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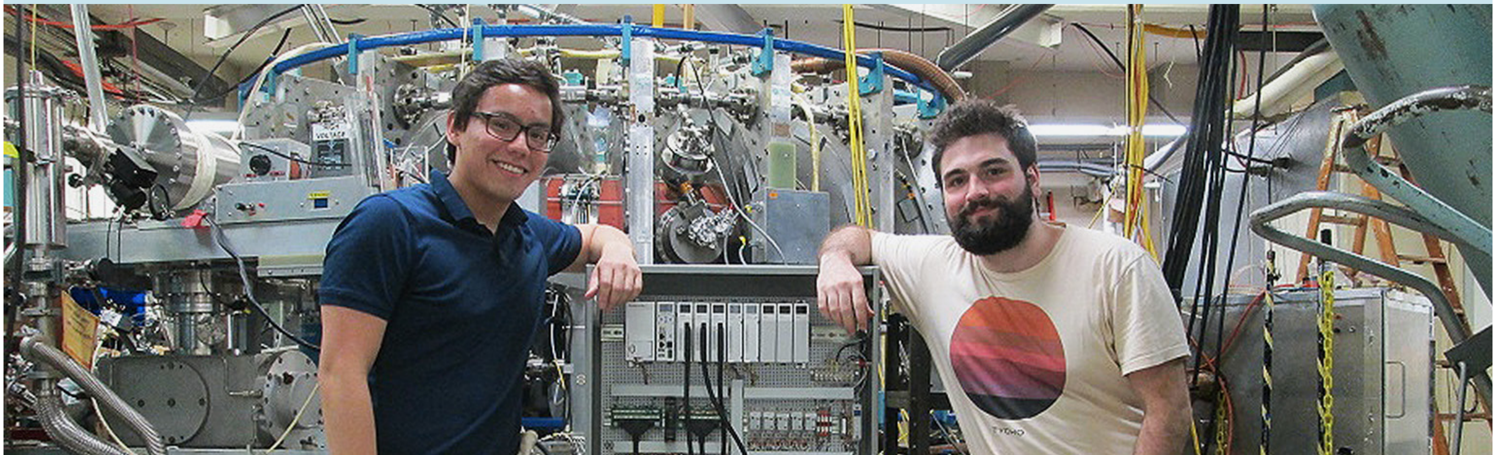
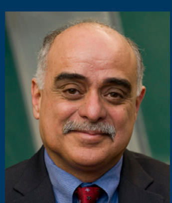
APAM NEWS

THE DEPARTMENT OF APPLIED PHYSICS & APPLIED MATHEMATICS

THE FU FOUNDATION SCHOOL OF ENGINEERING & APPLIED SCIENCE, COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK





Dear APAM Family,

As 2016 ends, I am pleased to report that APAM is healthy and successful. As you might see from the various news items in this newsletter, we are able to look back at a year of solid accomplishments.

Our new Transmission Electron Microscopy Facility is now fully operational. Several of our colleagues were in national news, others received prestigious awards, Professor Irving Herman was awarded a chaired professorship in SEAS, and Professor Michael Mauel became the chief editor of *Physics of Plasmas*.

In addition, this year we welcomed Professor Oleg Gang to APAM faculty. Prof. Gang, jointly appointed with the Chemical Engineering Department, is an expert in soft-matter physics, an area where we would like to grow. We have great plans for 2017 and are looking forward to it with optimism.

I wish all of you and yours Season's Greetings and a happy, healthy, prosperous New Year.

Best regards,

I. Cevdet Noyan
Chair, APAM

In This Issue

Photo: Edwin Vargas (left) & Steve Jaycox (right) kneel beside the new real-time digital controller for the HBT-EP experiment. Read the full story on page 2.

SEAS Students Build Controller for Plasma Control Experiment

How do you control Columbia University's high-temperature plasma control experiment? Very carefully, safely, and easily using a new real-time digital process controller built by two SEAS students.

SEAS undergraduate students **Edwin Vargas** (Applied Physics '17) and **Steve Jaycox** (Electrical Engineering '16) have completed the design, construction, programming, and testing of a new digital process controller for Columbia's High Beta Tokamak Experiment - Extended Pulse (HBT-EP). The new controller will give HBT-EP student and faculty researchers a modern and easy-to-program system for managing and scheduling critical high-voltage, vacuum, and safety systems for the tokamak experiment. Custom designed and built using parts from Georgia-based company AutomationDirect, the new process controller continually monitors 30 safety interlocks and up to eight high-voltage energy systems needed to operate the tokamak device. Vargas and Jaycox built the system to be easy for student-scientists to use, update, and modify how the experiment operates and the scientific parameters under study.

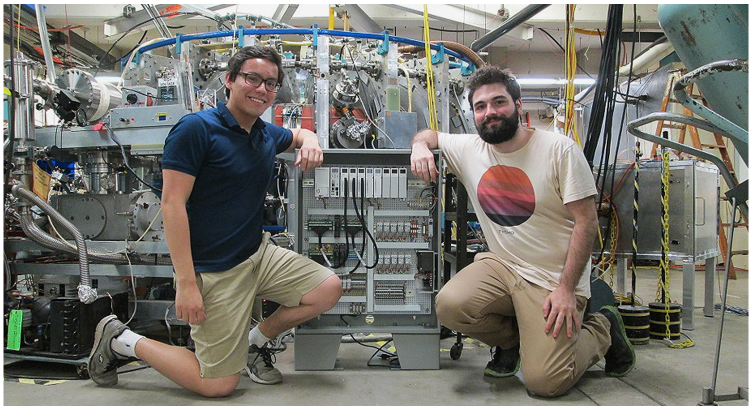
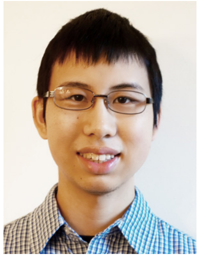


Photo: Edwin Vargas (left) and Steve Jaycox (right) kneel beside the new real-time digital controller for the HBT-EP experiment. Jaycox, an Electrical Engineering major, has worked in the Columbia Plasma Laboratory as a Lab Technician since 2014 and graduated this past May. He now works in Califorina as a hardware engineer. Edwin Vargus will be graduating May 2017 in Applied Physics and plans to attend graduate school to further his career in plasma physics.

