the Physics Illinois Bulletin

Fall 2013
Vol. 2 No. 1

Nanoscale resolution MRI

Nanotechnology for DNA Sequencing

Alumnus John Clem remembered

Best practices for STEM education reform

Dark Energy Survey begins

PhySoc to merge with national society

Department of Physics
College of Engineering
University of Illinois at Urbana-Champaign

A Message from the Head: 2014

Dear colleagues, alumni, and friends,

Watch us now! This will be a very exciting year in the Department of Physics as a phase transition that will sustain and enhance our excellence in education and research starts to take place. For several years, I have been telling everyone in our Physics community that forces are aligning that will enable us to make substantial investments in our program—transformative investments that will boost our faculty size and strength, enhance the educational experience for our students, expand our infrastructure, and allow us to launch new and exciting initiatives in teaching, research, and outreach. We hope that these investments will increase our stature and ranking, raise our visibility, and make our alumni and friends proud.

Driving these unique opportunities are many factors, most significantly strong, engaged leadership in the campus and College administration; availability of resources generated by sound campus financial practices, successes in acquiring federal grants by our faculty and a boost in major donor gifts; and rising enrollments of students taking and majoring in Physics that is bringing added tuition funds into our program. This comes following a difficult period for our University and for our department—a period that saw a financial crisis in the State of Illinois and inappropriate behavior by high-ranking officials that led to decreasing revenues, serious attrition in our faculty size, and uncertainty about what to do next. Although many challenging issues still remain, we find that a window of opportunity has opened up that gives us a chance to rebuild our core strengths, explore new directions, expand our space and infrastructure, and share the creativity and impact of our work with the world.

Watch our faculty! After dropping to a faculty size of just over 50 two years ago following decades at our traditional level of 60–70, we have focused on growing back our size and doing so by targeting specific areas in which we want to be the best. With the three faculty members who came to Physics Illinois last academic year and the six who will start in January of this academic year, we are now approaching 60. This growth has also depended on retaining our best and most productive scholars against aggressive efforts by some of our peer institutions to attract them away. We have been successful in recent years at doing that, not by blatantly trying to outbid them, but instead by understanding what our faculty are passionate about and providing what they need and want to carry out their careers and lifestyle ambitions. And more growth will come—we have four searches underway this year and special opportunities for additional faculty hires through aggressive campus dual-career and diversity programs and via the Grainger gift to the College of Engineering that will fund 35 new professorships and chairs, some in Physics. We are happy with this trend—nothing energizes an academic program more than bringing in new people and ideas.

Watch our staff! In addition to hiring stellar faculty, we have also been able to hire exceptional people in our staff to enhance our ability to deliver our courses, support our research operations, and expand our capabilities in communications and information management. As a team, our faculty and staff work closely together to meet the demands of our growing enrollments and expanding commitments in academic activities and public engagement.

Watch our research! With new faculty come new ideas, and we are poised to launch several new initiatives to expand the breadth and impact of our research portfolio. On the horizon are plans to establish a leadership role in the rapidly emerging field of Quantum Information/Quantum Computing that will encompass both existing schemes for qubit architectures as well as new ideas based on topologically protected quantum states. This effort will leverage our traditional campus strengths in Condensed Matter and AMO (Atomic-Molecular-Optical) Physics, Materials Science, Electrical Engineering, and Computer Science, and will integrate the unique computational resources on campus provided by the new Blue Waters supercomputer and the ability to attract and manage large university, industry, and government partnerships provided by the new Advanced Research Institute that has just opened in the University of Illinois Research Park. Blue Waters will also contribute to initiatives nucleating in Astrophysics/Cosmology, Biological Physics and Quantitative Biology, and Particle Physics.

Watch our teaching! Big changes are coming to our educational programs as well—we strive to be as innovative and impactful in our teaching as in our research endeavor. High on the list is a renovation of Physics 101–102, our algebra-based introductory sequence that is taken by students in the environmental and biomedical sciences, including premed students. We are modernizing these to incorporate the multimedia and active learning enhancements that have been successful in our 211–214 sequence; to better serve the needs of students in those disciplines; and to bring the content into alignment with the new standards for the MCAT exam. Attention is also being paid to our highly successful upper-level laboratory courses and senior thesis courses, to accommodate growth in the number of Physics majors. At the same time, we are keeping an eye on the groundswell of interest in and growth of online education and MOOCs; to reach more students in more places more efficiently, we are seeking opportunities to incorporate this into our curriculum and outreach activities.

Watch our building! This spring semester, Loomis Laboratory will undergo a $4-million classroom renovation funded by the campus to increase the size and improve the quality of our classrooms. It will be a challenge to accommodate all of our students and maintain normal operations during the (disruptive) construction period, but in the end it will be beautiful and transformative. We encourage you to follow our progress on our website. Once the classroom renovations are completed, we will proceed with construction of a flexible active-learning classroom and a new kitchen/faculty-staff lounge in the space behind the Interaction Room that had formerly been filled with research journals. Down the road we have even bigger dreams—an expansion on the west side of Loomis Laboratory that will bring up new lecture halls, space for the departmental and faculty offices, and an open atrium for events, along with a modern, new gateway to the campus on the corner of Goodwin and Green. There is also a plan in place for an experimental research building adjacent to MRL to accommodate advanced instrumentation that requires high-bay, low-vibration, acoustically and electromagnetically shielded space. This additional space would be transformative to our programs, and we are thinking creatively about how to acquire the funds to make this happen.

Watch for our story! The Department of Physics has always made significant accomplishments in our complementary missions of teaching, service, and research, but we have been less adept at telling the world about them. We are committed to become as good at telling our story as we have been at creating one. The image we convey is crucial to raise our ranking and stature, position us to recruit the best people, and enable us to attract significant funding sources for our research from agencies, foundations, and donors. This goal has prompted us to invest in building a dedicated staff in Physics to address outward-looking issues—anything that affects how we are perceived from the outside. We have just inaugurated a new committee in the department tasked to craft a strategy that will enable Physics Illinois to "make a splash," appropriately named ORCA, which stands for Outreach, Recruiting, Communication, and Advancement. We will not be hard to find—we will be sending out newsletters, electronic reports, and brochures, and you can follow us on Facebook, Twitter, LinkedIn and on our website. And if you like what you see, partner with us in our quest for excellence through your engagement and donations.

Watch us now! We are on a mission to enhance our academic excellence and to make a difference to science and society. **Watch closely now!**

the Physics Illinois
Bulletin

Dale Van Harlingen
Professor and Head

Celia Elliott
Director, External Affairs
and Special Projects

Erin Kirby
Assoc. Director of Advancement

Siv Schwink
Communications Coordinator

the Physics Illinois Bulletin
is a semiannual publication of the
Department of Physics
at the University of Illinois
at Urbana-Champaign.

Please send us your comments
or ideas for future stories:

the Physics Illinois Bulletin
Department of Physics
Loomis Laboratory
1110 West Green Street
Urbana, IL 61801-3080

or contact Siv Schwink at
sschwink@illinois.edu
or (217) 300-2201

Printed on recycled paper with soybean ink.

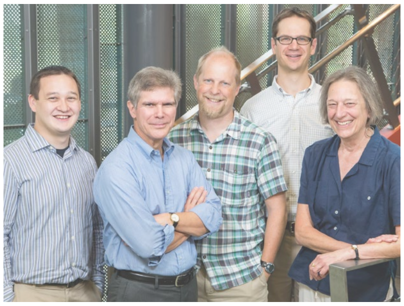
The stature of our department is measured by the accomplishments of our students. Tell us where you've been and what you've done.
Stay in touch!

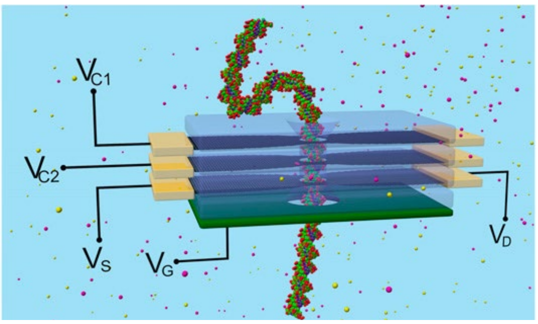
Get our latest news. Update your contact information.

http://go.physics.illinois.edu/alumni

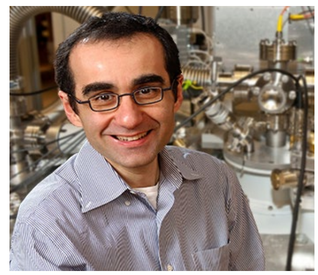
Follow us. Like us.
Connect with us.

Cover image: Professor Raffi Budakian stands in his laboratory in the Frederick Seitz Materials Research Laboratory, next to an instrument used to study correlated electron systems and superconductors: the ^{3}He refrigerator can achieve temperatures as low as 300 mK (about –273°C, or 0.3 degrees above absolute zero); connected to the ^{3}He refrigerator is a magnetic force microscope, which can image magnetic fields with a spatial resolution of about 20 nm.

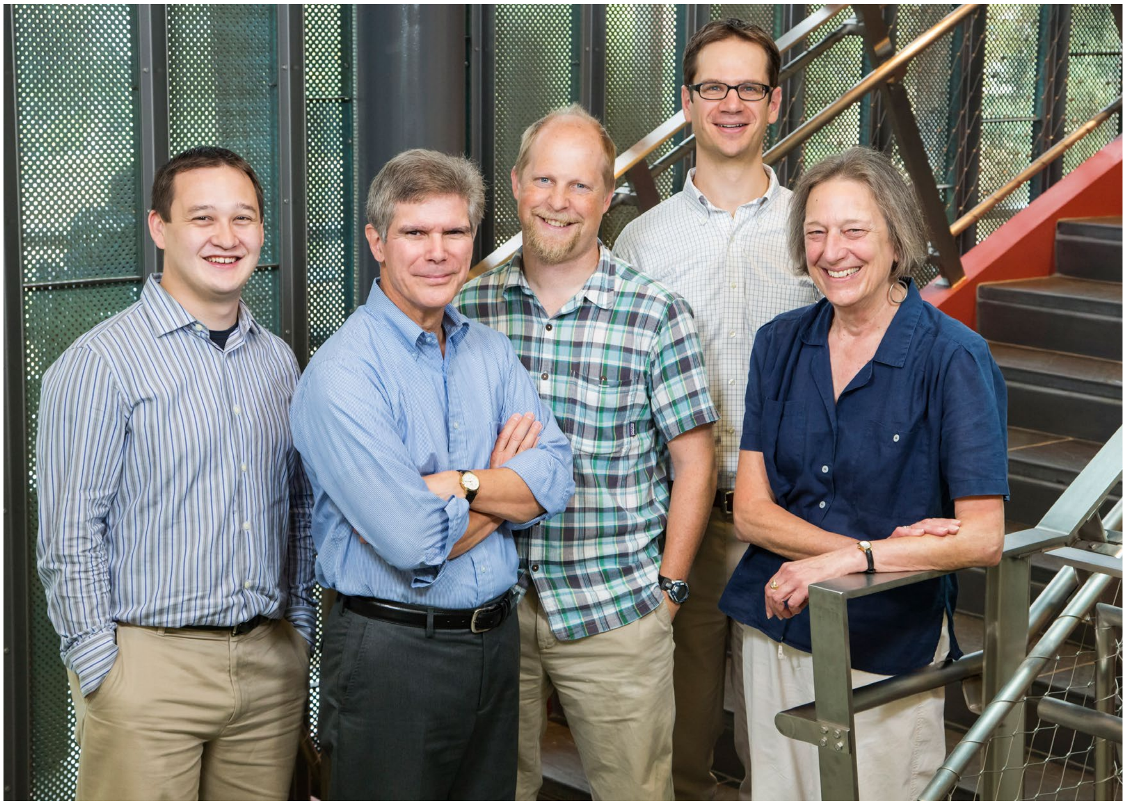




V_{C1}
V_{C2}
V_S
V_G
V_D



U. of I. team leads $2-million NSF study on best practices for STEM education reform



The U. of I. NSF WIDER team, led by Jose Mestre, has the potential to increase numbers and diversity in STEM degree programs across the US. Pictured from left to right are Professors Geoffrey Herman, Jose Mestre, Jonathan Tomkin, Matthew West, and Jennifer Greene.
Photo by L. Brian Stauffer

The NSF WIDER team at the University of Illinois will study the implementation of education reform in gateway STEM courses across 10 Illinois academic units on campus to develop a transferable model for implementing STEM education reform. Each unit will form its own "community of practice" to introduce evidence-based pedagogies that will improve student recruitment, retention, and diversity in STEM majors. The project, which has implications for STEM education reform at institutions of higher education across the US, will ultimately improve the learning experience for 17,000 STEM students at the U. of I.

A year ago, the Obama administration announced that increasing the number of US college graduates who have degrees in science, technology, engineering and math (STEM) by one million over the next decade is a top priority that will be bolstered by several federal agencies. A new study at the University of Illinois will seek to provide US institutions of higher education with a model of best practices and methods to reform gateway STEM courses offered in the first two years of study, where increased enrollments, student retention, and diversity are critical to meeting the growing national demand for STEM degree holders.

The National Science Foundation will fund the multi-year study, slated to begin in January 2014, through a $2 million WIDER (Widening Implementation & Demonstration of Evidence Based Reforms) grant. The ambitious U. of I. STEM education reform project spans three colleges—Liberal Arts and Sciences, Engineering, and Education—and targets 10 academic units—Physics, Mechanical Science and Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, Computer Science, Mathematics, School of Integrative Biology, School of Molecular and Cellular Biology, Geology, and Chemistry. The gateway courses in these units enroll over 17,000 students annually, and several of the courses are required for nearly all STEM majors on campus.

U. of I. physicist and educational psychologist Jose Mestre is the principal investigator on the study.

"The big idea here is not to invent new reforms," explains Mestre. "It's taking evidence-based reforms—these are best practices for teaching and learning in gateway STEM courses that have already been extensively tested and proven—and looking at how these can most effectively be implemented in an institutional setting. This is challenging because each department at a university will have its own methods and traditions and will generally resist change."

The team will attempt to circumvent that resistance by establishing "communities of practice"—collaborations of key faculty members within each academic unit that will develop each unit's strategy for implementing new pedagogies that move away from the traditional strictly lecture-based model of instruction. It's hoped that these communities, once established and provided with guidance and methodologies, will promote the organic emergence of the best-suited evidence-based reforms within their respective departments.

Co-principal investigator Geoffrey Herman is a visiting assistant professor with the Illinois Foundry for Innovation in Engineering Education at the U. of I. whose most recent research has focused on lowering barriers to sustainable education reform. He will head the instructional support team that will serve as a resource to all 10 units.

"One of the greatest challenges to education reform is that it is often pursued by passionate, but lone, heroes," observes Herman. "These pioneers can make great strides, but the changes they make are rarely sustainable or adopted by others. Our 'no heroes' approach first aims to create and sustain cultural change through communities of practice and to allow that cultural change to drive innovation and reform."

"The U. of I. is a large, research-intensive land-grant institution—an ideal setting for this kind of comprehensive study," adds Mestre. "The professors within each unit will have a large degree of choice in how to introduce and then maintain these evidence-based reforms, even with turnover of instructors. By evaluating what works and what doesn't—what efforts result in greater student engagement, improved student learning, and higher recruitment and retention—we hope to be able to develop a transferable model of institutional change for other institutions."

Co-principal investigator Jennifer Greene is a U. of I. educational psychologist and evaluation expert. She will head the team that will perform ongoing quantitative and qualitative assessments of each community of practice and will likewise evaluate student experiences and student performance in the courses. Evaluative feedback will be recorded and shared with the communities of practice to inform each unit's conversations and processes of change.

Greene says she is thrilled to be included in this timely initiative: "This exceptionally talented and dedicated team of STEM educators has generated a transformational vision for undergraduate teaching and learning in the sciences in the WIDER project. I am delighted and honored to provide this team with ongoing evaluative information on how well this vision is being implemented and received by Illinois students, colleagues, and administrators and then to share what has been learned about effective STEM teaching and learning with the larger global science-education community."

