featured in this month's CAS spotlight.

Message from the Chair:

We are privileged to live during a time of great scientific discovery. In recent years, we have witnessed enormous leaps in technology, ushering in the electronic and information revolutions that have reshaped our world. These transformational changes have their origins in fundamental research in physics.

At UVM, physicists have a long history of making important contributions to our understanding of the physical world; Dr. Wesley Nyborg, a member of the National Academy, is also a distinguished member of our physics faculty. His pioneering research over the past five decades in physical acoustics has helped make ultrasound imaging a safe and effective medical tool. In October, UVM celebrated the career of Professor Nyborg with a symposium featuring lectures by an international slate of prominent scientists. News from the symposium is featured in the physics events spotlight link.

Driven by the promise of new technologies and the development of a deeper understanding of our physical world, our talented faculty and students pursue ambitious research programs; for example, Dr. Randall Headrick, a 2004 NSF CAREER Award winner, is working to make low-cost, efficient photovoltaic materials. In his laboratories in Cook, he is busy inventing and patenting new methods of making organic thin films that could be used to harvest solar energy. You can read more about Professor Headrick and his research group in the graduate research link.

Our faculty members are committed to delivering the highest quality education in physics at both the undergraduate and graduate levels. We are fortunate to attract top students to our programs. This year, we applaud the accomplishments of Isabel Kloumann, a junior physics major from South Burlington, Vermont, who was named a Goldwater Scholar, and Kameron Harris, a 2009 physics graduate, who was awarded a Fulbright scholarship. More information on Isabel and Kameron is available in the physics undergraduate news link.

At the graduate level, the physics professional master's program was cited by the American Institute of Physics as one of the nation's top programs of its kind. We point with pride to a long roster of successful UVM physics alumni who have been trained by our faculty; for example, Dr. Richard Packard, Professor of Physics at UC Berkeley and a UVM Physics alumnus, is a leader in science. On the basis of his path breaking research in low temperature physics, Professor Packard was recently awarded the prestigious London Prize by the International Union of Pure and Applied Physics. In recent years, many UVM physics graduates have gone on to successful careers in academia, at national laboratories and the private sector with high tech and consulting firms.

I invite you to learn more about UVM physics by following these physics spotlight links. Detailed information about our degree programs and faculty research is available at uvm.edu/physics. I am very pleased to have the opportunity to share with you some news from our department. Thank you for your interest in physics at UVM.

Astrophysics research: Pulsar physics at UVM

Pulsars: some are 10 miles wide and heavier than the sun. Undergraduate researchers Isaac Backus and Isabel Kloumann are helping to draw a portrait of the "rotating carousel" of radio waves that shines forth from these strange stars.

(Photo: Joshua Brown)

To the Cosmic Lighthouse (By Joshua Brown)

And you thought the remote for your TV was tricky? Isabel Kloumann and Isaac Backus, both undergraduate students, sit in a cinderblock office on the fifth floor in the Cook Building entering coordinates into an iMac computer. One-thousand-eight-hundred-forty-seven miles away — in a limestone sinkhole on a mountaintop in Arecibo, Puerto Rico — the world's largest telescope moves to their commands.

"It's like playing a slow video game," says Kloumann.

Far stranger are the objects they are pointing the telescope toward: pulsars many light years away.

Compared to a black hole, a pulsar is a kind of scrawny cousin not quite massive enough to fall into complete light-sucking density. Still, these strange objects are staggeringly dense, holding about a billion tons per square centimeter. Imagine a teaspoon of sugar that weighed as much as three thousand Empire State Buildings.

"Pulsars are about the size of Burlington with mass comparable or greater than the sun," says UVM astrophysicist Joanna Rankin, who has employed Kloumann and Backus as independent researchers. "What we're observing this morning are city-sized remnants of medium-massed stars."

Contact?