Columbia's High Beta Tokamak Experiment - Extended Pulse (HBT-EP) is supported by the U.S. Department of Energy and seeks to understand the motion of ionized gas, called "plasma", that is heated to more than 10 million degrees and confined by very strong electromagnets. Using HBT-EP students and scientists actively control the shape of the plasma's magnetic boundary using arrays of control coils and electrodes. When these fields and currents are properly applied, instabilities of the plasma boundary are suppressed. Columbia students and scientists have pioneered many of the techniques used to control magnetized plasma instabilities that are now also used in larger national research facilities and may someday influence the safety and performance of the world's largest fusion energy experiment, ITER, now under construction in France.

The HBT-EP Research program is directed by Professors **Gerald Navratil** and **Mike Mauel** and by Dr. **Jeff Levesque**.



Egleston Scholar: Charles Liang (Applied Physics '18)

Charles Liang is from Carmel, just north of Indianapolis, Indiana. He is a junior majoring in Applied Physics and minoring in Applied Mathematics with research interests in sustainable energy, condensed matter physics, and materials science. In the spring of 2017, Charles will be studying abroad at University of Oxford.

During the summer of 2016, Charles conducted biophysics research in Prof. Ozgur Sahin's Laboratory on Bacillus subtilis spores that are quite responsive to humidity changes. In particular, Charles investigated and tested various adhesives that bind B. subtilis spores, which expand and contract greatly due to changes in humidity, onto a substrate and then characterized their performance (e.g. radius of curvature and speed of bending). Since there are humidity changes due to the natural evaporation of water, B. subtilis spore-based materials have potential applications in creating clean energy, evaporation-driven engines and generators.

During the summer of 2015, Charles conducted biomedical physics research in the Laboratory for Functional Optical Imaging under the guidance of Prof. Elizabeth Hillman. He conducted research on using ultrafast laser pulses on imaging the brains of mice and the living brains of fruit flies using light sheet microscopy. He then used computational methods to try to improve the image quality of resulting brain images.

Charles went to Carmel High School, where he discovered his interest in physics, research, and environmental community service. Charles has conducted research in quantum physics under the guidance of Prof. Yogesh Joglekar at Indiana University – Purdue University of Indianapolis (IUPUI). He investigated how special matrices called PT (Parity and Time)-symmetric Hamiltonians can better model how light flows in optical fiber networks and potentially lead to improved light transmission. As a result of his work, Charles has been recognized as a semifinalist in the Intel Science Talent Search and Siemens Competition and as a Third Award winner (Physics & Astronomy category) at Intel ISEF, while also holding a publication in the journal *Physical Review A*. His experiences in the lab have helped him further his passion in physics.

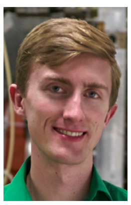
In his free time, Charles enjoys swimming, playing the violin, practicing Chinese calligraphy, and practicing French with friends. He is the outreach director of the Society of Physics Students, and in fall 2015, Charles founded the student initiative Phones4Education. Charles, along with several friends, won an Engineering Student Council Grant later that year. Their project is to seek used smartphones/tablets/e-readers donations, download free educational apps, podcasts, and eBooks (e.g. Khan Academy, TED, and Project Gutenberg's free e-books), and then donate these devices to local underserved students, such as those in foster care through a partnership with Columbia Law School's Adolescent Representation Clinic. In the future, Charles aspires to pursue a career in academia, hoping to conduct clean energy research to help those that are less fortunate, including the nearly two billion in the world without access to electricity.

RAMPS WINNER: A current student in APAM's Medical Physics Certificate Program, Reza Farjam, Ph.D., who is also a Medical Physics Resident at the Memorial Sloan Kettering Cancer Center (MSKCC), was a 2nd place winner in the 2016 RAMPS Young Investigator Symposium. RAMPS, The Radiological and Medical Physics Society of New York, is the local American Association of Physicists in Medicine (AAPM) chapter based at MSKCC.

Graduate Student Award Winners

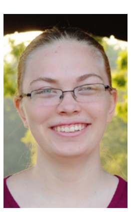
Elizabeth Culbertson - Presidential Fellowship
Elizabeth completed her B.S. degree in Engineering Physics at Stanford University. While an undergrad, she developed her interest in solid state physics by working on a research project at Virginia Tech determining thermal transport properties of self-assembled monolayers as well as a project at Stanford characterizing low-temperature phase transitions in strontium titanate. As a first-year Ph.D. student, she is currently exploring groups at Columbia affiliated with the Columbia Nano Initiative and hopes to pursue a research project involving nanoscale engineering and characterization of interesting crystalline materials.

Jared Ginsberg - NSF IGERT Fellowship
Jared attended high school on Long Island before completing his bachelor's degree in physics at Cornell University in 2015. Upon entering the APAM Department, Jared joined Prof. Alexander Gaeta's Quantum and Nonlinear Photonics Group with the support of the NSF IGERT fellowship program. He currently studies the rich process of nonlinear propagation of intense laser beams in a variety of materials, ranging from glass fibers to gases. After he completes his Ph.D. program, Jared plans to pursue a career in the rapidly growing field of photonics.