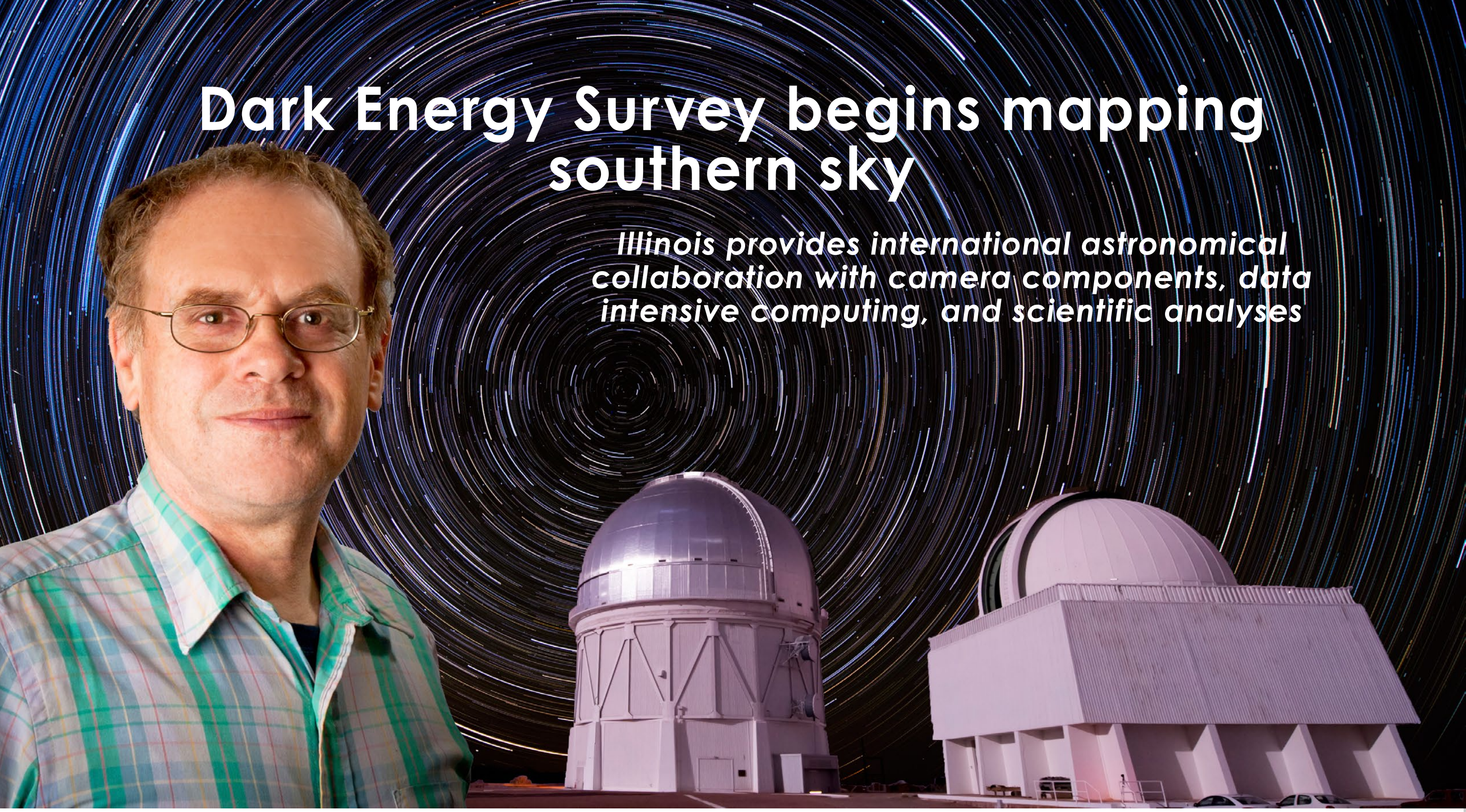
Two more co-principal investigators will coordinate reform efforts at each college. U. of I. geologist Jonathan Tomkin will work within the College of Liberal Arts and Sciences, and U. of I. mechanical engineer Matthew West, within the College of Engineering. Each will engage high-level administrative support for the reform efforts.

"The WIDER program will provide a substantial boost to reform efforts already underway in the College of Engineering, significantly enhancing the pace of innovation in our core gateway courses and allowing us to integrate our efforts with STEM departments in the College of Liberal Arts and Sciences, where engineering students learn core science subjects," says West. "In particular, the Engineering Strategic Instructional Initiatives Program (SIIP) provided a test bed for the communities of practice that form the centerpiece of our WIDER strategy, and going forward the SIIP and WIDER programs will synergistically interact to advance transformative pedagogy at the University of Illinois."

Tomkin adds, "Liberal Arts and Sciences has the largest introductory STEM courses in the University. Every semester, thousands of students take classes in chemistry, biology and math. By accelerating the adoption of the best educational approaches and technologies in these classes, WIDER will enhance every science and engineering undergraduate experience." ■

Dark Energy Survey begins mapping southern sky

Illinois provides international astronomical collaboration with camera components, data intensive computing, and scientific analyses



On August 31, the [Dark Energy Survey (DES)](), an international collaboration of more than 200 scientists, officially began the largest galaxy survey ever attempted. Over the five-year course of the project, physicists around the globe will use this remarkable instrument to try to answer some of the most fundamental questions about our universe.

The survey's goal is to find out why the expansion of the universe is speeding up, instead of slowing down because of gravity, and to probe the mystery of dark energy, the force believed to be causing that acceleration.

The main tool of the survey is the 570-megapixel Dark Energy Camera, the largest digital camera in the world, with five precisely shaped lenses (the largest is nearly a yard across!) that deliver sharp resolution across its entire field of view. It is able to see light from more than 100,000 galaxies up to 8 billion light years away in each snapshot.

This impressive camera was built at Fermilab in Batavia, Illinois, with components—data acquisition electronics and control software—designed and constructed at the Loomis Laboratory of Physics in Urbana by a team of particle physicists under the direction of Professor [Jon Thaler](). The camera is now mounted on the 4-meter Victor M. Blanco telescope at the National Science Foundation's Cerro Tololo Inter-American Observatory in the Andes Mountains in Chile, where excellent atmospheric conditions will make possible the sharpest-resolution pictures ever seen in a wide-field astronomy survey.

The DES, which will map one-eighth of the sky (5,000 square degrees), is expected to collect color images of 300 million galaxies and 100,000 galaxy clusters and to discover 4,000 new supernovae. Though it will not be able to detect dark energy directly, by studying the expansion of the universe over time, the survey will give scientists the most precise measurements of the properties of dark energy.

All DES digital images are being stored and processed at the U. of I.'s [National Center for Supercomputing Applications (NCSA)]().   of NCSA, working with research scientist Robert Gruendl of the Department of Astronomy at Illinois and other collaborators, developed the data management framework for processing, calibrating, and archiving the massive amounts of data—petabytes over the lifetime of the survey—that will be collected for the DES.

"NCSA provides the networking, computing, and archiving capabilities and sophisticated tools that this type of data-intensive science requires," comments Petravick. "This allows astronomers and physicists to focus on analysis of science-ready data, rather than spending their time on preliminary processing or technical issues."

The survey will use four methods to probe dark energy:

Counting galaxy clusters.

While gravity pulls mass together to form galaxies, dark energy pulls it apart. The Dark Energy Camera will see light from 100,000 galaxy clusters billions of light years away. Counting the number of galaxy clusters at different points in time sheds light on this cosmic competition between gravity and dark energy.

Measuring supernovae.

A supernova is a star that explodes and becomes as bright as an entire galaxy of billions of stars. By measuring how bright supernovae appear on Earth, we can tell how far away they are. Scientists can use this information to determine how fast the universe has been expanding since the star's explosion. The survey is expeted to discover 4000 of these supernovae, which exploded billions of years ago in galaxies billions of light years away.

Studying the bending of light. When light from distant galaxies encounters dark matter in space, it bends around the matter, causing those galaxies to appear distorted in telescope images. The survey will measure the shapes of 200 million galaxies, revealing the cosmic tug of war between gravity and dark energy in shaping the lumps of dark matter throughout space.

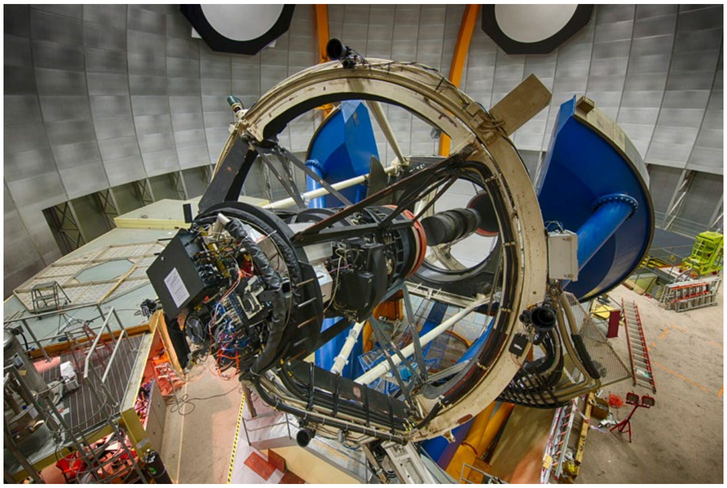
Using sound waves to create a map of expansion over time.

When the universe was less than 400,000 years old, the interplay between matter and light set off a series of sound waves traveling at nearly two-thirds the speed of light. Those waves left an imprint on how galaxies are distributed throughout the universe. The survey will measure the positions in space of 300 million galaxies to find this imprint and use it to infer the history of cosmic expansion.

Thaler remarks, "The combined analyses of the scientists in the DES collaboration are expected to contribute significantly to our understanding of the properties of dark energy and dark matter. The Illinois physics team will look at supernovae to chart the expansion of the universe over time, and at gravitational lensing to determine the history of the formation of structure (galaxies and galaxy clusters)."

Illinois astronomers in the collaboration will focus their analyses on galaxy clusters. Gruendl explains, "Hidden within the galaxy cluster distribution are clues to the nature of the universe we live in." ■

The NGC 1398 galaxy in the Fornax cluster is roughly 65 million light years from Earth. It is 135,000 light years in diameter, just slightly larger than our own Milky Way galaxy, and contains more than 100 million stars. Credit: Dark Energy Survey.



The Dark Energy Camera, mounted on the Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile. Credit: Reidar Hahn/Fermilab.

The Dark Energy Survey is supported by funding from the US Department of Energy Office of Science; the National Science Foundation; funding agencies in the United Kingdom, Spain, Brazil, Germany and Switzerland; and the participating institutions.

Magnetic charge crystals imaged in artificial spin ice

A team of scientists led by Vice Chancellor for Research and Professor of Physics Peter Schiffer has reported direct visualization of magnetic charge crystallization in an artificial material, a first in the study of a relatively new class of frustrated artificial magnetic materials-by-design known as artificial spin ice. These charges are analogs to electrical charges and have possible applications in magnetic memories and devices.

The unique properties of spin ice materials have fascinated scientists since they were first discovered in the late 1990s in naturally occurring rare-earth titanites. The material is aptly named: the highly complex ordering of nanoscale magnets in spin ice obey the same rules that determine the positional ordering of hydrogen and oxygen atoms in frozen water ice. Both have "spin"—degrees of freedom—with frustrated interactions that prevent complete freezing, even at absolute zero.

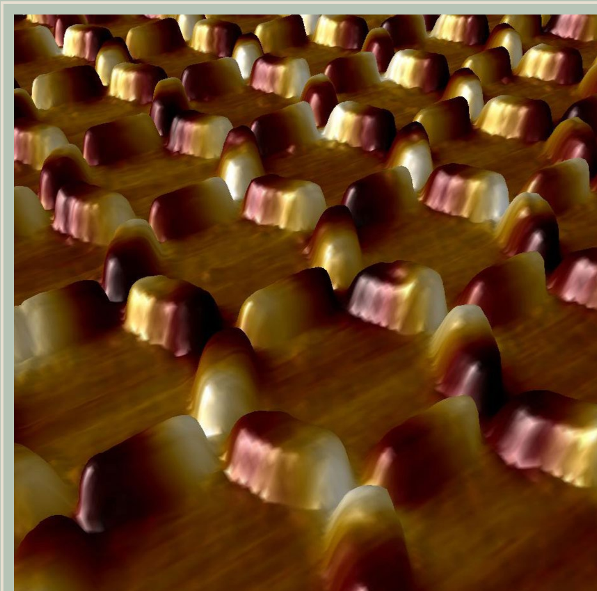
In 2006, an interdisciplinary team of physicists and materials scientists led by Schiffer designed the first artificial spin ice, a two-dimensional array of magnetic nanoislands that are fabricated to interact in complex ways, depending on the chosen design of the array. The islands were lithographically printed onto a substrate, arranged in a square-lattice pattern, with the north and south poles of each nanomagnet meeting and interacting at their four-pronged vertices.

Now the same research team has developed a new annealing protocol that allows the artificial material's full potential for highly complex magnetic interactions to be realized. The new protocol was applied to two artificial spin ice materials, one configured in a square-lattice pattern, the other in a hexagonal-honeycomb pattern with three-pronged vertices.

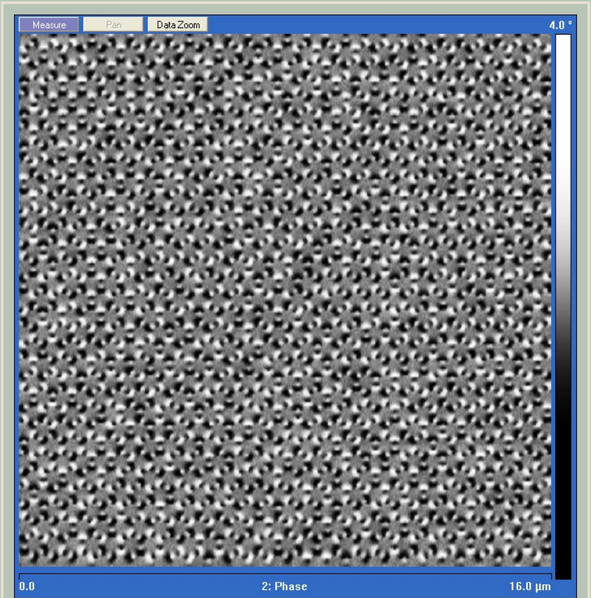
In the honeycomb pattern, where three magnetic poles intersect, a net charge of north or south is forced at each vertex. The magnetic "monopole charge" at each vertex influences the magnetic charge of the surrounding vertices. The team was able to image the crystalline structure of the magnetic charges using magnetic force microscopy.

Schiffer explains, "Nanomagnets are so small that their behavior becomes relatively simple. We can arrange the magnets in a particular lattice pattern—square or honeycomb—and they interact in a way that we can predict and control."

Schiffer adds, "The challenge—you have to get the nanomagnets to flip their north and south poles to show how they interact. It's hard to force them to show the effects of



A 3-D depiction of the honeycomb artificial spin ice topography after the annealing and cooling protocols. The light and dark colors represent the north and south magnetic poles of the islands. Image by Alex David Jerez Roman and Ian Gilbert, U. of I. Department of Physics and Frederick Seitz Materials Research Laboratory



Magnetic force microscope image of emergent domains of ordered magnetic charges in honeycomb artificial spin ice. The black and white dots in the image are the north and south magnetic poles of the nanomagnets. The ability to use the magnetic charges as degrees of freedom has implications for future technological applications. Image by Ian Gilbert, U. of I. Department of Physics and Frederick Seitz Materials Research Laboratory

interaction, since they get stuck in one particular arrangement."

The research team's new annealing protocol—heating the material to a high temperature where their magnetic polarity is suppressed (here, about 550°C) — allows the nanomagnets to flip their polarity and freely interact. As the material cools, the nanomagnets are ordered according to the interactions of their poles at the vertices.

The collective thermal behavior of the arrays is studied through statistical mechanics. As theorized, the monopole charge of each vertex was found to contribute to the order of the entire system in a manner analogous to the interactions of electric charges at the atomic scale during water ice crystal growth.

[Los Alamos National Laboratory]() staff scientist [Cristiano Nisoli]() explains, "The emergence of magnetic monopoles in spin ice systems is a particular case of what physicists call fractionalization, or deconfinement of quasi-particles that together are seen as comprising the fundamental unit of the system, in this case the north and south poles of a nanomagnet. We have seen how arranging magnets in a honeycomb configuration allows for these charges to be sort of 'stripped' from the magnetic islands to which they belong and become relevant degrees of freedom."

"Magnetic technology generally concerns itself with manipulation of localized dipolar degrees of freedom," explains Nisoli. "The ability of building materials containing delocalized monopolar charges is very exciting with possible technological implications in data storage and computation."

An advantage of artificial spin ice is that it can be designed in different topologies and examined subsequently to see the effects of those topologies. That allows physicists to explore a wide range of possible behaviors that are not accessible in natural crystals.

"This work demonstrates a direction in condensed matter physics that is quite opposite to what has been done in the last 60 years or so," says Nisoli. "Instead of imagining an emergent theoretical description to model the behavior of a nature-given material and validating it indirectly, we engineer materials of desired emergent properties that can be visualized directly."