This observing depends on the Arecibo telescope that Rankin and her students use several times each year through funding from the National Science Foundation. With a reflecting dish a thousand feet across and a colossal cable system to carry the receiver hither and yon overtop, the telescope gathers radio waves pouring in from clouds of cold gas throughout the Milky Way and beyond, like the famed Andromeda galaxy.

But the telescope also records the compact, highly regular, on/off bursts of radio energy that come from pulsars. ("Pulsar" is a contraction of pulsating star.). As these spheres of hyper-dense neutrons spin — some rotating once every few seconds, some hundreds of times per second — they shoot out two cones of radio emissions from above their boggglingly powerful magnetic poles.

"It's just like a lighthouse," says Kloumann, "every time it sweeps past, you get a flash." But, in 1967, when the first pulsar was discovered by an enterprising graduate student named Jocelyn Bell, nothing like it had ever been observed in the heavens. Nothing like it was even imagined.

"How could it be that we have a compact natural radio transmitter sending signals across the galaxy?" says Rankin, "it was completely unexpected."

"They were originally thought to be aliens," says Kloumann and so the first pulsar was dubbed LGM-1.

"The little green men turned out to be pulsars," says Backus.

Astrophysics research: Pulsar physics at UVM continued...

Flashy, with substance

Forty years later, more is known about pulsars, but their extreme physics are still mysterious. “We have a cartoon that is probably right,” says Rankin, “they tap their rotational energy — somehow — and turn it into radio waves.”

“A pulsar is highly conductive,” she says “as it rotates, it acts like a dynamo and you get huge electrical potentials across the star.”

“Those potentials appear in a narrow column of magnetic field above the star’s magnetic poles,” she says, and serve as the power source for the radio transmissions. Or something like that.

“We don’t exactly understand the emissions processes,” she says, “is it more like a laser or clouds of particles?”

To even get to the cartoon stage of understanding, astrophysicists like Rankin have tried to decipher the signature of emissions that different kinds of pulsars produce. And her students do the same.

“The flash is not just a flash,” says Kloumann, “it has structure to it.”

“If you shine a flashlight at the wall, some parts are bright, some are dim,” says Backus. Ditto for pulsar emissions. The radio beam surges and shifts like a rotating carousel of lights. Or consider pulsar B1944 + 17 that Kloumann has been studying on her own for the past year. Sometimes it just turns off. And no one is exactly sure why.

“We’re looking at these really unusual stars that don’t fit the perfect model,” she says. “They test the bounds of the theory — which is what you always should do in science: push the limits of the theory.”

Both Kloumann and Backus are publishing scientific papers as the first author. Or at least they’re optimistic. Backus has submitted his paper comparing two unusual pulsars to the well-regarded astronomy journal, the Monthly Notices of the Royal Astronomical Society. The journal’s referees, “liked it,” he says. “The comments were mostly about grammar. Well, with a few other things.”

Kloumann — an Honors College student, Goldwater Scholar, and “one of UVM’s stars in physics and mathematics,” says Rankin — will be submitting her study of pulsar B1944 + 17 to the same publication.

“My freshman year I wanted to be involved in research, so I went and found Joanna,” Kloumann says.

“I worked one-on-one with her every week and she would tell me about pulsars for three hours!” Kloumann says. “She’s a great mentor. She’s given us a lot of freedom and flexibility. And she’s there when you need her.”

Kloumann, Backus, and graduate student Megan Force have worked closely together, and each has had a chance to travel to Arecibo with Rankin to see the telescope in action.

“You feel like Galileo,” says Force, “right there next to the machine.”

The pulsar is in the details

For her part, Rankin calls herself a pulsar sociologist. “I make exploratory observations of a large number of pulsars looking for common features and then I am able to identify a set that would be interesting to study,” she says.

“Most of physical science is confirmation of theoretical expectations. That’s not quite what we do in some parts of astronomy — including pulsar work — because we don’t know enough,” she says.