Kenneth Hammond - DOE SCGSR Award
Ken is a Ph.D. candidate studying magnetically confined plasmas in the CNT stellarator in Columbia's Plasma Physics Laboratory. Working for advisor Prof. Francesco Volpe (APAM), his research to date has included magnetic error-field diagnosis and microwave plasma heating. The award funds a study of plasma initiation in the NSTX experiment at the Princeton Plasma Physics Laboratory (PPPL), where he is working with scientist Dr. Roger Raman. Ken hopes to continue to study magnetized plasmas, which have the potential to become the basis for nuclear fusion-based power plants.

Rachael Keller - NSF Graduate Research Fellowship
As an undergraduate at Louisiana State University, Rachael majored in Mathematics with a concentration in Computational Mathematics, and minored in Chinese, studying abroad one semester at Beijing Normal University. At Columbia, she works with Prof. Qiang Du in numerical analysis and Prof. Michael Weinstein in mathematical analysis. Her current research interests include analysis of the Schrödinger equation in lattice structures and, longer term, the discrete and numerical study and treatment of the Schrödinger operator. Her future goals are to continue academic research in applied and computational mathematics.



Jessie Oehrlein - Presidential Fellowship / NSF GRFP
Jessie earned a Bachelor of Science in Mechanical Engineering from Franklin W. Olin College of Engineering, and studied for a semester at Budapest Semesters in Mathematics. Her current research interests are in atmospheric science, and her long term plans are to be an applied mathematics professor.

Adam Overvig - NSF IGERT Fellowship
Adam obtained his B.S. in Engineering Physics from Cornell University in 2013. He is currently researching, under advisement from Prof. Nanfang Yu, dielectric metasurfaces for controlling light in both extremely broad and narrow spectral bandwidths. His future goals are to continue research in industry on photonics for commercial applications.

Izzo (Ph.D. '81) Receives Johnson Medal

Ralph Izzo (Ph.D. '81 Plasma Physics) received the Samuel Johnson Medal at the 2016 Columbia Engineering Alumni Awards dinner on June 3, 2016 in Low Library.

Dr. Izzo is "an influential thought leader on energy policy and chairman, president, and CEO of Public Service Enterprise Group, Inc. (PSEG). The Johnson Medal, named for the first president of King's College, the forerunner of Columbia University, was established in 2007 to recognize distinguished achievement in a field other than engineering and the applied sciences." (Jesse Adams, Columbia Engineering / Photo by Timothy Lee Photographers)

Alumni News

Dylan Brennan (M.S. '97 Applied Physics), physicist with the U.S. DOE and Princeton Plasma Physics Laboratory (PPPL), is the co-lead principal investigator on a project, called "Simulation Center for Runaway Electron Avoidance and Mitigation." The project will "combine simulations and data from worldwide experiments to explore the causes and solutions for runaway electrons." (*Newswise*, Article ID: 659503)

Michael Jenkinson (Ph.D. '15, Applied Mathematics) presented a talk at the Applied Mathematics Colloquium on "High-Order Finite-Difference Time-Domain Simulation of Electromagnetic Waves at Complex Interfaces Between Dispersive Media." Jenkinson is currently an RTG Postdoctoral Fellow in the Department of Mathematical Sciences at Rensselaer Polytechnic Institute (RPI).

David Ordinario (B.S. '11, Materials Science) received a highly competitive postdoctoral fellowship from the Japan Society for the Promotion of Science. Only 120 researchers from a pool of 1,265 applicants were selected for this honor. "Ordinario, who is creating an ultra-flexible ionic e-skin that can facilitate direct communication between biological systems and electronics, will work for two years at the University of Tokyo with Takao Someya, a world-renowned expert on flexible electronics." (A.L. Spitzer, UCI Engineering News)

Jonathan E. Spanier (Ph.D. '01, Applied Physics, Herman Group) was elected Fellow of the American Physical Society (APS) by the APS Council of Representatives at its September 2016 meeting upon the recommendation of the Division of Materials Physics. Dr. Spanier is currently a professors in the Department of Materials Science and Engineering at Drexel University.

Bal Elected AMS Fellow

Guillaume Bal, Professor of Applied Mathematics, has been elected a fellow of the American Mathematical Society (AMS) "for contributions to inverse problems and wave propagation in random media".

Prof. Bal's research interests focus on Partial Differential Equations; mathematical analysis of inverse problems, including hybrid inverse problems and inverse transport problems; applications in medical and geophysical imaging; equations with random coefficients and propagation of stochasticity; convergence to deterministic or stochastic models; and wave propagation and imaging in heterogeneous media.

Prof. Bal earned his Ph.D. in Applied Mathematics at the University of Paris VI, was a postdoctoral research associate at Stanford University, and was the L.E. Dickson Instructor at the University of Chicago. He joined the Columbia University faculty as an Assistant Professor in 2001, was promoted to Associate Professor in 2003, and was a visiting scholar at the Institute for Pure and Applied Mathematics at the University of California-Los Angeles in 2003. He was promoted to Professor in the APAM Department in 2008 and currently teaches undergraduate and graduate courses in PDE's, functional analysis, numerical analysis, inverse problems, homogenization theory, and waves in random media.

Prof. Bal was the recipient of the 2011 Calderón Prize, which is awarded by the Inverse Problems International Association (IPIA) to a researcher under the age of 40 who has made distinguished contributions to the field of inverse problems broadly defined. Other awards include an NSF Career Award in 2003 and an Alfred P. Sloan Fellowship, also in 2003.

Prof. Bal is a SIAM member, serves on the advisory panel for Inverse Problems (IP), and is an associate editor for *Kinetic & Related Models*, Inverse Problems and Imaging (IPI), Multiscale Modeling and Simulation (MMS), Mathematical Control and Related Fields (MCRF), Inverse Problems (IP), Asymptotic Analysis (AA), and SMAI-JCM.