The team, led by Peter Schiffer, of the University of Illinois's [Department of Physics]() and [Frederick Seitz Materials Research Laboratory](), published its findings in the August 29 issue of the journal *Nature*. The theoretical work for this research was performed at Los Alamos National Laboratory under Cristiano Nisoli and [Gia-Wei Chern](), and at [Penn State University]() under [Vincent Crespi]() and [Paul Lammert](). The synthesis of the magnetic materials and the high temperature treatment were performed at the [University of Minnesota's Department of Chemical Engineering and Materials Science]() under _. The magnetic measurements and lithography were performed at Penn State University and the University of Illinois's Frederick Seitz Materials Research Laboratory by graduate students Sheng Zhang and Ian Gilbert under the direction of Peter Schiffer. ■

[Link to the article.]()

This project was funded by the US Department of Energy, Office of Basic Energy Sciences, Materials Sciences and Engineering Division under Grant No. DE-SC0005313. Lithography was performed with the support of the National Nanotechnology Infrastructure Network. The work of C. Nisoli and G-W Chern was carried out under the auspices of the US Department of Energy at LANL under contract no. DE-AC52-06NA253962. Work at the University of Minnesota was supported by the NSF MRSEC under award DMR-0819885. Certain theory elements were supported by the NSF MRSEC under award DMR-0820404.

Novel DNA sensing technology could revolutionize modern medicine

by August Cassens

Swanlund Professor of Physics Klaus Schulten

Imagine a visit to a doctor where a simple blood test provides the key to your genetic code, and with that information, the doctor can base your care precisely on the treatment that will work best for you. No longer would it be one medicine, dosage, or treatment plan fits all—each patient would get the care that best fits his or her genetic makeup.

Accurately, quickly, and cheaply sequencing an individual's DNA is one way that medicine can personalize care for each patient. Based on sophisticated computational modeling, a team at the Beckman Institute at the University of Illinois— Professor of Electrical and Computer Engineering Jean-Pierre Leburton and Swanlund Professor of Physics Klaus Schulten, in collaboration with graduate students Anuj Girdhar and Chaitanya Sathe—has devised a new semiconductor nanotechnology with the potential to revolutionize individual healthcare by providing DNA sequencing on a scale never before attained.

After 10 years of research, Leburton has found a way to exploit the electrical properties of graphene—a mono-atomic layer of carbon—to create a solid-state transistor with a nanopore that has the ability to sequence the human genome electronically.

Current methods of sequencing DNA use various kinds of biochemical processes that are expensive and tedious. In their paper published in Proceedings of the National Academy of Sciences (PNAS), entitled "Graphene quantum point contact transistor for DNA sensing," the research team describes a novel methodology that exploits the high electrical conductivity of graphene in a very tiny transistor. An electrically charged DNA molecule threads through a nanopore within the solid-state device, and as each nucleotide along the strand passes in front of the graphene's mono-layer, it scatters the current in the graphene differently. The nucleotide's current-scattering signatures are used to identify the base sequence.

"There are two main reasons why this technology is revolutionary," Leburton explains. "It is a new paradigm for sequencing DNA, which uses an electrical constriction around a nanopore in graphene to sense and detect passing DNA nucleotides with the highest possible resolution.

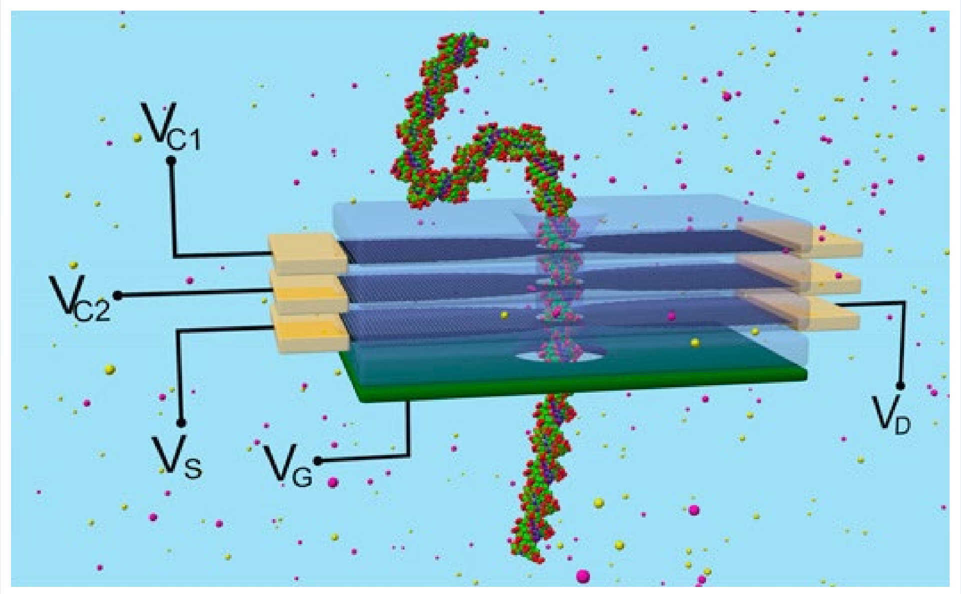
"Secondly, the graphene layer is embedded into a transistor structure containing an electrical gate that modulates the electrical sensitivity of the graphene layer, and corrects it from the detrimental influences of the edge roughness of the graphene constriction as well as from neighboring charges in the insulating layers of the solid-state membrane. This is a completely new way of approaching DNA sequencing, and one that can be done quickly, reliably, and cheaply, once the technology could be developed into mass production."

The researchers have more work to do before a graphene-based DNA-sensing device could be mass produced.

"This technology represents a huge step forward, but it's not the final solution," shares Schulten. "We get a strong signal, but there is a lot of noise—and that noise could kill the prospect. Now we have to find a way around that problem.

"We are looking at two possible solutions to make it work: First, by holding the DNA mechanically fixed, we would be able to keep it quiet—this is difficult but possible. Second, we will rip apart the double stranded DNA and thread a single strand through the nanopore—this shows much more of the interior properties of DNA and represents a better chance of success than with the double strand."

The first proposal for sequencing DNA with nanopores utilized ion channels in biological membranes of living cells to measure the variations of the blocking ionic current for each nucleotide passing through the channel with a specific signature. However, this method still lacks temporal and spatial resolution because of the finite thickness of the membrane. Moreover, ion channels designed by nature lack the flexibility and material versatility of semiconductor technology to control the sequencing process. Here, electronics through the transistor operation enables optimal sequencing control, which could lead to faster, cheaper, and more reliable DNA sequencing.



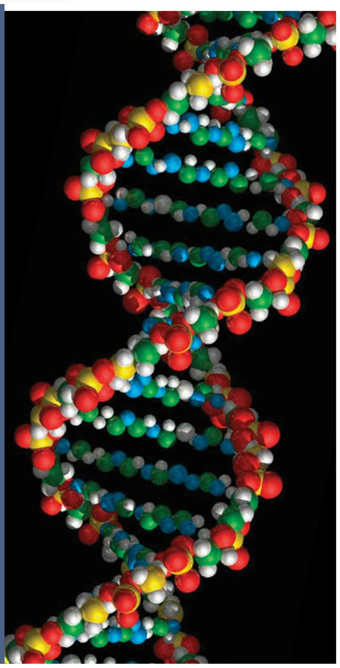
This schematic shows a four-layer device for rapidly and accurately sequencing DNA using electricity. It containing three graphene layers (purple) that control the motion of DNA through a nanopore. The bottom layer (green) acts as a gate to control the concentration. Image by Anuj Girdhar reprinted with permission from Anuj Girdhar, Chaitanya Sathe, Klaus Schulten, and Jean-Pierre Leburton, *PNAS*, published online ahead of print, Sept. 30, 2013, doi:10.1073/pnas.1308885110. Copyright 2013 by the National Academy of Sciences.

"We knew we could do things differently than by using biological membranes to sequence DNA," Leburton comments. "With semiconductor nanotechnology, we could fabricate a membrane with several electrically active layers, and assign a different function to each layer, so that translocating DNA would be efficiently controlled and detected with different electrodes."

Oxford Nanopore Technologies, a company that develops nanopore equipment to sequence DNA, funds part of the research on this new graphene-based approach.

According to the National Institutes of Health, costs of DNA sequencing have greatly declined since 2003, when the genome sequencing performed under the Human Genome Project was completed at a cost of approximately $1 billion. Only a year later, in 2004, sequencing a human genome cost an estimated $10-50 million, thanks to improvements in technologies and tools. By 2009, the NIH's National Human Genome Research Institute met its goal of producing high-quality human genome sequences at a 100-fold reduction in price, or $100,000. Today, sequencing a person's genome today costs about $5,000 to $6,000. That price can drop further still.

Rapidly sequencing the human genome in a cost-effective manner will revolutionize modern medicine. A group of researchers at Beckman have formulated a unique paradigm for sensing DNA molecules by threading them through an electrically active solid-state nanopore device containing a constricted graphene layer.



Leburton joined forces with Beckman researchers Rashid Bashir and Aleksei Aksimentiev to integrate their theoretical and experimental efforts and establish this new technology on real ground.

The next step for the technology is to implement the group's high-resolution simulation of the transistor structure into an operational computer model, to provide directions as well as feedback to the experimental effort.

"Our hope is to establish our ideas into a viable technology that can be ported to industry and advance medical practices," Leburton shares. "Because of its compactness and reduced number of operations, our sequencing scheme has great potential for portable medicine. It can be used out in the field rather than in the lab, where it could be a long and expensive process. If you can rapidly sequence DNA, you have quick access to your own genetic information and can determine if you've been exposed to external hazards or if you are ill. Then the doctor will provide, effectively and quickly, the appropriate treatment or medicine. This technology has the potential to revolutionize modern medicine." ■

This research was funded in part by Oxford Nanopore Technology and by National Institutes of Health Grants 9P41GM104601 and NIH 5 R01 GMO98243-02. The conclusions presented are those of the scientists and not necessarily those of the funding agencies.

Aksimentiev team to explore novel DNA sequencing using plasmonic light focusing with nanopore technology

by Rick Kubetz

Associate Professor Aleksei Aksimentiev will lead an international team of scientists in research that will advance a novel form of nanopore technology for more accurate and efficient DNA sequencing. The National Institutes of Health (NIH) has awarded a $2.47 million grant to the team from the University of Illinois at Urbana-Champaign and Delft University of Technology (TU Delft) in the Netherlands for this project. The grant is part of the $17 million awarded to eight research teams through the NIH National Human Genome Research Institute (NHGRI)'s Advanced DNA Sequencing Technology program, launched in 2004.

Nanopore-based DNA sequencing involves threading single DNA strands through tiny pores. Individual base pairs—the chemical letters of DNA—are then read one at a time as they pass through the nanopore.

"This research project aims to combine the unique and powerful capabilities of two exciting, rapidly evolving fields—plasmonics and nanopores—for the analysis of single DNA molecules," explains Aksimentiev, principal investigator for the project. "More specifically, recent advances in nanoplasmonics will be utilized to enable label-free, single-molecule trapping and sequencing of DNA using nanopores.

"We are among the first ones to explore this powerful combination of nanopores and plasmonics," Aksimentiev adds. "We will explore this using molecular dynamics simulations here at Illinois, then with experiments supervised by our co-PIs, Magnus Jonsson and Cees Dekker at Delft."

"We use nanopores as sensors," explains Dekker, who chairs the Department of Bionanoscience at TU Delft. "These nanopores are less than a millionth of an inch in size, through which we let a biomolecule such as DNA flow. Upon feeding the molecule through the hole we aim to read off information about it. Our ultimate goal is to read off the sequence of a single DNA molecule in this way."

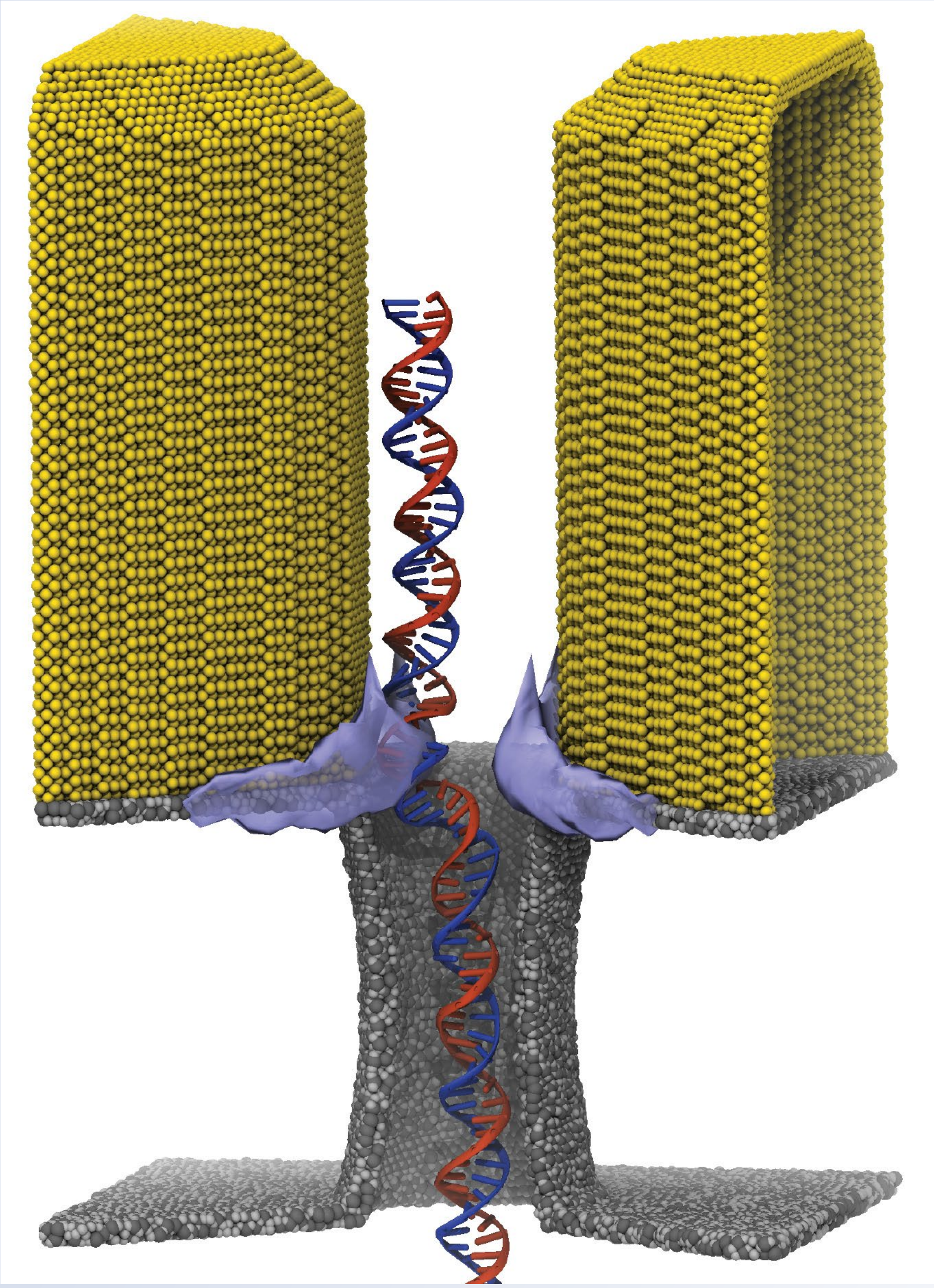
Nanopore DNA sequencing generally entails passing a single DNA strand through a nanopore sensor, where individual nucleotides are distinguished from one another.

"The novel ingredient of our new sensor is a gold nanostructure that acts as an optical antenna and allows us to focus light to a highly intense nanoscale region right at the nanopore," explains Jonsson, who is the third co-PI of the program and a postdoc in Dekker's lab at TU Delft. "DNA fragments moving through the nanopore will be exposed to the strong optical fields in this 'plasmonic hot spot', offering a unique means for both controlling the motion of the DNA and for optical readout of the DNA sequence."

This novel approach to advancing DNA through the nanopore simultaneously enables DNA sequence detection through surface-enhanced Raman spectroscopy. Because locally confined plasmonic fields enhance Raman scattering many orders of magnitude and because of the direct relationship of Raman spectra to the underlying molecular structure, sequence detection will be possible directly, without any labeling.

Jeffery A. Schloss, program director for NHGRI's Advanced DNA Sequencing Technology program and director of the Division of Genome Sciences, comments, "Nanopore technology shows great promise, but it is still a new area of science. We have much to learn about how nanopores can work effectively as a DNA sequencing technology, which is why five of the program's eight grants are exploring this approach."

Schloss further states that this technology offers many potential advantages over current DNA sequencing methods, including real-time sequencing of single DNA molecules at low cost and the ability for the same molecule to be reassessed over and over again. ■



Molecular dynamics simulations predict plasmonic trapping of double-stranded DNA.Image courtesy of Aleksei Aksimentiev

NHGRI is one of the 27 institutes and centers at the National Institutes of Health, the nation's medical research agency. The NHGRI Extramural Research Program supports grants for research and training and career development at sites nationwide. Additional information about NHGRI can be found at www.genome.gov.