“You can think of what I do as phenomenology, which isn’t quite theory. It’s observationally based efforts to identify what are the important physical principles,” she says. “What I hope my work will do is to stimulate theorists to do a better job with the mathematical theory, using Maxwell’s equations and quantum mechanics, to figure out, in detail, why pulsars work the way they to. And that’s a very complex problem.”

“The early theories were heroic, but they were wrong,” she says, and then turns back to her computer to adjust some power levels on the telescope in Puerto Rico. “You can’t study pulsars in general; you have to deal with the specifics.”

Undergraduate News:

Isabel Kloumann, a junior physics major, was named a 2009 Goldwater Scholar. Goldwater Scholars are selected on the basis of academic merit from a field of typically over one thousand mathematics, science, and engineering students who were nominated by the faculties of colleges and universities nationwide. Goldwater Scholars have very impressive academic qualifications that have garnered the attention of prestigious post-graduate fellowship programs. Recent Goldwater Scholars have been awarded 73 Rhodes Scholarships, 102 Marshall Awards (7 of the 40 awarded in the United States in 2009), and numerous other distinguished fellowships.

Kameron Harris, a 2009 UVM physics graduate, was named a 2009 Fulbright Scholar. Kameron will begin work on his project entitled "Traffic Modeling for a Busier World" in March 2010 in Valparaiso Chile. There, he will work with Andres Moreira, a computer scientist with the Universidad Tecnica Federico Santa Maria (UTFSM), as his advisor, and Eric Goles, mathematician and director of the Instituto de Sistemas Complcjos de Valparaiso, with whom both will collaborate. In addition to his research, Kam will enter the computer science master's program at UTFSM. Kam will use his Fulbright fellowship to study current issues related to mass traffic associated with Transantiago, the new bus system in Santiago, Chile.

Nyborg Symposium

On Saturday, October 10, 2009, the University of Vermont hosted a special symposium in celebration of Dr. Wesley Nyborg's fiftieth year in the Department of Physics and honoring his pioneering work in the field of physical acoustics and biomedical ultrasound. The symposium featured a morning session of invited papers related to Dr. Nyborg's research interests and a brief afternoon session of contributed papers. The celebration continued with an evening banquet held in the Livak Ballroom of the UVM Davis Center.

Professor Richard Packard (UC Berkeley) praised Dr. Nyborg as a researcher, educator and mentor at the symposium banquet.

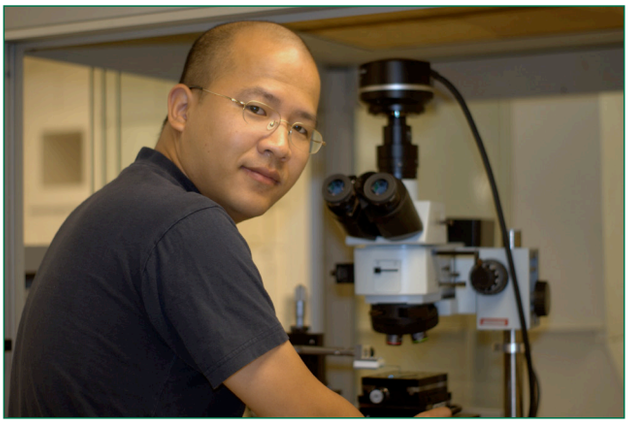
Professor Wesley Nyborg (left) with his former graduate student Professor Douglas Miller (University of Michigan) and Professor Marvin Ziskin (Director of the Center for Biomedical Physics, Temple University).

Professor Nyborg receives a gift from Dr. Lian Zhang (Chongqing University, China).