Prof. Bal is a SIAM member, serves on the advisory panel for *Inverse Problems (IP)*, and is an associate editor for *Kinetic & Related Models*, *Inverse Problems and Imaging (IPI)*, *Multiscale Modeling and Simulation (MMS)*, *Mathematical Control and Related Fields (MCRF)*, *Inverse Problems (IP)*, *Asymptotic Analysis (AA)*, and *SMAI-JCM*.

Herman Named Armstrong Professor of Applied Physics

Irving Herman has been named the Edwin Howard Armstrong Professor of Applied Physics in the Fu Foundation School of Engineering and Applied Science. His appointment was approved by the Trustees of Columbia University and he was honored at the SEAS Faculty Excellence Celebration on September 20, 2016.

Prof. Herman graduated with S.B. and Ph.D. degrees in physics from M.I.T. in 1972 and 1977. From 1977-1986 he was a member and section leader in O-group within the Physics Department at the Lawrence Livermore National Laboratory, where he was engaged in research in laser isotope separation of deuterium and tritium, and the use of direct laser writing in thin film processing. In 1986, he joined the faculty of Columbia University, where he is now the Edwin Howard Armstrong Professor of Applied Physics and a member of the Columbia Nanoinitiative (CNI) and the Columbia Materials Research Science and Engineering Center (MRSEC). He is Director of the Columbia Optics and Quantum Electronics IGERT (Integrative Graduate Education and Research Traineeship program). From 2006-2012 he was chair of the Department of Applied Physics and Applied Mathematics. From 1998-2010 he was Director of the Columbia Materials Research Science and Engineering Center (MRSEC) [The Center for Nanostructured Materials], and as part of this he led an extensive education outreach program. He has overseen the Shared Materials Characterization Laboratory and is a member of the CNI Facilities Committee. He is a fellow of the American Physical Society and the Optical Society of America.

His career at Columbia University has been one of diverse scholarly activities. His research activities have included the use of lasers to induce reactions at surfaces and for surface analysis, Raman microprobe spectroscopy, and topics in nanoscience and optics, including the assembly and analysis of nanocrystals and, more recently, van der Waals layers. In addition, he has written two comprehensive books: a monograph on optical diagnostics for thin film processing and a textbook on physics of the human body, which is now in its second edition. He has developed three interactive seminars on ethics and presents them to students in his department, and has published on this subject. He has also examined the interwoven history of the Columbia University School of Engineering and Applied Science and events in New York City.

Du Named Finalist for ACM Gordon Bell Prize

Supercomputing 2016 selected six outstanding research efforts in high performance technical computing as finalists in supercomputing's most prestigious competition, the ACM Gordon Bell Prize in High Performance Computing.

One of the finalists, titled "Extreme-Scale Phase Field Simulations of Coarsening Dynamics on the Sunway Taihulight Supercomputer," involved the joint work of **Qiang Du**, the Fu Foundation Professor of Applied Mathematics in APAM, along with his former postdoc (the lead author, currently a research scientist at the Chinese Academy of Sciences), Prof. Du's former student (currently a professor at the University of South Carolina), and other collaborators in China.

For many years, Prof. Du has been working on the phase field modeling of microstructure evolutions - an important research subject in computational materials science. The work, selected as a Gordon Bell prize finalist this year, presented a scalable algorithm to numerically integrate phase field equations and its efficient implementation, as well as simulations at an unprecedented scale on the world's most powerful supercomputer.

The Gordon Bell Prize recognizes the extraordinary progress made each year in the innovative application of parallel computing to challenges in science, engineering, and large-scale data analytics and many Columbia researchers have had success winning the Gordon Bell competition in the last century. Research in large-scale high performance computation and its applications, in particular to materials science research, remains active at Columbia, as evidenced by the formation of two working groups within the Data Science Institute (Frontiers in Computing Systems and Materials Discovery Analytics). The honor of being named as a finalist for the Gordon Bell competition this year reflects the continued development of computational science research at Columbia University.

Marianetti Wins DOE Grant on Phonon Interactions

A new approach to the interacting phonon problem

Performing high-risk-high-reward research at universities can be inherently difficult due the nature of funding for scientific research. Even when stated otherwise, government funding agencies cling to research that has basically already succeeded and is extending into a more linear regime of exploration; which is easy to understand given the tight constraints on federal funding. Fortunately, Columbia has a number of seed funding programs in place to act as an incubator for high-risk-high-reward research; one such program being the Columbia Research Initiatives for Science and Engineering (RISE) grant. In 2013, **Chris Marianetti** was awarded a RISE grant entitled "A new approach to the interacting phonon problem", which allowed for the support of a postdoctoral researcher and resulted in, among other things, a publication in a noted physics journal, *Physical Review Letters*[1]. This work was substantial enough to form a foundation for a proposal to the Department of Energy (DOE) Basic Energy Sciences (BES) division, and this was recently (September 2016) funded at a level of $415,000 over a period of three years.

While the topic of "phonon interactions" may sound somewhat obscure, it is actually extremely general. Phonons and their interactions influence, or sometime entirely dictate, many materials properties at non-zero temperatures, including phase stability, thermal transport, and mechanical behavior. Furthermore, there are various experimental phenomena related to phonon interactions which lack a firm theoretical understanding and could have technological relevance, such as intrinsically localized modes. Understanding technologically relevant materials at high temperatures necessitates a strong handle on the interacting phonon problem, and applications run the gamut from turbines in jet engines to nuclear fuel materials to thermoelectrics. In order to be able to successfully predict materials properties at a wide range of temperatures and to understand experimental anomalies, a new approach which can reliably treat the interacting phonon problem is needed. In line with the other research thrusts in Marianetti's group, the goal is to start with nothing more than the Schrödinger equation (i.e. the laws of quantum physics for interacting nuclei and electrons) and predict materials behavior; which in this case are phonon interactions at a broad range of temperatures.