Aksimentiev's team demonstrates DNA origami bends and twists in solution

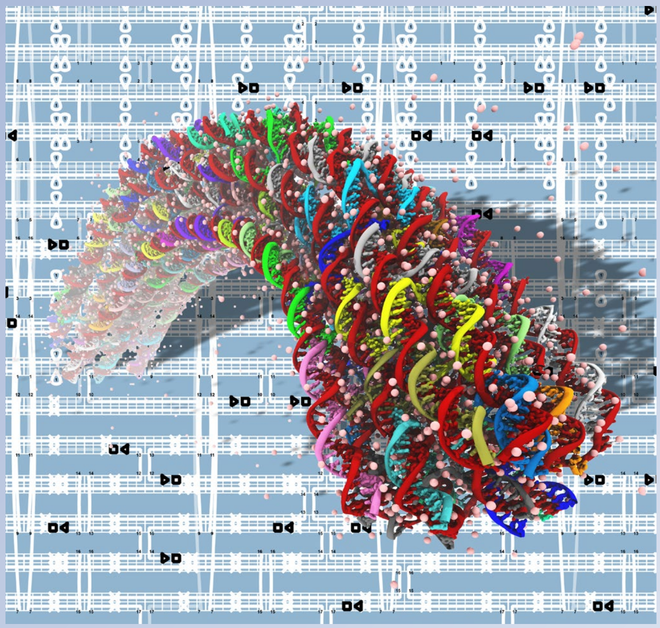
DNA has been used as a nanoscale construction material in scientific experiments since the early 1980s. The invention of DNA origami—the deliberate folding of long viral DNA strands into two or three dimensional shapes using several smaller DNA segments as "staples"—opened up new potential for nanoscale applications, such as advanced drug delivery vehicles and enzyme immobilization; at the same time, it provided experimental physicists with greater design control over nanoscale DNA structures, which are frequently used as scaffolding material to support other molecules.

Scientists have successfully imaged DNA origami structures, but until now, no one had ever seen how the structures behave in the aqueous environment used to make them.

Now, University of Illinois physicists at the Center for the Physics of Living Cells have for the first time uncovered the atomic structure and dynamics of DNA origami within an aqueous solution. Associate Professor Aleksei Aksimentiev, working with postdoctoral researcher Jejoong Yoo, designed a simulation modeling and analysis program and ran it on the Stampede supercomputer at the Texas Advanced Computing Center (TACC) in Austin, TX.

The team's findings are reported in Proceedings of the National Academy of Sciences, "In situ structure and dynamics of DNA origami determined through molecular dynamics simulations," published online ahead of print on November 25, 2013.

Pictured is an atomic-scale model of DNA origami consisting of a long scaffold strand (red), stapled together by short fragments of DNA (various colors). The background image shows the blueprint of the structure. Yoo and Aksimentiev used a large supercomputer system to describe behavior of such DNA nanostructures in solution, elucidating their intrinsically dynamic nature. Image courtesy of Aleksei Aksimentiev



"DNA origami permits easy fabrication of nanoscale objects with a high level of resolution and reproducibility," explains Aksimentiev. "Experimentally, people just mix the stuff and it falls into whatever shape they want."

"The custom program we wrote took the design of a DNA origami structure and converted it to an all–atom representation, then placed it in an aqueous environment. Our simulations show how a structure that was at first a static geometrical design is actually quite dynamic and undergoes structural fluctuations. These conformational fluctuations reveal the local mechanical properties of DNA origami in solution: its propensity for bending and twisting at the nanoscale."

DNA origami structures are designed using computer modeling programs, so the team's findings are a game changer—this new understanding of dynamics will improve the structural integrity it's possible to achieve within DNA origami. Aksimentiev and his team will use the new atomic-modeling method to further their studies of nanopore sequencing of DNA and proteins.

"Understanding the local mechanical properties of DNA origami structures will help us to design new structures, including scaffolds for nanoelectronic applications or advanced drug delivery vehicles," comments Aksimentiev. "One particularly attractive area of application for DNA origami is nanopore sensing of DNA and proteins, which is our next target". ■

This research was funded in part by grants from the National Science Foundation (DMR-0955959, PHY-0822613, and ECC-1227034) and the National Institutes of Health (R01-HG005115). The conclusions presented are those of the scientists and not necessarily those of the funding agency.

A new paradigm for nanoscale-resolution MRI, experimentally achieved

A team from the University of Illinois and Northwestern University has devised a novel nuclear magnetic resonance imaging (MRI) technique that delivers a roughly 10-nanometer spatial resolution. This represents a significant advance in MRI sensitivity—modern MRI techniques commonly used in medical imaging yield spatial resolutions on the millimeter length scale, with the highest-resolution experimental instruments giving spatial resolution of a few micrometers.

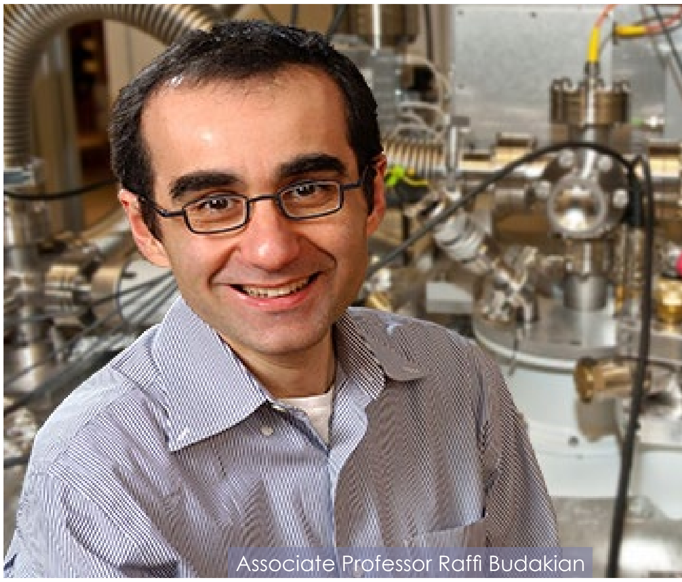
"This is a very promising experimental result," comments associate professor Raffi Budakian, who led the research effort. "Our approach brings MRI one step closer in its eventual progress toward atomic-scale imaging."

MRI is used widely in clinical practice to distinguish pathologic tissue from normal tissue. It is noninvasive and harmless to the patient, using strong magnetic fields and non-ionizing electromagnetic fields in the radio frequency range, unlike CT scans and tradiational X-rays, which both use more harmful ionizing radiation.

MRI uses static and time-dependent magnetic fields to detect the collective response of large ensembles of nuclear spins from molecules localized within millimeter-scale volumes in the body. Increasing the detection resolution from the millimeter to nanometer range would be a technological dream come true.

The team's breakthrough—the new technique introduces two unique components to overcome obstacles to applying classic pulsed magnetic resonance techniques in nanoscale systems. First, a novel protocol for spin manipulation applies periodic radio-frequency magnetic field pulses to encode temporal correlations in the statistical polarization of nuclear spins in the sample. Second, a nanoscale metal constriction focuses current, generating intense magnetic field-pulses.

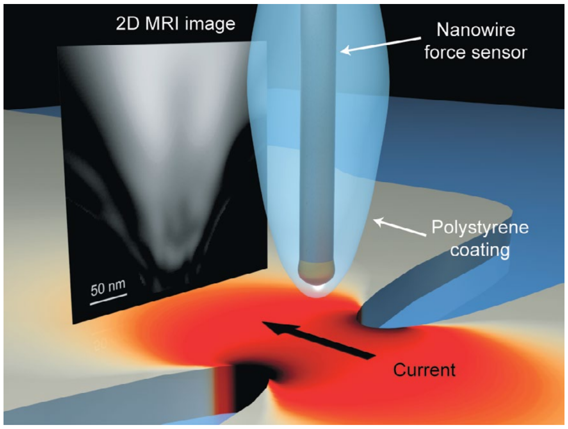
In their proof-of-principle demonstration, the team used an ultrasensitive magnetic resonance sensor based on a silicon nanowire oscillator to reconstruct a two-dimensional projection image of the proton density in a polystyrene sample at nanoscale spatial resolution.



Associate Professor Raffi Budakian

"We expect this new technique to become a paradigm for nanoscale magnetic-resonance imaging and spectroscopy into the future," adds Budakian. "It is compatible with and can be incorporated into existing conventional MRI technologies."

The team's work is published in "Nanoscale Fourier-Transform Magnetic Resonance Imaging" in Physical Review X, v. 3, issue 3, 031016. ■



This illustration of the experimental setup shows the team's novel MRI technique that was successful in producing a 2D MRI image with spatial resolution on the nanoscale. Image courtesy of Raffi Budakian

This work was supported by the Army Research Office through Grant No. W91 1NF-12-1-0341 and by the Department of Physics and the Frederick Seitz Materials Research Laboratory Central Facilities at the U. of I. Work at Northwestern University was supported by the National Science Foundation Grants No. DMI-0507053 and DMR-1006069. The conclusions presented are those of the scientists and not necessarily those of the funding agencies.

CPLC summer school, immersive learning in leading-edge biophysics research

2013 CPLC summer school students learn single-molecule fluorescence resonance energy transfer (SmFRET), a technique used to measure distances in single molecules at the 1-nm to 10-nm scale, during an advanced module. Pictured left to right are CPLC graduate student and TA Digvijay Singh, participants Olga Rechkoblit and Megan Mayerle, CPLC graduate student and TA Helen Hwang, and participant Stephanie Johnson.

Each summer for the past five years, outstanding up-and-coming scientific researchers have convened at The Center for the Physics of Living Cells (CPLC) at the U. of I. Department of Physics. They are graduate students, postdoctoral researchers, and working scientists who come from universities and research institutions around the globe to advance their training in biophysics research by studying under leading experts in the field.

A six-day intensive program, the Physics of Living Cells Summer School, exposes these talented young scholars to a wide set of research topics in biophysics, teaches them new laboratory skills and methods through hands-on experience, and provides them with an exceptional opportunity to develop their professional networks.

CPLC Director of Education and Outreach Jaya Yodh has organized the summer school since its inception in 2009.

"Our summer program is recognized among the international biological physics community as an excellent venue for researchers to gain hands-on, intensive training in cutting-edge experimental single-molecule, live-cell, and computational and theoretical biophysics," comments Yodh. "It's an outstanding professional-development opportunity, and the participants who take advantage of it each year are truly top caliber. The program itself strongly reflects the CPLC's educational mission, to foster collaborations and training of the next generation of scientists who will shape the field of biological physics."

Each day of the program is packed with new information and experiences. "Basic training" in the early part of the week includes several mini-courses that introduce fundamental techniques and software, including total internal reflection fluorescence (TIRF) microscopy optics and Visual Molecular Dynamics (VMD), MATLAB, and LabVIEW software. The students then move on to an advanced laboratory module of their own choosing. Starting on day three, the participants work in small groups in one of the laboratories of the participating professors. Summer school students also attend faculty lectures and participate in poster sessions focusing on both participants' and CPLC research.

In 2013, 40 participants from a variety of fields—biophysics, The advanced modules offered in 2013 gave participants hands-on experience in leading-edge biophysical research tools.

Computational analysis of cellular structures and processes
Klaus Schulten, Zaida Luthey-Schulten, **and** Aleksei Aksimentiev

Eigenfish: neural dynamics of fish locomotion
Martin Gruebele **and** Yann Chemla

Following the fate of individual viral genomes within the infected cell
Ido Golding

Intracellular diffusion and nucleoid organization
Tom Kuhlman

Membrane dynamics in living fruit fly embryos
Anna Sokac

Optical trapping and fluorescence imaging of individual swimming cells
Ido Golding and Yann Chemla

Optical trapping: Single-Molecule Force Spectroscopy of protein-DNA interaction
Yann Chemla

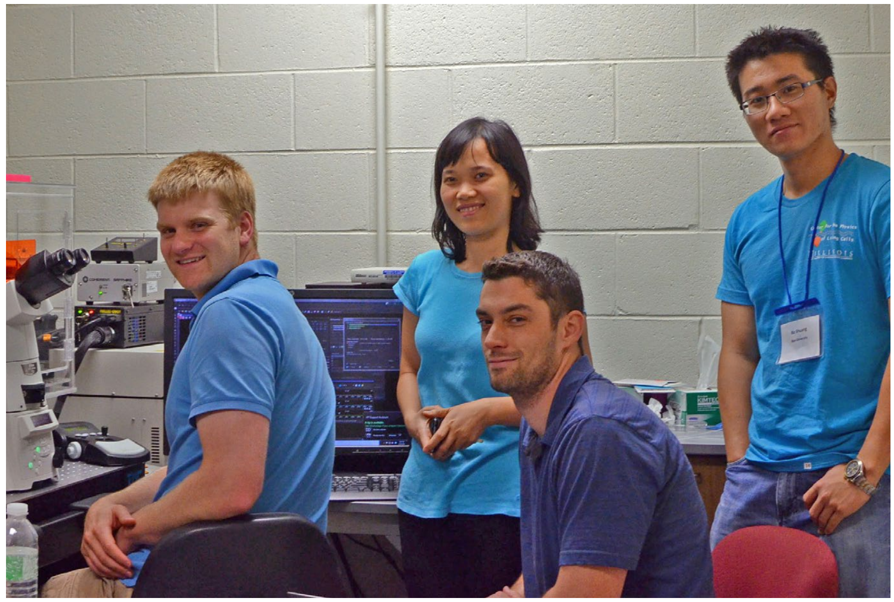
SiMPull: Single-Molecule Pull-Down
Taekjip Ha

Single-Molecule FIONA
Paul Selvin

Single-Molecule FRET
Taekjip Ha

Super-resolution fluorescence microscopy
Taekjip Ha

Tagging and labeling methods for single-molecule studies in vivo and in vitro
Aaron Hoskins



CPLC postdoctoral researcher and TA Cac Nguyen (2nd from left) teaches the Intracellular Diffusion and Nucleoid Organization advanced module to 2013 summer school students (L-R) Peter Kekenes-Huskey, Brett VanVeller, and Bo Shuang.

physics, chemistry, biochemistry molecular biology, pharmacology, computer engineering—had the opportunity to study with one of 12 participating professors, including visiting professors Aaron Hoskins from the University of Wisconsin-Madison, Ido Golding and Anna Sokac from Baylor College of Medicine and new CPLC and U. of I. physics faculty member Tom Kuhlman.

A near 1:1 ratio of students to teaching assistants contributes to the intensive program's success. In 2013, 35 CPLC grad students and postdocs developed and taught mini-courses and advanced modules.

Patrick Mears, a sixth-year graduate student in physics at the U. of I., has served as a workshop TA each of the five years it's been offered. Mears, who aspires to work in the medical industry developing new diagnostic tools and methods, says preparing for and teaching in the summer school program has been hard work, but well worth it.

"They come to learn new research skills. Some come to learn a specific technique that borders on what they are already doing," observes Mears. "The experiments end up being very time consuming, but this is where the students are most strongly motivated. Many of them will start in the morning and stay as late as 9 p.m.—some going as late as midnight."

Nick Horan, a graduate student at the University of Wollongong in Australia, where he is studying the structure and function of bacterial DNA replication machinery, participated in 2013.

"I applied for the CPLC Summer School to learn the latest techniques and be exposed to exciting current research from a top-class single-molecule biophysics research center," states Horan. "The program was interesting and informative—well worth the trip. I am looking forward to discussing aspects of the course with my supervisor and colleagues when I return home."

David Jacobson, a graduate student in physics at the University of California, Santa Barbara, took part in the 2013 program to expand his exposure to many different

CPLC graduate student and TA Barbara Stekas teaches LabVIEW software to 2013 summer school student Vincent Fiore.

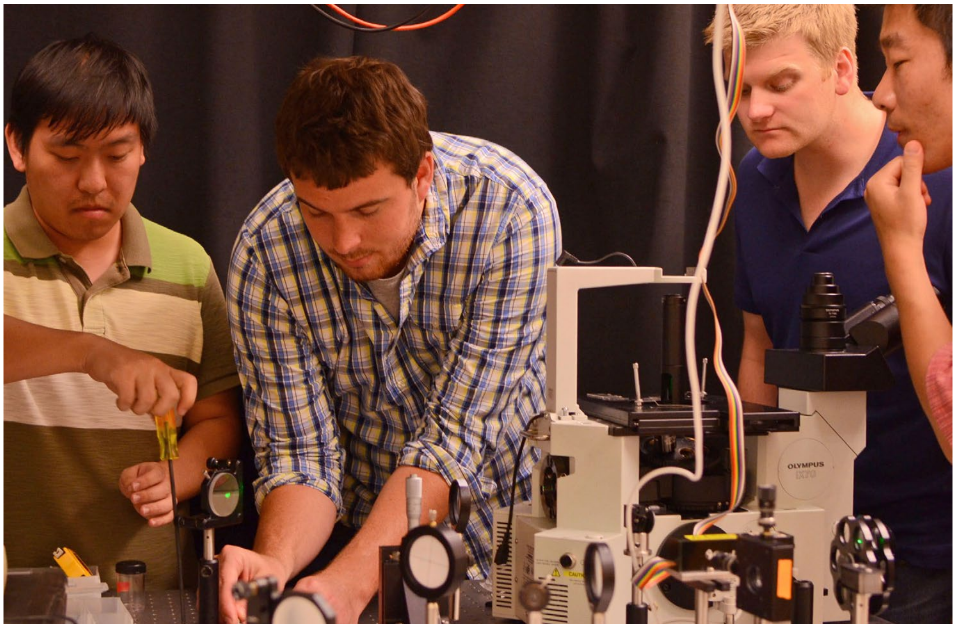
aspects of biophysics research.