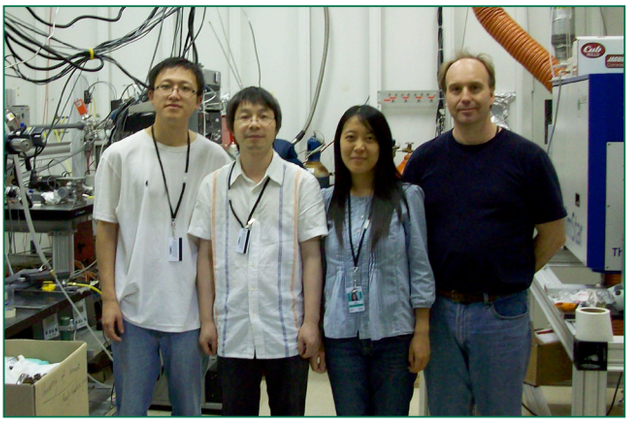
Ms. Annemieke Spoelstra performed a program of Chopin piano concerti to conclude the evening.

Professor Randall Headrick

Since coming to UVM from Cornell University in 2001, Professor Headrick's research has primarily focused on finding new ways to make and characterize thin films of metals and semiconductors. In his laboratories on the fifth floor of Cook Building, he and his research team are busy growing films of organic semiconducting materials with an eye to making the next generation of photovoltaic materials. He has developed a method of making thin films from liquid solutions by "painting" them onto a surface, an idea which has earned a United States Patent in 2008 because of the potential to produce solar cells or organic electronic circuits with high performance but very low cost. Headrick's group is also studying several other methods of making films, and are currently working on a laser deposition method that uses a beam of light to vaporize materials for films that can be used in magnetic data storage devices. The group combines their thin film deposition work with studies of the molecular structure of the films using x-ray beams from the National Synchrotron Light Source on Long Island, and studies how the structures relate to the electronic, magnetic, and optical properties of the materials. Dr. Headrick currently serves as Director of the Materials Science Program at UVM, an interdisciplinary program involving researchers from CAS, CEMS and COM. Two of Professor Headrick's graduate students, Mr. Songtao Wo and Ms. Lan Zhou are expected to finish their PhD work in Materials Science by May, 2010.



Songtao Wo, a graduate student in Dr. Headrick's group, with the thin film deposition equipment that they recently constructed. This research is supported by the National Science Foundation (NSF MRI #DMR-0722451 and CAREER #DMR-0348354).



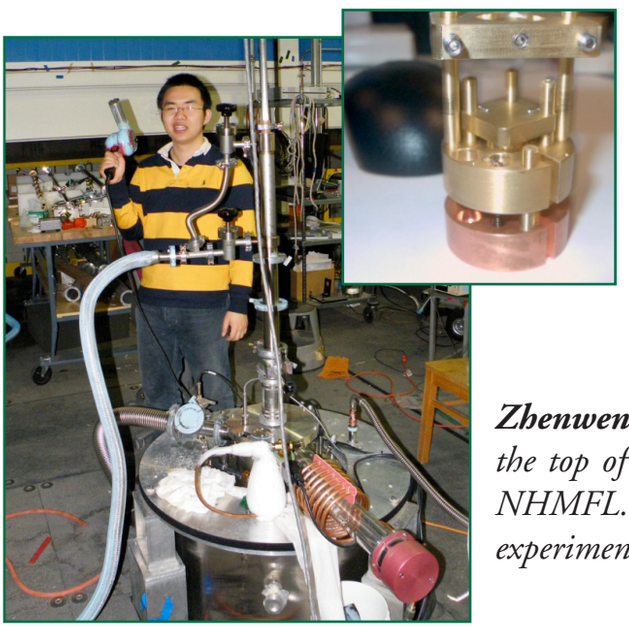
Some of the Headrick group during their first laser deposition this year at Brookhaven National Laboratory, Upton, NY. Group members, from left to right are: Minghao Li, Yiping Wang, Lan Zhou, and Randall Headrick. This work is supported by the United States Department of Energy (DE-FG02-07ER46380).