The proposed research involves two different thrusts. The first thrust is to characterize the irreducible interactions between phonons. Computing phonon's themselves is a somewhat established technique, and phonons can be precisely computed for a wide range of materials. The same cannot be said for phonon interactions. Therefore, the first step is to compute phonon interactions over a broad range of materials while exploiting the full power of group theory. The longer term goal will be to execute this in the spirit of the Materials Genome Initiative, addressing a broad range of materials, storing the results in a database, and mining information using machine learning techniques. These phonon interactions could immediately be used to perform traditional classical simulations such as molecular dynamics. The second thrust addresses the inclusion of quantum fluctuations when solving this interacting phonon problem. While traditional perturbative and quantum Monte-Carlo techniques have made substantial progress in this space, there is still a need for an accurate, efficient approach which could be broadly applied to real materials.

[1] Y. Chen, X. Ai, and C. A. Marianetti. First-principles approach to nonlinear lattice dynamics: Anomalous spectra in pbte. *Phys. Rev. Lett.*, 113:105501, Sept. 2014.

New Faculty: Oleg Gang

Oleg Gang joins the Columbia faculty as a Professor of Applied Physics and Materials Science and a Professor of Chemical Engineering. He earned his M.S. and Ph.D. (2000) from Bar-Ilan University, Israel, specializing in atomic spectroscopy and soft matter. As a postdoctoral fellow in the School of Engineering and Applied Sciences at Harvard University, he studied nanoscale liquid phenomena. Dr. Gang started at Brookhaven National Laboratory in 2002, rising through the ranks to lead the Soft and Bio-Nanomaterials group at the Center for Functional Nanomaterials from 2008. Dr. Gang has received the University President Award and Wolf Foundation scholarship for his Ph.D. work, Distinguished Rothschild (2000) and Goldhaber (2002) fellowships, Department of Energy Outstanding Mentor Award (2009), and the Gordon Battelle Prize for Scientific Discovery (2010). Dr. Gang has been named Battelle Inventor of the Year (2016), and is a Fellow of the American Physical Society.

Celebrating Faculty Excellence

APAM faculty and reserachers were honored at the 2016 Faculty Excellence Celebration hosted by the SEAS Dean's office.

JOHN (JACK) W. BERKERY
Research Scientist, Applied Physics
&
STEVEN A. SABBAGH
Sr. Research Scientist & Adjunct Professor of Applied Physics

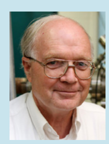
Landau-Spitzer Award
Presented jointly by the American Physical Society & the European Physical Society every 2 years to an individual or group for outstanding theoretical, experimental, or technical contributions in plasma physics, & for advancing the collaboration & unity between the European Union & the United States. (See page 10 for more details)

CHIA-KUN CHU
Fu Foundation Professor *Emeritus* of Applied Mathematics

Columbia Impact Award
Asian Columbia Alumni Association for pioneering work in computational fluid dynamics & computational magnetohydrodynamics

MICHAEL MAUEL
Professor of Applied Physics

Scholarly Leadership
Editor-in-chief, *Physics of Plasmas*, American Institute of Physics



RICHARD M. OSGOOD JR.
Higgins Professor *Emeritus* of Electrical Engineering
& Professor *Emeritus* of Applied Physics

National Academy of Inventors
For demonstrating "a highly prolific spirit of innovation in creating or facilitating outstanding inventions that have made a tangible impact on quality of life, economic development, & welfare of society"

LATHA VENKATARAMAN
Professor of Applied Physics

Promotion to Full Professor

NANFANG YU
Assistant Professor of Applied Physics

Faculty Early Career Award
Young Investigator Award, U.S. Office of Naval Research for exceptionally creative research with far-reaching implications for technological needs of the Navy & the Department of Defense through his project, "Phase-Change Correlated Perovskites as a New Platform for Photonics"

Revealing the Nature of Magnetic Interactions in Manganese Oxide

Reprinted with permission from Brookhaven National Laboratory

For nearly 60 years, scientists have been trying to determine how manganese oxide (MnO) achieves its long-range magnetic order of alternating up and down electron spins. Now, a team of scientists led by **Simon Billinge,** professor of materials science and engineering and applied physics and applied mathematics at Columbia Engineering and a physicist at Brookhaven National Laboratory, has used its recently developed mathematical approach to study the short-range magnetic interactions that they believe drive this long-range order. By comparing measurements of the local magnetic interactions in MnO with those predicted by competing theoretical models, they determined that the antiparallel electron spin alignment is due to neighboring Mn ions interacting magnetically through an intermediary nonmagnetic oxygen ion—a mechanism called superexchange.

The research was described in a paper published on May 11 in *Physical Review Letters* by scientists from Columbia Engineering, the U.S. Department of Energy's (DOE) Brookhaven National Laboratory, DOE's Oak Ridge and Los Alamos National Laboratories, Institut Laue-Langevin in France, and the University of Warwick in England. The mathematical approach, called magnetic pair distribution function (mPDF) analysis, was developed at Brookhaven Lab and Columbia Engineering. It holds great promise as a new tool for understanding the magnetic properties of superconductors, transition metal oxides, and other materials whose electrons strongly interact.

"This research demonstrates that our technique can be used to study fluctuating local magnetism and yield important scientific insights about a material's magnetic properties, which are closely related to its ability to conduct electricity without resistance (superconductivity), change electrical resistance under an applied magnetic field (magnetoresistance), and transition from a conducting to an insulating state," said Billinge, lead author of the paper and co-developer of mPDF. "If we can understand how materials get these properties, we can make power transmission more efficient, increase data-storage capacity, and build smaller electrical components."