"The summer school offers a great opportunity to get to know big names in the field, as well as their students and other researchers from around the world, all in a fun and informal setting," Jacobson observes. "I signed up for an advanced module that is pretty far removed from my own research: I study the conformation of RNA using force spectroscopy, but this week I am studying the locomotion of baby zebrafish with Martin Gruebele and his student, Kiran Girdhar. Earlier in the week, I was introduced to a fantastic software package, Visual Molecular Dynamics (VMD), which is developed at the U. of I. I had previously never even heard of it, but can now definitely see ways of applying it to my research," he adds.

Thayaparan Paramanathan, a postdoctoral fellow in biochemistry and biophysics at Brandeis University in Massachusetts, says the hands-on course modules proved most useful to him: "There is no better way of learning than finding out for ourselves, and I will never forget what I learned at the CPLC. It was a great experience where we gained new knowledge and friends that will last a lifetime."

To date, the Physics of Living Cells Summer School has advanced the training of 164 scientists from 79 institutions in the US and abroad. ■

The CPLC is a National Science Foundation Physics Frontiers Center at the University of Illinois at Urbana-Champaign, co-directed by Taekjip Ha and Klaus Schulten in the Department of Physics. It comprises 13 faculty from U. of I. physics, chemistry, biochemistry, and bioengineering and Baylor College of Medicine who pioneer new directions in collaborative research applying the latest technical advances.



CPLC graduate student Alex Krieg (2nd from left) teaches the total internal reflection microscopy technique to 2013 summer school students (L-R) Fanghou Hu, Brett VanVeller, and Dahai Luo.

PhySoc to merge with U. of I.'s SPS chapter

Students packed into 141 Loomis for the 2013/14 joint introductory meeting in August for the Physics Society, Physics Van, and Society of Women in Physics. The informational meeting was followed by a free liquid nitrogen ice cream social.

Last year, U. of I. students active in the Physics Society (PhySoc) restored the U. of I. chapter of the national Society of Physics Students (SPS) when they registered as members. Now undergraduate physics major David Rhodes, who currently serves as president of both of the closely associated student groups, is spearheading a merger, to combine the advantages each offers to its members.

"PhySoc has a legacy of strong membership and good events, while SPS is our fledgling chapter of a national organization," explains Rhodes. "PhySoc is currently free and open to anyone, while SPS requires annual dues and is only practical to join at the beginning of the year. Our aim is to combine the two, using SPS to better connect with other chapters across the country while still maintaining the tradition of dedication and spirit within our local organization."

The merger is slated for the start of the 2014/15 academic year, and Rhodes is making sure that free membership and participation will remain an option for all students.

"We will remove the requirement of SPS national membership for members of our local chapter, so anyone will be able to freely attend our events, just as is currently possible through PhySoc," explains Rhodes. "The change will be primarily one in name—our plan is to maintain all the great events the Physics Society has a tradition of holding, but do it under the banner of our SPS chapter."

Members who opt to join the national organization (dues are $24 annually) will qualify for SPS scholarships, awards, travel grants, and summer internships; will be able to take advantage of networking opportunities at regional and national meetings; and, because SPS is a member society of the American Institute of Physics, SPS members receive certain AIP membership benefits (including a free print and online subscription to Physics Today

An SPS chapter was founded at the U. of I. in January of 1999, but it dissolved in 2004. In fact, U. of I. held membership in SPS's predecessor, the AIP Student Sections, prior to SPS's creation in 1968. In August 2011, U. of I. students reopened communications with SPS, brought their paperwork up to date, and were given active status. In fall 2012, 21 students registered as members of the national organization. Currently in its second year, the U. of I. SPS chapter has about 45 registered members, a subset of the students who turn out regularly for PhySoc meetings and events.

PhySoc's Relay for Life team raises over $1,000 during the U. of I. campus-wide event in April 2013. Pictured from left to right are Lauren Rush, Katrina Litke, Michael Boehme, Samuel Baurac, David Rhodes, Ryan Swindeman, Alexander Papak, and Conan Huang. PhySoc plans to send a team again in 2014.

PhySoc members talk physics with U. of I. students on the Quad in August 2013.

PhySoc members enjoy an *al fresco* meal together at the annual picnic in September 2013.

PhySoc members practicing order-of-magnitude estimation skills with their fellow students in a Fermi problem challenge competition, held in the Interaction Room in September 2013. Winning teams were recognized with prizes and candy.

(PT) and access to the PT career network).

"None of these benefits interfere with our chapter's normal operations, so membership at the national level can be offered as an optional add-on to our local chapter membership," adds Rhodes.

It was attending the SPS Zone 8 Meeting at the University of Louisville in Kentucky, October 25 through October 27, 2013, that convinced Rhodes that a PhySoc–SPS chapter merger would result in greater synergy.

"We sent seven SPS chapter members to the conference. We weren't sure what it would be like and it was a last-minute decision, but we decided to just go for it. And I'm so glad we did. It was exciting to see people outside our program who are passionate about physics and to hear from world-renowned physicists," describes Rhodes.

The attendees spent Saturday listening to presentations, talking with physics majors from Kentucky and Tennessee, and giving poster presentations (conveniently, the seniors had already prepared posters for Physics 499). They drove home immediately after the closing ceremony, energized and inspired by the experience.

Rhodes shares, "For me, by far the best part of the conference was the presidents' meeting. We shared ideas about what works and what doesn't, about how to fundraise—it was valuable to learn what other groups are doing and to connect with other chapter presidents. Attending this type of event will benefit the long-term growth of our organization, and it's only feasible through a national organization like SPS."

PhySoc has a long history at the U. of I. and a very active body of members. The group holds its regular meetings every Wednesday at 9 p.m., during which they prepare for upcoming events and sometimes hold tutorials or fun competitions (e.g., trying to solve Fermi problems such as "How many dollar bills would you have to stack to reach the moon?").

An especially popular meeting this term, with more than 100 students in attendance, featured a talk by Celia Elliott, the department's director of external affairs, on how to write an effective résumé.

The group also holds regular liquid nitrogen ice cream socials, a start-of-year picnic, and monthly dinners with a professor of the members' choosing at a favorite local eatery, Papa Del's Pizza.

"The monthly dinners are informal meetings with researchers who are at the forefront of their fields," explains Rhodes. "We've been lucky to be able to host Professors Dale Van Harlingen, Richard Weaver, and Gregory MacDougall, and all three events confirmed for me that our faculty members are exceptional mentors and cool people. The meetings are a chance to talk about life, about research, about what it's like to be a professor, or about how the Bears are doing. We just hang out."

In early November, the group joined forces with the U. of I. Society of Women in Physics to host a graduate student panel.

"The panelists gave our undergrads a sense of what it's like to be a graduate student. It's good to get inside information and advice, to learn how they picked where they wanted to go and if they're happy with their choice," observes Rhodes.

PhySoc members tour the Advanced Photon Source at Argonne National Lab during a field trip in November 2013.

And in late November, the group hosted an undergraduate research panel.

"We brought in four excellent undergraduate-student researchers within the physics department to serve as panelists for our event, with questions ranging from the basics—how to get into research and what students really do during research—to the difficult—how to best prepare for research," shares Rhodes.

The group also organizes on-campus laboratory tours for its members and occasionally plans tours farther afield. At the start of November, members took a Saturday trip to Argonne National Laboratory. Two years ago, students visited Fermi National Accelerator Laboratory.

And starting in Fall 2013, PhySoc members were invited to perform physics demos in the foyer of Loomis Laboratory, to warm up the crowd before the Saturday Physics for Everyone public lectures (there were more than 900 attendees at the six lectures combined).

To support all of these activities, PhySoc members sell physics-themed T-shirts.

Rhodes believes the planned merger can only enhance PhySoc's activities: "By holding all of our events under the SPS chapter, we'll be eligible for support from the national SPS organization. This will allow us to better publicize our activities to our peer student organizations at other institutions, to achieve visibility to a wider audience."

And student members will be able to develop their professional networks beyond the U. of I.

"We'll be able interact with students from other universities at future zone meetings and at the PhysCon, a quadrennial physics student congress. Maybe we'll even be able to host a zone meeting—that would definitely generate excitement about a future in physics for students who are still on the fence.

"I hope that I can set an example now of good planning, solid leadership, and innovative activities so that my successors can build upon the past and achieve things I haven't even dreamed possible. I will be happiest if I can come back thirty years from now and still see our chapter thriving as it is today," says Rhodes. ■

Nadya Mason elected General Councilor of the American Physical Society

Associate Professor of Physics Nadya Mason has been elected general councilor of the American Physical Society (APS) by a vote of its membership. The APS Council, which meets twice a year, is the main governing body of the Society, responsible for both policy and actions. Mason begins her four-year term on January 1, 2014.

Mason looks forward to serving the APS in this advisory role: "I'm delighted to have been elected as a councilor and look forward to working to increase the breadth and impact of physics. Working in physics has been a joy for me, and this is a great opportunity to give back to the community."

During her term, Mason plans to focus on several specific calls to action. Among these, she asserts that prioritizing funding at the national level for physics research is essential to the nation's long-term economic and intellectual prosperity.

"It will be important to find new ways to help the public and policy-makers recognize the crucial role that physics has played and will continue to play in the development of our society," Mason comments.

Mason will advocate for fundamental scientific research, in addition to application-related work. And she will work through the APS Council to broadly communicate the significant results and impact of physics research, particularly taking advantage of new media.

Mason would also like to look at how the APS can further support increased diversity within the field of physics. A longtime advocate for women and underrepresented minorities in the field, Mason says the APS must help to ensure that all students are given the opportunity to engage with physics.

"In my experience, increased diversity and a welcoming climate enrich the field for everyone," says Mason.

Mason is a member of the Frederick Seitz Materials Research Laboratory. Her experimental research in condensed matter physics focuses on the electronic properties of carbon nanotubes, graphene, and topological insulators. Because of the low dimensionality of these systems, they often display novel electronic properties and hold promise for applications in superconductivity and quantum computing. Mason's work has direct bearing on our understanding of electronic transport in these materials, which is essential for the design of nanoscale circuit elements, an emerging area of study.

Mason has received numerous recognitions for her work, including the U. of I. College of Engineering Dean's Award for Excellence in Research (2013), APS's Maria Goeppert Mayer Award (2012), the Denice Denton Emerging Leader Award of the Anita Borg Institute (2009), a Woodrow Wilson Career Enhancement Fellowship (2008/09), a National Science Foundation CAREER Award (2007), and her appointment as a Center for Advanced Study Fellow (2011/12) at the University of Illinois. She was one of 122 young scientists to take part in the National Academy of Sciences' US and Chinese-American Kavli Frontiers of Science symposia (2011).

Mason received her bachelor's degree in physics from Harvard University in 1995 and her doctoral degree in physics from Stanford University in 2001. She then returned to Harvard for a postdoctoral fellowship and was in short order elected to the Harvard Society of Fellows. She joined the Physics Illinois faculty in 2005. She is currently serving as the chair of the Facilities Committee for MRL and as as one of the theme leaders for the DOE Basic Energy Sciences cluster on quantum materials and nanoarchitectures.

The 2014 APS Council meetings are scheduled for April 4, in Savannah, GA, and November 24, in San Francisco, CA. ■

Budakian named John Bardeen Scholar

Associate Professor Raffi Budakian has been named the John Bardeen Faculty Scholar in Electrical and Computer Engineering and Physics, an appointment that will continue indefinitely.

Budakian, who works in experimental condensed matter physics, has been extensively published in peer-reviewed journals and has delivered more than 50 invited lectures the world over. His research has focused on single nuclear spin detection and imaging using magnetic resonance force microscopy, ultra-sensitive force/displacement detection, and design and fabrication of micro- and nano-mechanical devices.

Most recently, Raffi Budakian and his students have achieved high-resolution magnetic resonance force microscopy by using a highly sensitive silicon nanowire mechanical oscillator as a low-temperature NMR force sensor. With this new technology Budakian's research group presented last year, it is now possible to perform 3D magnetic resonance imaging with 10-nm resolution, far more sensitive than the millimeter resolution of medical MRI. Ultimately, with further break-through advancements to this technology, 3D imaging of single molecules would become a possibility.

Another area of his research is geared toward applying high-resolution low-temperature magnetic force microscopy to study strongly correlated condensed matter systems. This work includes the study of vortex matter in unconventional superconductors and strongly correlated magnetic materials, and developing techniques for imaging surface currents.

Budakian is also an excellent teacher, invested in providing physics students with an exceptional learning experience. In 2007, Budakian took on a two-year project, working to modernize the lab experiments in Physics 401, Classical Physics Laboratory, to introduce upper-division physics students to advanced experimental techniques.

Budakian earned his bachelor's (1994 *summa cum laude*), master's (1995), and doctoral (2000) degrees in physics from the University of California, Los Angeles. He remained at UCLA as a postdoctoral fellow for two years. From 2002 to 2005, he worked as a visiting scientist at the IBM Almaden Research Center in San Jose, CA, where his research focused on detecting the spin of a single defect in glass using magnetic resonance force microscopy. In 2005, he was named a Fellow of the World Technology Network when he was selected for the World Technology Award in materials, presented for single-spin detection by magnetic resonance force microscopy (2005). He was named a Fellow of the U. of I. Center for Advanced Study in 2010/11.

The John Bardeen Faculty Scholar in Electrical and Computer Engineering and Physics is sponsored by the Sony Corporation. This award is presented to faculty members relatively early in their careers who excel in their research, teaching, and service contributions to the College of Engineering and the University. ■

Two physics faculty members elected to CAS Professorships

The U. of I.'s Center for Advanced Study (CAS) has elected two from the Department of Physics to its membership. Nigel Goldenfeld and Klaus Schulten are among the nine campus faculty members newly named CAS Professors, selected for their outstanding contributions to their respective fields. A permanent appointment as a CAS Professor is one of the University's highest academic honors.

Swanlund Professor of Physics Nigel Goldenfeld leads the Biocomplexity Theme at the Institute for Genomic Biology (IGB) and is the director of the IGB-based Institute for Universal Biology, a component of the NASA Astrobiology Institute network. His diverse research interests embody the interdisciplinary spirit of the IGB, encompassing fields such as physics, microbiology, evolutionary biology, fluid mechanics, materials science, and quantitative finance. The common thread in his research is the study of complexity: how complex patterns develop over time and the process by which interactions between the simpler components of a complex system produce emergent states. Recent work by his group includes developing statistical theories for fluctuating turbulent flows; modeling the relationship between the dynamics of dislocations at the nanoscale and large-scale properties of plastically-deformed solid matter; and, in collaboration with fellow IGB faculty member Bryan White, investigating the ecology of gut microbiota. Together with the late Professor Carl Woese, Goldenfeld developed a dynamical theory for the evolution of the genetic code, suggesting that life arose from an early collective state more than 3 billion years ago.

Goldenfeld received his doctoral degree in physics from the University of Cambridge in 1982. He worked as a postdoctoral fellow at the Institute for Theoretical Physics, University of California, Santa Barbara, from 1982 to1985 before joining the Department of Physics at Illinois as an assistant professor in 1985. Goldenfeld is a Fellow of the American Physical Society and the American Academy of Arts and Sciences, and a Member of the National Academy of Sciences.

Swanlund Professor of Physics Klaus Schulten heads the Theoretical and Computational Biophysics Group at the Beckman Institute for Advanced Science and leads the National Institutes of Health Center for Macromolecular Modeling and Bioinformatics. He also co-directs the Center for the Physics of Living Cells in the Department of Physics, a National Science Foundation "Physics Frontiers Center." His research is focused on molecular assembly and cooperation in biological cells, using large-scale computing for scientific discoveries and groundbreaking simulations. He was the first to demonstrate that parallel computers can be practically employed to solve the classical many-body problem in biomolecular modeling and was the first to simulate an entire life form, the satellite tobacco mosaic virus. Hundreds of thousands of researchers worldwide use his group's software in molecular graphics (VMD) and modeling (NAMD), both on personal computers and at the world's leading supercomputing centers. Schulten's group recently discovered the molecular structure of the HIV capsid, comprising 64 million atoms—research that holds far-reaching implications for

HIV pharmaceutical interventions.