Professor Madalina Furis

Professor Furis's research group explores the quantum realm of novel nanostructured materials where the intrinsic spin of the electrons shapes the materials' properties. The team is currently conducting optical spectroscopy experiments to probe properties of electrons in nitride semiconductor nanostructures and crystalline organic semiconductor films. Such materials are of interest for many energy-saving applications such as solid state lighting, spin-based computing and photovoltaic devices for solar energy harvesting.

Since arriving in 2006, with support from the National Science Foundation, Professor Furis has been building UVM's first magneto-microscopy facility that integrates the latest generation of ultrafast lasers with superconducting magnet technology and top-of-the-line polarization optics into spectroscopy experiments that map electron spin dynamics at micron resolution in high magnetic fields. The facility will be used by faculty in physics, chemistry and engineering to conduct high magnetic field studies of electrons in a variety of materials systems, including semiconductor nanostructures, proteins and polymers. Such systems are of interest for many applications ranging from quantum computing to nanotechnologies and imaging-based diagnostics.

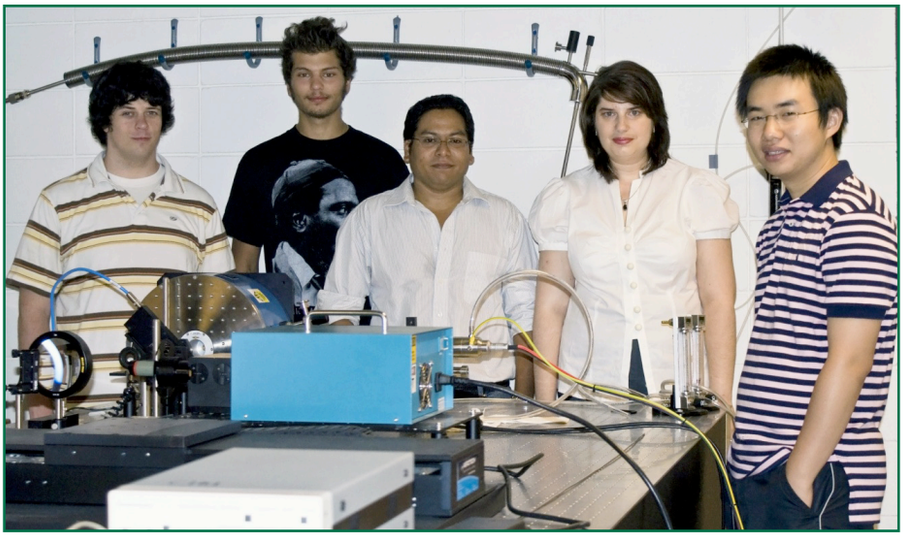
Professor Furis and her students are also conducting very high magnetic field experiments at the National High Magnetic Field Laboratory (NHMFL) in Tallahassee Florida. As a member of the lab Users Executive Committee, Professor Furis is involved in the development of experimental infrastructure around the upcoming Florida Split Coil Helix 25 Tesla magnet, a ground breaking piece of technology that will enable research in electron spin physics and ultrafast phenomena never accessible till now. She was also recently featured as one of the promising young high magnetic field scientists in the "Science Starts Here" profile series of the NHMFL.



Current members of the group include PhD Materials Science students Zhenwen Pan, Naveen Rawat and Lane Manning and undergraduate physics majors Chris Libby and Margaret Sutton. More details about projects and research group members can be found on the group's webpage.

Zhenwen Pan, *a graduate student in Dr. Furis's group, next to the top of the ten foot -high 17T SCM3 optics magnet at the NHMFL. The inset shows the sample mount he designed for the experiment run of April 2009.*

Professor Madalina Furis continued...



Some of the Furis past and present group members with the first high field experimental setup at the magneto-optics lab located in Cook Building. From left to right: *Chris Libby (junior physics major), Eli Kinigstein (junior physics major) Naveen Rawat (PhD graduate student–Materials Science) Madalina Furis and Zhenwen Pan (PhD graduate student–Materials Science). This work is supported by the National Science Foundation (DMR 0821268).*