Magnetism in manganese oxide

At low temperatures, the magnetic moments, or electron spins, of neighboring Mn ions spontaneously line up in an ordered, alternating up-down-up-down pattern. As the temperature is increased, the magnetic moments start to vibrate and become less ordered. Above a critical temperature of 118 Kelvin, the long-range antiparallel order seems to disappear entirely, with the magnetic moments randomly fluctuating.

However, even above 118 Kelvin, scientists have observed fleeting, short-ranged remnants of magnetic order in the fluctuating moments, which are expected to contain crucial information about the nature of the magnetic interactions. Unfortunately, these short-ranged correlations have been very difficult to study because conventional measurement techniques are not sensitive enough to capture the details of the correlations, such as how the magnetic moments are arranged on the nanometer scale. mPDF is intended to rectify this problem.

"The ultimate goal of our research is to understand what causes these magnetic moments to line up," said Billinge.

In the MnO structure, there are Mn-O-Mn chains, and the O ion can serve as a "bridge" for the second-nearest neighbor Mn ions to exchange magnetic information through electron hops—an interaction called superexchange.

Benjamin Frandsen & Simon Billinge
Photo by Timothy Lee Photographers

Alternatively, Mn ions can directly exchange magnetic information through first-nearest neighbors (ions that are diagonal from one another) by direct electron hops through space. Both mechanisms are known to occur, but it has been unclear which one is dominant.

"Determining which of these two interactions—those between nearest neighbor spins or second-nearest neighbor spins—is primarily responsible for the ordering of the magnetic moments is key to understanding how the material gets its magnetic properties," said Benjamin Frandsen, a Columbia University graduate student in physics who works in Billinge's group and the lead developer of mPDF.

Examining the short-range magnetic correlations that exist above the critical temperature provides unique information about the magnetic interactions that drive the long-range correlations at lower temperatures.

"As the temperature is increased, the magnetic correlations over long ranges are lost. Five neighbors over from an Mn ion, the electron spins are completely random," said Billinge. "But there are remnants of what the locally ordered state looked like. Using mPDF, we can measure patches of remaining magnetic order, even when these patches are fluctuating and short-range ordered only, and compare predictions of competing models based on superexchange versus direct-exchange interactions."

Nuclear and magnetic scattering data analysis

To measure the correlations, the team first conducted neutron scattering experiments to collect the data needed to apply their technique. They directed beams of neutrons at a powder sample of MnO for temperatures between 15 Kelvin and 300 Kelvin and detected the angle and energy at which the neutrons were scattered after interacting with the sample. They measured two types of scattering signals: nuclear (how the neutrons interacted with sample's atomic nuclei) and magnetic (how the neutrons' magnetic moments interacted with the magnetic moments of Mn ions).

From these signals, the team simultaneously calculated the atomic and magnetic pair distribution functions (PDF), mathematical equations that represent correlations in a sample. The atomic PDF is the probability of finding any two atoms separated by a given distance. The magnetic PDF is similar to the atomic PDF but also encodes information about the relative orientations of the electron spins.

The scientists then compared these experimental measurements with the PDF signals calculated by structural and magnetic models of MnO. They also fitted models of atomic structure and magnetic order to the experimental PDF data—iteratively changing parameters such as the direction of electron spins on each Mn ion or the position of Mn ions—until the computed PDF agreed with the measured PDF. Both of these modeling capabilities are available in a software program called mPDF that the team recently made available to other scientists. **(Continued on page 7)**

Revealing the Nature of Magnetic Interactions in Manganese Oxide (Continued)

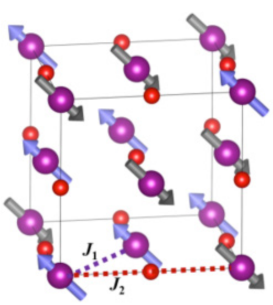
At temperatures above 118 Kelvin, the measurements revealed that local atomic structure of MnO was slightly distorted from cubic to rhombohedral, while the long-range average structure remained cubic. Analysis of the mPDF signals confirmed the existence of short-range magnetic correlations at these temperatures and revealed that they are subtly different from those in the long-range magnetic structure.

"The local structure exhibits a slightly different type of magnetic order than that found in the low-temperature average structure—for example, the second-nearest neighbor spins have significantly stronger local correlations than would be expected from the low-temperature structure," said Frandsen. "Our experimental mPDF signals do not match the signals generated by the known long-range magnetic order."

To compare competing theories for magnetic exchange, Julie Staunton of the University of Warwick led the team in calculating the magnetic correlations at high temperatures for several different magnetic exchange ratios between first- and second-nearest neighbors. The value of these ratios is theoretically predicted to be lower for interactions dominated by superexchange and higher for direct exchange. Using the calculated magnetic correlations, the scientists then calculated the mPDF and compared it to the experimental data. The predicted and experimentally observed ratios were close in value, and both pointed toward a superexchange model of magnetic interactions in MnO.

Now that scientists know that superexchange is the dominant mechanism for magnetic exchange in MnO, the next step is to determine why.

Billinge and Frandsen are also interested in using their technique to explore the magnetic interactions in other materials.



"Our technique provides a new diagnostic tool for studying the physics of strongly correlated electron systems. If we can understand the physics of these systems—how their magnetic, electronic, and structural properties relate—we can design new materials for specific applications," said Billinge.

This research was supported by DOE's Office of Science and the National Science Foundation.

Image: Magnetic structure of manganese oxide (MnO), with Mn ions as purple spheres and O ions as red spheres. The dashed purple line labeled J1 shows a direct-exchange interaction between nearest-neighbor Mn ions; J2 shows a superexchange interaction between second-nearest neighbor Mn ions through an intermediary O ion.