Schulten holds a *Diplom* degree in physics from the University of Münster, Germany, and a doctoral degree in chemical physics from Harvard University. He was a junior group leader at the Max–Planck–Institute for Biophysical Chemistry from 1974 to 1980 and worked as a professor of theoretical physics at the Technical University of Münich from 1980 to 1988, before joining the faculty at Illinois. Schulten is a Fellow of the Biophysical Society and of the American Physical Society. He is the recipient of many honors, most recently the 2013 Distinguished Service Award of the Biophysical Society and the 2012 Sidney Fernbach Award of the IEEE Computer Society.

The CAS brings together top scholars from diverse disciplines and backgrounds to encourage and reward excellence in all areas of academic scholarship. CAS Professors contribute to the center's annual lecture series, as well as serving on committees that select recipients of CAS Associate and Fellow research appointments. Candidates for CAS Professorship may be nominated by a dean, director, or department head; they are rigorously evaluated by all current CAS Professors based on the strength of their academic record and history of prior awards and honors, before being elected by a majority vote of current CAS Professors.

Goldenfeld and Schulten join nine other CAS members from physics, CAS Professors David Ceperley, Laura Greene, Tony Leggett, and Dale Van Harlingen, and CAS Emeritus Professors Gordon Baym, Hans Frauenfelder, Miles Kline, David Pines, and Charles Slichter. ■

Grosse Perdekamp selected for Distinguished Promotion

Promoted this academic year to full professor of physics, Matthias Grosse Perdekamp has been selected by the University of Illinois Office of the Provost for the 2013 Campus Distinguished Promotion Award.

Nominees for this award are selected from a large pool of stellar scholars through a rigorous promotion review process conducted by the Campus Committee on Promotion and Tenure, identifying scholars whose contributions and achievements within their respective fields are particularly excellent. Grosse Perdekamp is one of four campus faculty members to receive this honor this year.

Vice Chancellor for Academic Affairs and Provost Ilesanmi Adesida comments, "Professor Grosse Perdekamp was recommended to me for this special recognition based on the scope, quality, and impact of his scholarship, teaching, service, and engagement efforts. His accomplishments stood out as particularly remarkable."

Grosse Perdekamp works in experimental high-energy nuclear physics. He is a member of the PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. The PHENIX collaboration, which includes 498 physicists and engineers from 70 institutions in 14 countries, engages in a broad program of studying QCD phenomena, including the physics of heavy-ion collisions, the spin-dependent structure of the proton in polarized proton-proton collisions, and nucleon structure in a nuclear environment in proton- or deuteron-ion collisions. Gross Perdekamp has taken a leadership role in PHENIX's spin-physics program, which will employ the polarization of the proton beams at the RHIC collider to perform spin-dependent measurements at the highest energy scales yet explored.

Grosse Perdekamp received his *Diplom* in physics from Freiburg University in 1990 and his doctoral degree in physics from the University of California, Los Angeles, in 1995. He was an associate research scientist at Yale University from 1995 to 1998, and a research scientist at Johannes Gutenberg University in Mainz, Germany, from 1998 to 1999. In 2002, he was selected as a RIKEN Fellow at RHIC. He joined the faculty at Physics Illinois as an assistant professor in 2002, remaining a Fellow at RIKEN through 2007. He was the recipient of the Xerox Research Award in 2008 and was named a Willett Faculty Scholar in 2010. ■

Pitts named University Scholar

Associate Head for Undergraduate Programs and Professor Kevin Pitts was one of six campus faculty members to be named a University Scholar by the U. of I.

Pitts is an international leader in experimental high-energy physics who has made seminal contributions to measuring CP violation in the B-meson system at the Collider-Detector Facility (CDF) experiment at Fermilab. Unraveling CP violation, a tiny difference in the behavior of matter and antimatter, is essential to understanding how our universe evolved from equal parts of matter and antimatter immediately after the big bang to its current state of being nearly 100-percent matter.

Pitts led the Illinois CDF group responsible for the construction, installation, integration, and operation of the very-high-speed digital trigger (XTRP), a central component of the CDF trigger system. Pitts was also CDF physics coordinator and co-leader of the Bottom Physics working group. He was the overall project manager for the electronics for the CDF central outer tracking chamber (COT), which included coordinating design and development of the front-end electronics and trigger and the integration of data acquisition.

Pitts now works on a new experiment to measure the magnetic properties of the muon with unprecedented precision, g-2, which is being moved from Brookhaven National Laboratory to Fermilab.

Pitts served as chair of Fermilab's User Executive Committee (2008-2010). He

Photo by L. Brian Stauffer

also served on the National User Facility Steering Committee (2008–2010)and on the American Physical Society's Division of Particles and Fields Executive Committee (2008–present). Pitts is currently serving on the National High Energy Physics planning panel. On campus, he currently serves as a member of the advisory committee for the Office of Undergraduate Research, the Campus Budget Oversight Committee, and in the past served on the U. of I. Engineering Open House Committee (2007–08), and the University of Illinois Faculty Senate (2005–2007).

Serving as associate head for undergraduate programs since 2010, Pitts has undertaken many new initiatives to improve the undergraduate student experience and outcomes in our department—strengthening student advising, engaging students in regular town-hall meetings, and increasing opportunities for undergraduate research. His commitment to increasing the participation in physics of women and other historically underrepresented groups is evidenced in his outreach and in the highly successful summer program he manages, the NSF-funded Research Experiences for Undergraduates (REU).

A dynamic and inspiring teacher and mentor, Pitts regularly makes the University's "List of Teachers Ranked Excellent by their Students" and is a six-time recipient of the U. of I. Engineering Council's Award for Outstanding Undergraduate Adviser.

Through his numerous outreach activities, Pitts regularly brings science learning to the non-scientific community at and beyond the University, from junior high and high school students to lifelong learners. A great advocate for science, he conveys to young people and the general public the importance of scientific thinking and an appreciation for the benefits of scientific research.

Pitts is the recipient of numerous honors. He received an NSF CAREER Award (2004) and the Xerox Award for Outstanding Research (2007). He was named a DOE Outstanding Junior Investigator (2002), a Universities Research Association Visiting Scholar (2009), and a Beckman Fellow at the Center for Advanced Study (2001/02).

Pitts received his bachelor's degree in physics and mathematics from Anderson University (1987) and his master's (1989) and doctoral (1994) degrees in physics from the University of Oregon. He worked as a research assistant at Fermi National Accelerator Laboratory (1994-1999), before joining the faculty at Physics

Illinois in 1999.

The University Scholars Program of the Office of the Vice President for Academic Affairs was established in 1985 to recognize outstanding members of the faculty for excellence in teaching, scholarship, and service and to provide each with a total $45,000 funding allocation paid over a three-year period, to enhance scholarly activities.

"Recognition of the achievements of our stellar faculty is crucial," says Christophe Pierre, vice president for academic affairs. "It is an apt tribute to their outstanding scholarship, an investment in their future productivity, and a key to our ability to retain extraordinary faculty.

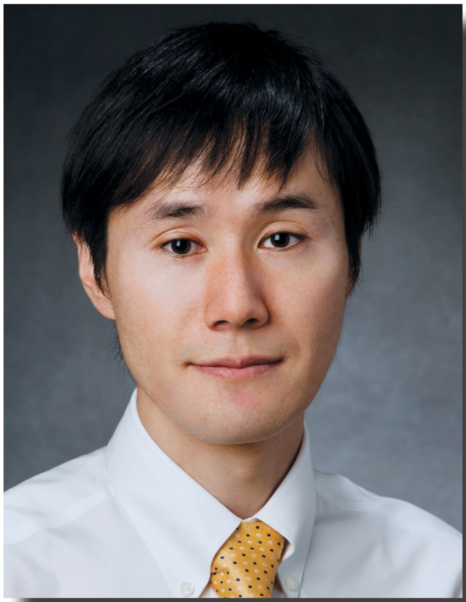
Pitts was honored at a campus reception on September 10, 2013. ■

Ryu shares 27th Nishinomiya-Yukawa Memorial Prize

Assistant Professor Shinsei Ryu was awarded the 27th Nishinomiya–Yukawa Memorial Prize for outstanding research in theoretical physics for his "Holographic Derivation of Entanglement Entropy from the anti-de Sitter Space/Conformal Field Theory Correspondence," published in the May 9, 2006, issue of *Physical Review Letters*. Ryu shares the prize with his collaborator and coauthor, Tadashi Takayanagi, a professor of physics at Yukawa Institute for Theoretical Physics at Kyoto University.

In their study on quantum entanglement, Ryu and Takayanagi apply the holographic principle from superstring theory to the measurement of quantum states, called entanglement entropy, used in quantum field theories, to address persistent gaps in superstring theory.

Superstring theory attempts to explain all of the interactions of particles and fundamental forces of nature by one universal theory, treating matter, force, and gravity in a fully quantum mechanical way. However, superstring theory has not yet been fully successful in treating spacetime in a fully quantum mechanical way, particularly as applied to black holes and the genesis of spacetime.



Ryu and Takayanagi address these gaps using the holographic principle to describe quantum entanglement. The holographic principle suggests that quantum field theories in non-gravitating spacetime are a "shadow" of gravitational theory in one higher dimension.

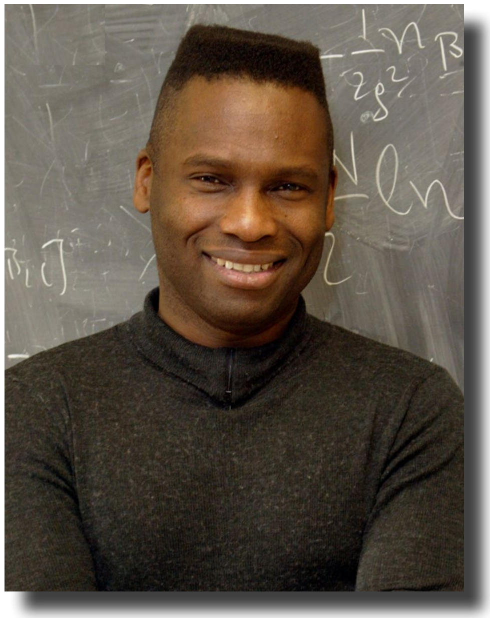
Using the holographic principle, quantum entanglement in quantum field theories is described in terms of a geometrical quantity, given by the area in the dual gravity theory. This suggests an interpretation of the entropy of a black hole in terms of quantum entanglement, revealing an important aspect of quantum gravity. It also gives great insight into strongly interacting quantum field theories.

Ryu received his bachelor's degree (2000) in physics and his master's (2002) and doctoral (2005) degrees in applied physics from the University of Tokyo. In 2001, he received the Tanaka Shoji Prize (master's thesis prize) from the Department of Applied Physics at the University of Tokyo. He was awarded a research fellowship by the Japan Society for the Promotion of Science (2002/03). He was awarded Japan's 7th Condensed Matter Science Prize (2012) for his development of a "periodic table" for the classification of topological phases of matter in three spatial dimensions.

The Nishinomiya–Yukawa Memorial Prize is presented to promising young physicists under 40 years of age by the City of Nishinomiya to encourage research in theoretical physics. The award was established by the city to honor Dr. Hideki Yukawa, the first Japanese Nobel laureate in physics, who developed the meson theory while living in Kurakuen in Nishinomiya.

Ryu and Takayanagi were presented with the award in a ceremony in Nishinomiya, Japan, on November 1, 2013. ■

Philip Phillips selected for Rudranath Capildeo Award for Applied Science and Technology



Professor Philip Phillips was selected for the 2013 Rudranath Capildeo Award for Applied Science and Technology by the Republic of Trinidad and Tobago's National Institute of Higher Education, Research, Science and Technology (NIHERST). This is the highest scientific honor of this country, presented to a national for outstanding achievements in science and technology, for providing a positive role model to youth, and for contributing to Caribbean scientific heritage.

Phillips is a theoretical condensed matter physicist whose leading-edge research on high-temperature cuprate superconductors focuses on explaining current experimental observations that challenge the standard paradigms of electron transport and magnetism. Phillips applies geometry and quantum field theory to disordered and strongly correlated low-dimensional systems to understand the properties of these materials.

Phillips's work has earned him an international reputation. He is the inventor of various models for Bose metals, of the term "Mottness," and of the random dimer model, which exhibits extended states in one dimension, thereby representing an exception to Anderson's localization theorem. He is the author of the comprehensive textbook *Advanced Solid State Physics*, published by the Cambridge University Press.

Phillips earned his bachelor's degree in math and chemistry from Walla Walla College in 1979 and his doctoral degree in theoretical chemistry from the University of Washington in 1982. After a Miller Postdoctoral Fellowship at Berkeley, he joined the faculty of the Department of Chemistry at Massachusetts Institute of Technology (1984–1993). Phillips research interests led him to the Department of Physics at the University of Illinois in 1993.

Phillips is a Fellow of the American Physical Society and served the society as general councilor (2000–2004). He is also a Fellow of the American Association for the Advancement of Science. He is the recipient of many honors; among these, he received the Senior Xerox Faculty Award in 1998, was named a Beckman Associate at the Center for Advanced Study for the 1998/1999 academic year, was the Edward A. Bouchet Lecturer of the American Physical Society in 2000, was selected as a University Scholar at the University of Illinois in 2004, was named Bliss Faculty Scholar by the College of Engineering in 2005, and was chosen one of twelve inaugural National Science Foundation American Competitiveness Initiative Fellows in 2008.

The Rudranath Capildeo Award is named for Dr. Rudranath Capildeo, renowned for his intellectual contributions to the fields of applied mathematics and physics. His interest in and understanding of Einstein's Theory of Special Relativity resulted in new theories, such as the theory of rotation and gravity, or Capildeo's theory. He was also a gifted mathematics and physics educator and taught at the University College London among other institutions.

The award was presented to Phillips by NIHERST, together with the Trinidad and Tobago Ministry of Science and Technology, and the Caribbean Academy of Sciences, in a ceremony in Port of Spain on November 23, 2013. ■

Wei-Cheng Lee selected for Michelson Postdoctoral Prize Lectureship

Postdoctoral researcher Wei-Cheng Lee has been selected for the prestigious Michelson Postdoctoral Prize Lectureship at Case Western Reserve University and was invited to present three technical lectures and a colloquium at CWRU in Fall 2013.

Lee, who joined the Department of Physics in 2010, works in condensed matter theory alongside Professors Philip Phillips and Anthony Leggett. His research, which is supported by the Center for Emergent Superconductivity, is focused on unconventional superconductors and Mott systems. Most recently, he has studied the effects of orbital degrees of freedom on high-temperature iron-based superconductors, which were first discovered in 2008, using various theoretical techniques such as generalized random-phase approximation (RPA) and multidimensional bosonization.

"Wei-Cheng is a highly productive and valuable member of our research team," shares Phillips. "He is particularly noted for the idea, now well accepted in the field, that orbital ordering underlies the transport anisotropies in strontium ruthenate and iron-based superconductors."

Lee says it has been a tremendous experience to study superconductivity at Illinois: "The department is famous for this area of research—I feel honored to be here. In addition to my colleagues working in theoretical physics, I have also enjoyed my collaboration with Professor Laura Greene. Her team has performed experiments that gave me a lot of inspirations and demonstrated that several novel features observed in point contact spectroscopy are in fact associated with the orbital degrees of freedom, as predicted."

Lee also maintains collaborations with scientists at the Materials Science Division of the Argonne National Laboratory and Brookhaven National Laboratory.

Lee received his bachelor's and master's degrees in physics from the National Taiwan University in 1999 and 2002, respectively. He earned his doctoral degree in physics from the University of Texas at Austin in 2008, working under Professor Allan MacDonald. There, he was awarded the University Continuing Fellowship, one of the highest honors to UT graduate students, and selected for the Outstanding Dissertation in Physics award. From 2008 to 2010, Lee worked as a postdoctoral researcher at the University of California, San Diego, under Professor Congjun Wu, before coming to Physics Illinois in 2010. ■

Calling all Physics Van alumni and friends!

For more information and to register, go to http://van.physics.illinois.edu/20-years-of-smiles/.

Drell and Slichter inducted into Hall of Fame

Professor Charles Slichter

Alumnus Sidney Drell

Professor Charles P. Slichter and his long-time friend and colleague, Physics Illinois alumnus Sidney D. Drell (MS 1947; PhD 1949) were elected to the 2013 class of the College of Engineering Hall of Fame, the highest honor the College bestows on faculty and alumni. An induction ceremony was held on September 27, 2013, at the Beckman Institute for Advanced Science and Technology in Urbana.

Slichter is internationally recognized as one of the world's top condensed matter physicists. He and his students and colleagues pioneered novel nuclear magnetic resonance (NMR) techniques to reveal the fundamental molecular properties of liquids and solids. His inspired teaching has led generations of physicists and chemists to develop countless modern technologies in condensed matter physics, chemistry, biology, and medicine.

In 1949, Wheeler Loomis personally recruited Slichter to Illinois as an instructor in physics. He advanced rapidly through the faculty ranks, becoming a full professor in 1955. Now professor emeritus, Slichter continues as an involved researcher and a revered mentor in the Department of Physics. He has passed on his deep physical insight and infectious zest for physics to four generations, advising a total of 63 PhD students and 17 postdoctoral scientists. Through three editions, his textbook, Principles of Magnetic Resonance, has served as a standard in the field for more than 50 years.