Faculty Updates


APAM faculty, Alexander Gaeta (left) and Michael Weinstein (right), along with Gadi Fibich from Tel Aviv Univ. and Catherine Sulem from the Univ. of Toronto, organized the Institute for Mathematics and its Applications (IMA) Workshop "Mathematical and Physical Models in Nonlinear Optics". The workshop, which took place from October 31-November 4, 2016, at the Univ. of Minnesota, aimed "to bring together scientists working on the mathematical and physical aspects of nonlinear optics". Weinstein is also on the organizing committee for the IMA's spring workshop, "Novel Optical Materials," which will take place from March 13-16, 2017.



(left-right) Mark Cane, Michael Tippett, and Lorenzo Polvani were featured in the *Columbia Engineering* article, "SEAS Scientists Explore the World's Ever-Changing Climate," by Jessica Driscoll. "Their work underpins mitigation solutions designed to slow the effects of climate change, detailed models to more accurately gauge how solutions will affect society, and adaptation strategies to help the world adjust to expected and actual climate change."

Adam Sobel was featured in *The New York Times* Opinion Pages, "Where Are the Hurricanes?" and in the PBS News hour video, "Scientists analyze recent extreme weather events in relation to climate change." Sobel was also featured in the *Columbia Engineering* article, "A New Approach to Modeling Amazon Seasonal Cycles," by Amy Biemiller about his collaboration with Prof. Pierre Gentine in a study led by Sobel's Ph.D. student, Usama Anber. The team developed "a new simulation strategy to more accurately models Amazon seasonal cycles."

Chris Wiggins gave the closing keynote address at the annual NIH "All Hands Meeting" for the NIH Big Data to Knowledge (BD2K) program. A day later, Wiggins also served on a 3-person panel with the current NIH Director, Dr. Francis Collins, and former NIH and former NCI Director, Dr. Harold Varmus, at the NIH's "Open Data Science Symposium 2016: How Open Data and Open Science are Transforming Biomedical Research".

Frontiers in Computing Systems

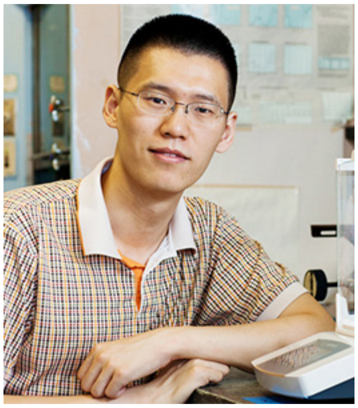
Professors **Mark Cane** and **Chris Marianetti** were featured in the Columbia Data Science article, "New Working Group Takes On Massive Computing Needs of Big Data," by Kim Martineau.

"The Data Science Institute's newest working group - Frontiers in Computing Systems- will try to address some of the bottlenecks facing scientists working with massive data sets at Columbia and beyond. From astronomy and neuroscience, to civil engineering and genomics, major obstacles stand in the way of processing, analyzing and storing all this data.

Prof. Marianetti, vice chair of the new working group, is trying to understand how lithium atoms pass in and out of a material, one of the secrets to designing a longer-lasting lithium battery. But computational limits have stymied him on this problem and others. "We can burn through as much computing time as we're given," he said. "Materials scientists are notorious. You don't want to be sharing computer time with us."

Columbia's Lamont-Doherty Earth Observatory and Earth Institute, and the NASA Goddard Institute for Space Studies are among the institutions represented in the new working group."

The full article is available on line at: **datascience.columbia.edu/new-working-group-takes-massive-computing-needs-big-data**



New Method Increases Energy Density in Lithium Batteries

Novel technique may lead to longer battery life in portable electronics and electrical vehicles

by Holly Evants, originally published by *Columbia Engineering News*

Yuan Yang, assistant professor of materials science and engineering, has developed a new method to increase the energy density of lithium (Li-ion) batteries. He has built a trilayer structure that is stable even in ambient air, which makes the battery both longer lasting and cheaper to manufacture. The work, which may improve the energy density of lithium batteries by 10-30%, is published online in *Nano Letters*.

"When lithium batteries are charged the first time, they lose anywhere from 5-20% energy in that first cycle," says Yang. "Through our design, we've been able to gain back this loss, and we think our method has great potential to increase the operation time of batteries for portable electronics and electrical vehicles."

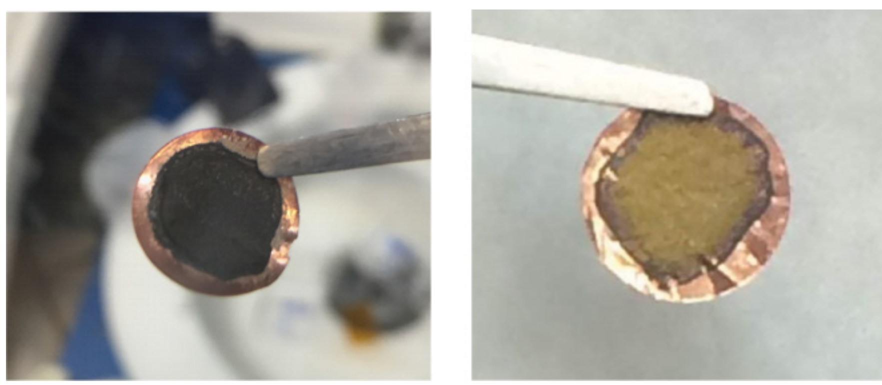
During the first charge of a lithium battery after its production, a portion of liquid electrolyte is reduced to a solid phase and coated onto the negative electrode of the battery. This process, usually done before batteries are shipped from a factory, is irreversible and lowers the energy stored in the battery. The loss is approximately 10% for state-of-the-art negative electrodes, but can reach as high as 20-30% for next-generation negative electrodes with high capacity, such as silicon, because these materials have large volume expansion and high surface area. The large initial loss reduces achievable capacity in a full cell and thus compromises the gain in energy density and cycling life of these nanostructured electrodes.