A member of the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society, Slichter has won numerous professional honors, including the Irving Langmuir Prize, the Oliver E. Buckley Prize, the Comstock Prize, and the ISMAR Triennial Prize. He received the National Medal of Science in 2007.

Sidney Drell (MS 1947, PhD, 1949) is a renowned theoretical high-energy physicist and arms control expert. He is a professor of theoretical physics emeritus at Stanford University's SLAC National Accelerator Laboratory, where he served as deputy director until his retirement in 1998, and is a senior fellow at the Hoover Institution at Stanford.

Drell is internationally known for his seminal work in quantum field theory and quantum chromodynamics, and he has made lasting contributions to national policies in security and intelligence.

He is one of the original and still active members of JASON, an elite group of academic scientists who advise the government. Since the 1960s, Drell has advised the executive and legislative branches of the U.S. government on national security and technical defense issues. In 1993, a collection of Drell's writings and congressional testimony was published in the American Institute of Physics' Masters of Modern Physics series under the title In the Shadow of the Bomb: Physics and Arms Control.

Among Drell's many awards and honors are a MacArthur Foundation "genius" grant, the Ernest Orlando Lawrence Award, the Enrico Fermi Award, the Rumford Prize, and the National Medal of Science. He is a member of the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society.

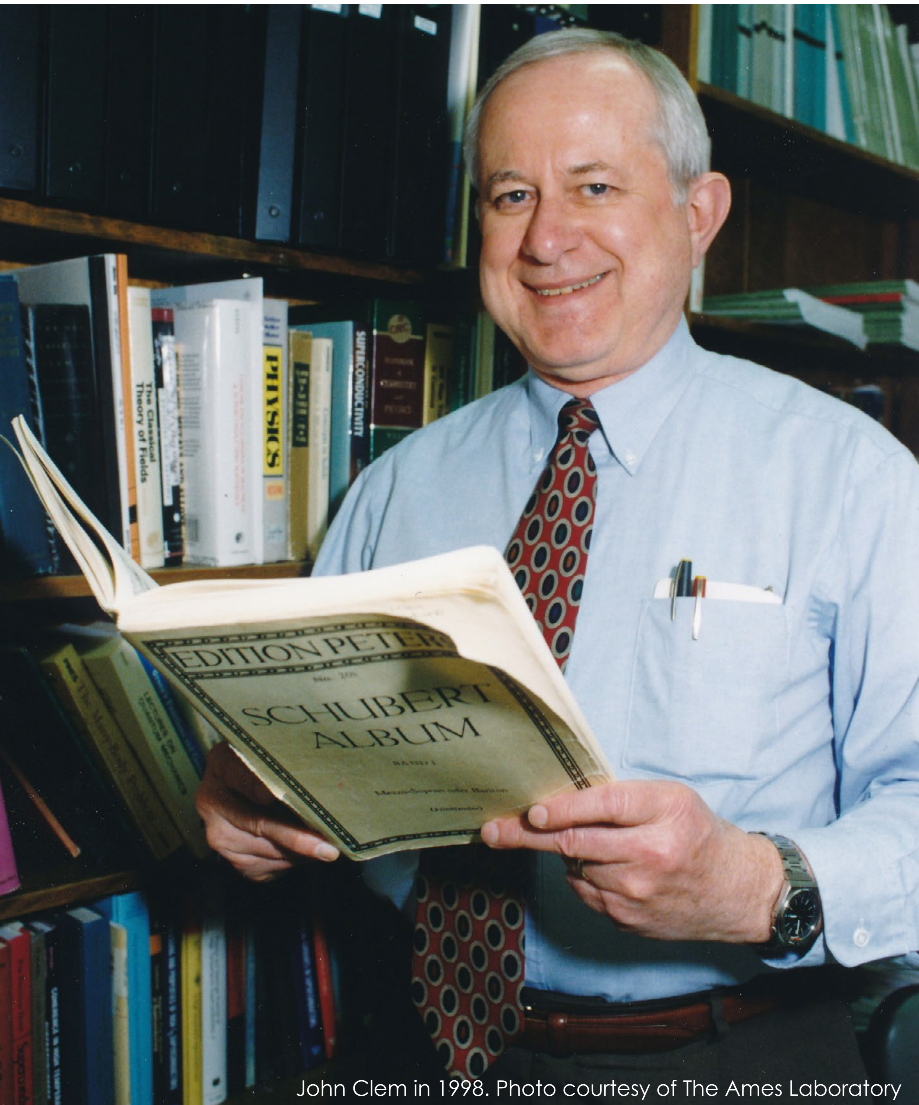
Drell was unable to attend the ceremony. ■

Top left: Professor Charles Slichter is presented with a medallion by Dean of Engineering Andreas Cangellaris, while President Robert Easter and Chancellor Phyllis Wise look on.

2nd photo: Guests of honor visit with colleagues before the induction ceremony.

3rd and 4th photos: Slichter visits with friends and collagues at the reception that followed the ceremony.

Alumnus John Clem remembered



John Clem in 1998. Photo courtesy of The Ames Laboratory

Iowa State University Professor Emeritus of Physics and Astronomy John Clem, 1938–2013

Physics Ilinois alumnus John Richard Clem, a gifted theorist in condensed matter physics and world-renowned expert in the theory of superconductivity, passed away August 2, 2013. He leaves a lasting impact on the science that was his great passion and the deep admiration of colleagues and scientists near and far.

The Iowa State University distinguished professor emeritus of physics and astronomy and DOE Ames Laboratory senior scientist emeritus made significant theoretical advances in our understanding of the electrodynamic behavior of superconductors. After the discovery of high-temperature superconductors in 1986, he turned his full attention to these materials; his work focused on fundamental problems related to flux pinning, critical currents, flux flow, ac losses, noise, spiral and intersecting vortices, instabilities, surface and interface effects, proximity effects, and two- and three-dimensional arrays of Josephson junctions.

Clem is perhaps best known for the two-dimensional pancake vortex, a term he coined to describe Abrikosov vortices in layered high-temperature cuprate superconductors, and for the high-temperature superconductivity newsletter he founded in 1987, *High-T_c Update*, for which he wrote the highly useful Nota Bene, briefs on the best papers and most notable research findings to emerge from the great worldwide surge of investigations into high-temperature cuprate superconductors that followed their discovery. For his briefs, he tirelessly read every preprint that was sent to his department for review, often working until three in the morning to meet his own publishing deadline the next day.

Physics Illinois Department Head and Professor Dale Van Harlingen held Clem in high regard.

"John was one of my favorite people in condensed matter physics, a great scientist, and a true gentleman," remembers Van Harlingen. "For decades, he was undisputedly the leading expert in modeling the dynamics of vortices in superconductors and superconducting devices, and I sought his help on the analysis of many of our experiments, especially early in my career. In every case, John enthusiastically agreed to help and was always able to provide valuable insight and often a viable theoretical model that captured the essential physics. He was probably best known worldwide as the editor of the newsletter *High-T_c Update* that became the central exchange repository for the latest experimental results and theoretical models in the rapidly growing field of high-temperature superconductivity."

While Clem recognized the enormous value of fundamental research, he was greatly motivated by the potential for eventual applications of superconductivity, in high-field magnets and large-scale power transmission, as well as in smaller-scale applications such as filters, resonators, and Josephson devices for use in sensitive detectors and logic devices.

In a 2012 interview with Iowa State Daily reporter Elizabeth Polsdofer, posted online Tuesday, August 21, 2012, Clem shared, "I would like to have the feeling that what I do has some—if not immediate—eventual application in superconductivity… There are some theorists who like the idea of just the mathematical world, just the theoretical world and just working in that world without any thought of actual experimental applications or experimental manifestations. I'm not that sort, but I respect those people. That just never interested me."

In the same interview, Clem admitted that from the theoretical side of the fence, the experimental side looked rather enjoyable: "I'm a theorist. I've never done any experiments in superconductivity, but I've always enjoyed stopping by a laboratory and seeing how things were going. Sometimes I even had the opportunity to turn a dial or something like that to see what happens... I remember a very pleasant experience when I was collaborating with a fellow physicist at Argonne National Laboratory, and he and his co-workers went off to lunch one day, and he let me sit in his lab and play around with the apparatus. I didn't break it, and it was okay. I got to turn up the current, then turn down the current, turn up the magnetic field—it was a lot of fun."

Clem was an associate member of the Center for Emergent Superconductivity (CES), a DOE Energy Frontier Research Center established as a collaboration among scientists at Brookhaven National Laboratory, Argonne National Laboratory, and the University of Illinois at Urbana-Champaign.

Co-director of the CES Illinois group, Swanlund Professor of Physics Laura Greene, writes about Clem's contribution to the CES: "In our Center, his most scientifically important published result was 'Theory of flux cutting and flux transport at the critical current of a type-II superconducting cylindrical wire,' published in Phys. Rev. B 83, 214511 (2011). This result contributed to the CES objective of maximizing critical currents by understanding and controlling vortex dynamics. In the CES, of our three themes, the vortex theme has been the most successful, meeting and surpassing objectives."

Greene notes how much Clem was missed by colleagues and friends at the 14th International Workshop on Vortex Matter in Superconductors in Nanjing, China, last summer: "John never missed one of these meetings but was not able to travel due to his failing health. The attendees of this workshop are a fairly tight group so John's presence was very much missed and he came up in conversation often — good stories and lots of respect."

Clem continued his work on problems related to vortex physics, with undiminished zest throughout his four-year battle with mesothelioma.

Clem was born in 1938 in Waukegan, IL. His parents were both teachers. An exceptional student, Clem attended the University of Illinois at Urbana-Champaign on scholarships. He earned his bachelor's degree in engineering physics (1960) and his master's (1962) and doctoral (1965) degrees in physics from Illinois.

Clem excelled in his studies at Illinois and, as an undergraduate, he also found time to pursue his great love of music. He played in the U. of I. bands, including the Marching Illini, and sang with his fraternity. After graduation, he married his high school sweetheart, Judith Clem.

As a graduate student, Clem set aside his musical pursuits, but

Clem looks over an issue of *High-T_c Update* in 1987. Photo courtesy of Iowa State University, Department of Physics and Astronomy

would later pick them up again during his years at ISU, studying voice under top instructors and performing with ISU's Music Antiqua, singing baritone in his church choir, and sharing his gift with colleagues in his department and a few times at physics conference banquets.

Clem's doctoral thesis adviser was John Bardeen. In the 2012 Iowa State Daily interview, Clem describes Bardeen as a mild-mannered, modest man whose genius was well appreciated by his colleagues: "When I was a graduate student, I tended to be a very independent student. So my contacts with Bardeen were rather limited," Clem said. "He was a very quiet individual. Everybody knew he was very quiet and he had the reputation of being so smart that when reverent people had a problem they couldn't do, they would go into his office, describe the problem to him, and he would get out a 3×5 card, write the solution, and give it to them."

"I remember one time I had told [Bardeen] what all I had done, and he said, 'I think you have enough here for a thesis.' That was music to my ears, and so I began writing my thesis. When various chapters were completed, I would send them around the world, wherever he was visiting, and finally I had my Ph.D. exam in August of 1965."

Clem's doctoral thesis, "Effects of anisotropy of the superconducting energy gap," is available online in the Physics Illinois dissertations and theses library.

After postdoctoral appointments at the University of Maryland and at the Technical University in Münich, Clem joined the Iowa State University physics department and Ames Laboratory in 1967, where he spent his 46-year career, serving as head of the department from 1982 to 1985.

From 1971 through 2010, Clem enjoyed various appointments as a consultant at Los Alamos National Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, IBM Thomas J. Watson Research Center, Allied-Signal Aerospace Company, Underground Systems, Inc., American Superconductor Corporation, and Pirelli Cable Corporation.

In 1992/93, he was a visiting professor of applied physics at Stanford University and a visiting scientist at Electric Power Research Institute in Palo Alto, CA.

Among the professional honors Clem received over the course of his career was the 2012 Institute of Electronic and Electrical Engineers Council on Superconductivity Award for Significant and Sustained Contributions to Applied Superconductivity.

The citation reads, "For significant and sustained contributions to the development of superconducting materials by advancing the science of both low-temperature and high-temperature superconducting materials, in particular: for his many significant theoretical contributions to the electrodynamic behavior of current-carrying superconductors; for applying his theoretical understanding to explain the observed behavior in various applications of superconductivity, both large-scale and small-scale; and for his service as science editor of *High-T_c Update* from 1987 to 2000, when he reviewed and summarized the 'tsunami' of papers that were written following the discovery of high-temperature superconductivity."

Clem was a Fellow of the American Physical Society (APS) and of the Institute of Physics in London. He was a member of the American Association for the Advancement of Science, the American Association of University Professors, the Iowa Academy of Science, Sigma Xi, the Scientific Research Society, Tau Beta Pi, and Phi Kappa Phi.

He was a Distinguished Lecturer at the 13th International Workshop on Vortex Matter in Superconductors in Chicago (2011), was named an APS Outstanding Referee (2010), was a 1997 ISU

Chapter Phi Kappa Phi Centennial Medalist, received a special award from the 1990 Applied Superconductivity Conference, Inc., for contributions to the superconductivity community, and received the1988 DOE Annual Award for Sustained Outstanding Research in Solid State Physics. He was a Fulbright Research Fellow to Kernforschungsanlage Jülich in Germany in 1974/75.

He chaired the ISU Department of Physics and Astronomy from 1982 to 1985. He was also a revered teacher and mentor; he received the 1999 and the 1991 Most Valuable Instructor teaching award from graduate students in the ISU physics department.

Clem is survived by his wife, Judith Clem, and by his two children, Paul Clem and Jean (Clem) Latzke; and three grandchildren. ■

Physics Illinois wants to network with you on LinkedIn

The Physics Illinois community includes academics and professionals in a wide variety of interesting occupations. With our alumni LinkedIn group, we are building a network of faculty, alumni from both our undergraduate and graduate programs, and current students to share ideas and build connections. We hope you'll network with us.

"The LinkedIn group is a great way to make and renew contacts as well as share experiences and advice with our current students. When asked how we can improve our physics programs, students most frequently answer, 'Provide opportunities for contact with alumni.'

"Your contributions to the LinkedIn group would be greatly appreciated. Our student body is growing, and the interests of our students are both broad and diverse. Join our group to network and connect with alumni and students alike."

—Professor Kevin Pitts, associate head for undergraduate programs

Physics Illinois Alumni

Yu Gan receives Lam Research Corporation's Outstanding Graduate Student Award

Physics Illinois doctoral student Yu Gan has been selected to receive the Lam Research Corporation's Outstanding Graduate Student Award for his work in developing innovative inelastic x-ray scattering techniques, which have implications for our understanding of the fundamental behavior of electrons in novel materials.

Gan works in experimental condensed matter physics as part of Professor Peter Abbamonte's group. Gan's thesis work employs inelastic X-ray scattering to precisely measure the electronic properties of materials, with an emphasis on imaging the ultrafast response of materials to perturbations. In an invited article in a special issue of Chemical Physics on attosecond phenomena (v. 414, pp 160-167), Gan describes his new experimental technique using coherent inelastic X-ray scattering.

The new technique is based on one Abbamonte had developed that can produce "movies" of ultrafast electronic behavior of materials. Abbamonte's technique assumes a homogeneous system of electrons, a reasonable first approximation for many materials. Gan's technique does the same for materials having an inhomogeneous distribution of electrons, theoretically recovering the material's complex electronic behavior for imaging.

"I'm trying to refine the technique to make it applicable to more materials," explains Gan. "We may be able to use it to process data to get real-time and -space data out. Ultimately, I am imaging what electrons do in a system as a result of perturbations, like when we remove or add an electron. This response to perturbation is a fundamental property of a material."

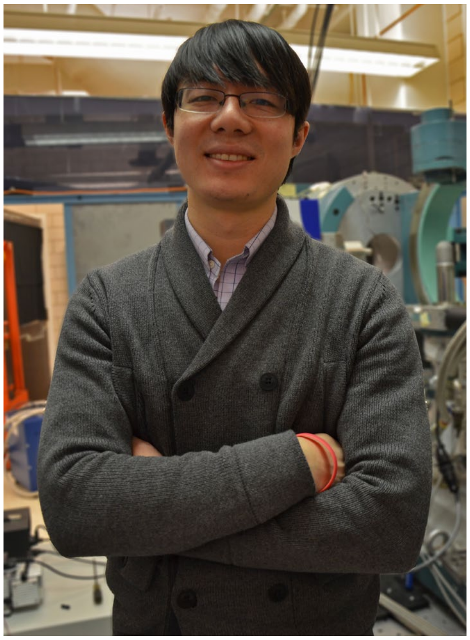
"Gan has done an outstanding job of giving life to this experimental concept," Abbamonte comments. "The study would not have been possible without his fearlessness and attention to detail."

Gan has also been using inelastic X-ray scattering to study graphene, an inhomogeneous material having many exotic properties. His recently completed experiments at Argonne National Laboratory look in particular at graphene's electronic interactions, measuring whether these are as strongly correlated as theoretically postulated.

Gan chose this field of research for his graduate studies because he wanted the opportunity to build an experiment from the ground up. As an undergraduate, he did research in high energy physics using data from Fermilab:

"When you are part of a collaboration with 3,000 physicists, working on one small piece, it's easy to feel your contribution is insignificant. I wanted more of a table-top research experience from my graduate work," remarks Gan. "X-ray groups are smaller, but still have features of big science. I have the best of both worlds—I get to work with staff scientists at world-class, state-of-the-art facilities, but also get to design and execute my own experiment."

Gan has been a visiting scholar at Argonne National Laboratory since 2011, working under staff scientist



Diego Casa. Gan has co-authored a number of publications in peer-reviewed journals and presented his findings at many conferences across the US during his tenure at Physics Illinois.

Gan says working under Abbamonte has been a great benefit to him: "Peter is a great guy. He's very enthusiastic about science."

Gan was a National Merit Scholar (2003). He received his bachelor's degree in physics from Princeton University (2007), where he completed an undergraduate thesis entitled, "An Investigation of LEP's Sensitivity to the NMSSM Higgs Sector," with advisor Christopher Tully. He also completed a minor in theater and dance.

This award is made possible by a generous gift from Lam Research Corporporation of Fremont, CA. ■

Yu Gan's research is supported by US Department of Energy grant DE-FG02-07ER46453 through the Frederick Seitz Materials Research Laboratory.

CONNECT

THE TRADITION CONTINUES...

Mark your calendar for the annual gala Physics alumni reunion on Tuesday evening, March 4, in Denver. The reception, which is held every year in conjunction with the American Physical Society's March meeting, will start at 6:00 p.m. in the Governor's' Square 15 (Plaza Building, Concourse Level), Sheraton Downtown, Denver.

Sponsored by the Department of Physics and the Physics Alumni Association, the Illinois reunion has long been known as the best party at the March meeting. Please join us to maintain that reputation of warmth and collegiality. You'll have a great opportunity to renew old acquaintances and learn about exciting new initiatives for Physics Illinois in a relaxing, friendly atmosphere.

You need not be an APS member or registered for the meeting to attend—we are also extending an invitation to all our alumni living in the greater Denver area. Great refreshments and door prizes, too!

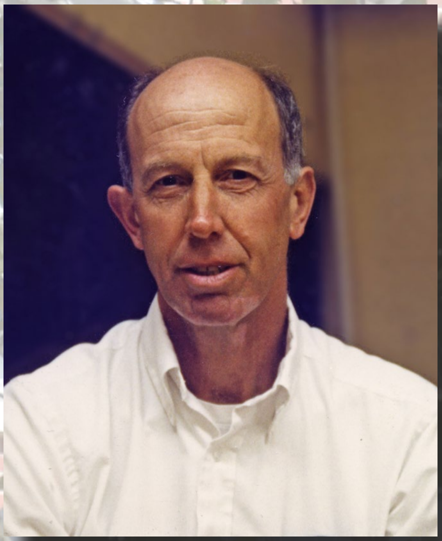
2014

Department of Physics

ALUMNI Reception

Sheraton Downtown, 1550 Court Place, Denver, CO

Tuesday, March 4 | 6:00 - 8:00 P.M.



Ulrich E. Kruse

1929–2013

Professor Emeritus of Physics Ulrich "Uli" Ernst Kruse, 84, died on November 12, 2013, after a five-year struggle with Parkinson's disease. Kruse was born in 1929 in Berlin, Germany. His family immigrated to Boston, MA before his tenth birthday. He is survived by his wife, Mary Ullmann Kruse, by his children Sarah, Thomas, and Julie, and by four grandchildren.

Kruse was a highly regarded experimentalist in high-energy physics who combined a gift for careful and rigorous analysis with excellent data-reduction skills. He enjoyed a productive research career and was a dedicated and innovative teacher.

In his early work at Illinois, Kruse analyzed bubble chamber data studying pion-proton and proton-proton interactions. Later he became interested in the idea of colliding proton-antiproton beams at Fermilab and joined the central detector group (G. Ascoli, L.E. Holloway, I. Karliner, R.D. Sard, V.J. Simaitis, D.A. Smith, and T.K. Westhusing). He participated in the design, construction, testing, and commissioning of Fermilab's CDF central muon detector, a key component of experiment.

Professor Emeritus of Physics and former head of department Ralph Simmons valued Kruse as a colleague and friend. He remembers many conversations that conveyed Kruse's great love for music and informed and strong sense of justice in civil society.

"Kruse was exceedingly clear, responsive, and cheerfully exacting as a teacher," shares Simmons. "His knowledge of the fundamentals of physics was admirably broad and secure. As a research scientist he was a valued and tenacious collaborator in the critical analysis of complex data."

Kruse spent a sabbatical year at CERN in Geneva, Switzerland, in 1967, working on bubble chamber experiments. In a hand-penned note to then-head Gerald Almy, Kruse wrote about his family's enjoyable experiences abroad (the oldest of the three children was then six years old) and about the excellent interaction between experiment and theory at CERN:

"[Director General Leon] Van Hove has done much to push this and he has succeeded well in finding among the theoreticians people who both are doing excellent new work far ahead of experiment as well as those more 'useful' to people like me who are willing to translate the latest into terms which start good new experiments."

Kruse returned to CERN with colleagues Giulio Ascoli and Robert Sard for eight months in 1972 to test theoretically proposed models of particle structure through the study of the production and decay of meson resonances. This work substantially contributed to our ultimate understanding of strong interactions.

While on sabbatical at the Max Planck Institute for Physics in Munich, Germany (1974–75 and 1980–82), Kruse worked in the high-energy group participating in experiments at DESY in Hamburg, Germany. In 1974, DESY was Europe's largest electron accelerator facility and one of two such facilities in the world strong enough to produce the newly discovered charm quark and its antiparticle.

At Illinois, Kruse demonstrated a great passion for teaching and was esteemed by faculty and students alike; he was known for his enthusiasm, dry wit, animated style, and engaging demonstrations. He inspired generations of physics students, frequently meeting with them outside of his regular office hours to hold special discussion or problem sessions. His courses never failed to receive the highest rankings from students.

Kruse's former student, Physics Illinois alumnus Bancherd DeLong (BS 1975; MS 1977; PhD,1981) remembers, "Professor Ulrich Kruse was a good man and a great teacher. He was one of the rare individuals who could convey difficult theoretical concepts in such a manner that was easy to visualize and understand. In my undergraduate classical mechanics class, he gave me the 'Aha moment' and made me realize that physics was in my future. Thank you Professor Kruse, you will be missed."

Starting in 1985, Kruse introduced the use of microcomputers as a pedagogical tool in large introductory physics courses at Illinois. With funding from both the IBM Corporation's EXCEL program and the Apple Seedling program, students had access to department computers and participated in innovative interactive lab demos that Kruse designed. The in-class demos, revolutionary at that time, involved rapid data acquisition, displayed measurements in real time with graphical comparisons, and covered a wide range of topics, including classical mechanics, thermodynamics, electricity, light, special relativity, general relativity, and quantum mechanics.

Around the same time, Kruse was instrumental in developing a comprehensive TA training program for the department's large elementary program that introduced an interactive pedagogical approach.

Kruse gladly shared his expertise on the use of computers in physics instruction and gave several talks on the subject. In 1988, he was invited to participate in NSF's Disciplinary Workshops on Undergraduate Education, tasked with addressing critical issues related to curriculum development, student recruitment and retention in US undergraduate education in the sciences, mathematics and engineering.

Professor Steven Errede remembers Kruse's contributions: "Uli Kruse was an amazing, technically-competent experimental high-energy physicist—I was extremely impressed with him and much enjoyed collaborating with him on the CDF experiment at Fermilab. Later on, after Uli had retired, I also spent much time continuing to interact with him, when I got involved with upgrading upper-level undergraduate physics labs in the 1990s. His guidance and sage advice on many of the critical details associated with various experiments in the undergraduate physics labs was incredibly helpful to me, and I very much appreciated all of his help and the depth of his knowledge and expertise. I miss all of those interactions with him, today!"

An avid nature lover who enjoyed climbing, hiking, skiing, kayaking, and canoeing, Kruse was also a great proponent of developing a campus-wide solid waste recycling effort. After running a pilot recycling program in the physics department, he wrote a letter to all department heads asking for support of a proposal that urged campus administration to establish a cost-effective recycling program to meet what Kruse believed was the University's moral obligation—to be exemplary stewards of the natural environment.

Kruse was a Fellow of the American Physical Society. He served the National Research Council for many years as a panelist for the Fellowship Office of the Office of Scientific Personnel. He also served on many national committees, including the the NATO Fellowship Committee, the NSF Graduate Fellowship Committee, and several organizing committees for international high-energy physics conferences.

At Illinois, Kruse served on the campus Excellence Committee, on the Graduate College's University Fellowship Committee, on the department's Advisory Committee, Undergraduate Studies Committee, and Physics Department Library Committee. He also served for many years as an adviser for LAS physics.

After his retirement, Kruse pursued his interest in geology, informally joining the research group of Illinois Geology Professor Wang-Ping Chen and participating actively in weekly discussions of earthquakes and how the study of earthquake waves can provide important clues about the nature of the earth's interior.

Kruse received his A.B. in physics from Harvard in 1950, attending on a full scholarship and graduating summa cum laude. As an undergraduate, he participated on the Harvard rowing team. He was named a Junior Fellow by the Harvard Society of Fellows and continued his studies at Harvard. He earned his doctoral degree in 1954, carrying out early proton-proton scattering experiments using Harvard's cyclotron under thesis adviser Norman Ramsey.

In 1954, Kruse was hired as an assistant professor of physics at the University of Chicago, where he participated in experiments on polarized protons, as well as in experimental studies of dispersion relations in pion scattering and later in pion-proton scattering. He also participated in the first successful extraction of a proton beam from the UC's synchrocyclotron.

In 1959, Kruse joined the faculty at Physics Illinois as an assistant professor of physics and was in short order promoted to associate professor in 1960 and to full professor in 1963. Upon his retirement in 1990, he was conferred the title of emeritus professor of physics. ■

Henry "Bill" Wyld
1928–2013

Emeritus Professor of Physics Henry William "Bill" Wyld, Jr., 85, died on Oct. 16, 2013, in Urbana. Wyld was born in Portland, OR, in 1928. He was preceded in death by his wife, Jeanne-Marie Bergheim Wyld, by a daughter, Karen, and a son, Derek. He is survived by a daughter, Sandra, and a grandson.

Wyld was a theoretical elementary particle physicist, gifted with an understanding that was imaginative, profound, and clear. His steady leadership, scholarship, and service over the course of 33 years at Physics Illinois proved a great asset to the department. He was well respected in his field for his sound judgment and for his proper, careful treatment of theoretical calculations—colleagues turned to him when they had a particularly bothersome problem or puzzle, whether in research or teaching.

Wyld took advantage of supercomputing capabilities as these were being developed to run large-data simulations; he always pushed for more computing power to answer fundamental problems.

In his early career, Wyld worked in low- and high-energy physics on weak interactions and several problems related to K-meson proton scattering. Wyld is particularly noted for his significant theoretical contributions related to the effects of the breakdown of quantum mechanical symmetry properties, written shortly after the discovery of parity violation in 1957, that presented detailed calculations of a number of effects to be expected. This work enabled various experimental groups to correlate and evaluate their results.

University of California at Berkeley Professor of Physics J. D. Jackson first met Wyld at Princeton in the fall of 1956 and collaborated with him and Sam Treiman in a theoretical investigation of the violation of time reversal symmetry in beta decay, after the discovery of parity symmetry violation in beta decay in December of that year.

"We published several papers together; they became standards in the field," shares Jackson. "Our mode of calculation of the rather complex results for the various correlations for the most general form of the four-particle allowed beta decay interaction is worthy of note. We each worked independently to have checks on our results. Bill and Sam used the calculational methods of Feynman and Dyson. I used the more old-fashioned methods of Heitler's book. As we completed our separate computations for a particular correlation, we compared results. Sometimes we found agreement, sometimes not. If not, all went back to the drawing board. The results of all our published papers proved invulnerable to 'attacks' by other teams of physicists who obtained different results. In all cases, we were 'the gold standard.' This gave Bill, Sam, and me modest satisfaction."

Wyld also took a strong interested in applications of field theory techniques to statistical mechanics and the many-body problem.

Later work focused on the theoretical study of fluid and plasma physics. His theory of turbulence in an incompressible fluid, which involved elaborate mathematical analyses, represents a significant contribution in this area.

While on sabbatical leave in

1963/64 at the Theoretical Physics Department at Oxford University on a National Science Foundation Senior Postdoctoral Fellowship, Wyld's interest in elementary particle physics was rekindled: he studied symmetry violations in baryon-baryon interactions, looking at both strong and weak interactions.

On a half-year sabbatical in 1970, Wyld worked at the Theory Division of CERN on a Guggenheim Fellowship, studying the theory and phenomenology of strong interactions in high-energy particle physics, and in particular on the theory of high-energy diffraction scattering and the multiperipheral model.

Wyld took advantage of supercomputing capabilities as these were being developed to run large-data simulations; he always pushed for more computing power to answer fundamental problems. On sabbatical Leave in 1983/84, he used the large computing capabilities at Los Alamos National Laboratory to carry out large-scale Monte Carlo computer simulations of quantum chromodynamics on a discrete space-time lattice, concentrating on phase transitions associated with chiral symmetry restoration and quark deconfinement in strongly interacting quark-gluon matter at finite temperatures and high densities. At the time, this work was at the forefront of the nonlinear quantum field theory of elementary particles.

Swanlund Professor of Physics Nigel Goldenfeld remembers, "Bill not only did important work in lattice gauge theory and high-energy physics, but was the first person to apply quantum-field-theory methods to the problem of fluid turbulence. The Feynman diagram expansion of the Navier–Stokes equations is to this day called the Wyld expansion, and the resulting diagrams are named after him. Bill's modesty and quiet demeanor belied a deep and clever thinker."

Wyld was also a well-loved teacher and mentor. In the 80s, he advocated for strengthening the education of physics students in modern mathematics and was one of a group to reorganize the quantum mechanics graduate course into a unified 3-semester course. Wyld's book, Mathematical Methods for Physics, first published in 1976 with a 2nd edition in 1999, is a classic that remains relevant and helpful to graduate students of physics today.

Wyld was a member of Phi Beta Kappa and Sigma Xi honorary societies.

During his tenure, he served on several committees, including the campus's Computer Allocation Subcommittee Research Board, the College of Engineering Policy and Development Committee, and the College of Engineering's Engineering/Math Liason Committee. He was a long-time member of the department's Qualifying Exam Committee, which he chaired for a number of years. He also served as a graduate student advisor.

Wyld earned his A.B. in physics in 1949 from Reed College in Portland, OR, where he was a member of Phi Beta Kappa and received a James B. and Mabel B. Kerr Scholarship and an Alfred Greenburg Scholarship.

Wyld continued his studies at the University of Chicago, earning his master's (1951) and doctoral (1954) degrees in physics. Here, studying under Marvin Goldberger and Murray Gell-Mann, he became interested in quantum field theory; his doctoral thesis was a field theoretic study of meson-nucleon scattering, entitled "Fourth order corrections to meson-nucleon scattering in pseudoscalar meson theory," published in Phys Rev 96, 1661¬1678 (1954). While at UC, Wyld was selected for a William Rainey Harper Fellowship and an Atomic Energy Commission Pre-doctoral Fellowship.

In the summer of 1955, Wyld married Jeanne-Marie Bergheim; the couple had met as students at Reed.

From 1954 to 1957, Wyld worked as an instructor of physics at Princeton University. He spent the summer of 1956 at Los Alamos National Laboratory working on plasma physics, his first introduction to the subject that would prove a life-long interest.

During the summers of 1952–1963, Wyld worked as a consultant at Space Technology Laboratories and Ramo Woodlrige Corp. in Los Angeles, where he provided theoretical work on basic problems in plasma and fluid physics.

Wyld joined the faculty at Physics Illinois as an assistant professor in 1957, hired by then Head of Department Wheeler Loomis; he was promoted to associate professor in 1959 and to professor in 1963.

From 1968 to 1975, he worked as a consultant for the seismology department at Gulf Oil Company and helped in the early mathematical development of tomography technology for oil exploration .

Upon his retirement in 1995, Wyld was conferred the title of emeritus professor of physics. ■

Department of Physics
University of Illinois at Urbana-Champaign
Loomis Laboratory of Physics
1110 W. Green Street
Urbana, IL 61801-3080