The traditional approach to compensating for this loss has been to put certain lithium-rich materials in the electrode. However, most of these materials are not stable in ambient air. Manufacturing batteries in dry air, which has no moisture at all, is a much more expensive process than manufacturing in ambient air. Yang has developed a new trilayer electrode structure to fabricate lithiated battery anodes in ambient air. In these electrodes, he protected the lithium with a layer of the polymer PMMA to prevent lithium from reacting with air and moisture, and then coated the PMMA with such active materials as artificial graphite or silicon nanoparticles. The PMMA layer was then dissolved in the battery electrolyte, thus exposing the lithium to the electrode materials. "This way we were able to avoid any contact with air between unstable lithium and a lithiated electrode," Yang explains, "so the trilayer-structured electrode can be operated in ambient air. This could be an attractive advance towards mass production of lithiated battery electrodes."

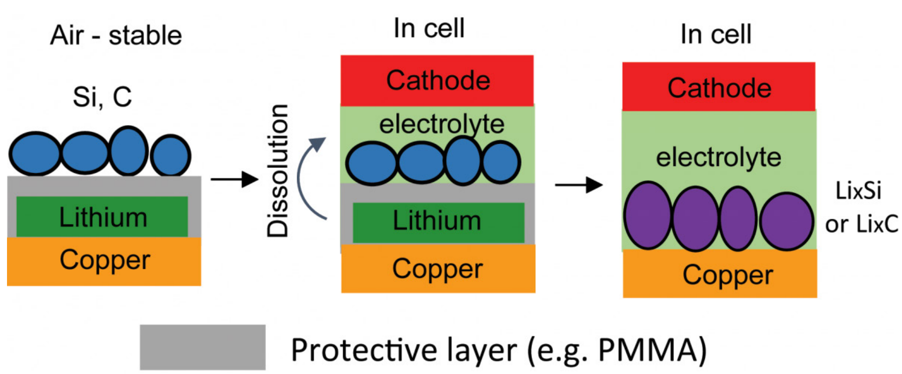
Yang's method lowered the loss capacity in state-of-the-art graphite electrodes from 8% to 0.3%, and in silicon electrodes, from 13% to -15%. The -15% figure indicates that there was more lithium than needed, and the "extra" lithium can be used to further enhance cycling life of batteries, as the excess can compensate for capacity loss in subsequent cycles. Because the energy density, or capacity, of lithium-ion batteries has been increasing 5-7% annually over the past 25 years, Yang's results point to a possible solution to enhance the capacity of Li-ion batteries. His group is now trying to reduce the thickness of the polymer coating so that it will occupy a smaller volume in the lithium battery, and to scale up his technique.

"This three-layer electrode structure is indeed a smart design that enables processing of lithium-metal-containing electrodes under ambient conditions," notes Hailiang Wang, assistant professor of chemistry at Yale University, who was not involved with the study. "The initial Coulombic efficiency of electrodes is a big concern for the Li-ion battery industry, and this effective and easy-to-use technique of compensating irreversible Li ion loss will attract interest."

The study received startup funding from Columbia Engineering, and additional support from the Lenfest Center for Sustainable Energy.



Graphite/PMMA/Li trilayer electrode before (left) and after (right) being soaked in battery electrolyte for 24 hours. Before soaking in electrolyte, the trilayer electrode is stable in air. After soaking, lithium reacts with graphite and the color turns golden.



TOC: procedure to fabricate the trilayer electrode. PMMA is used to protect lithium and make the trilayer electrode stable in ambient air. PMMA is dissolved in battery electrolyte and graphite contacts with lithium to compensate the loss due to reduction of electrolyte. (Photos courtesy of Yuan Yang)

Yu's Team Discovers New Optical Material that Offers Unprecedented Control of Light & Thermal Radiation

by Holly Evants, originally published by *Columbia Engineering News*

A team led by **Nanfang Yu**, assistant professor of applied physics, has discovered a new phase-transition optical material and demonstrated novel devices that dynamically control light over a much broader wavelength range and with larger modulation amplitude than what has currently been possible.

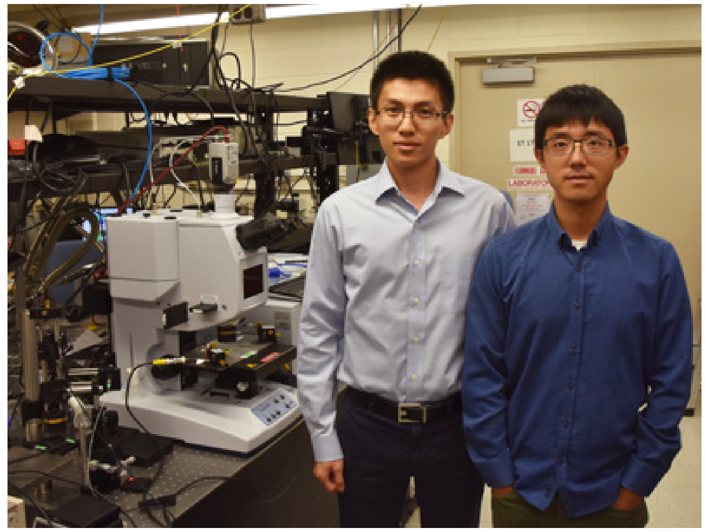
The team, which includes researchers from Purdue University, Harvard University, Drexel University, and the Brookhaven National Laboratory, found that samarium nickelate ($SmNiO_3$) can be electrically tuned continuously between a transparent and an opaque state over an unprecedented broad range of spectrum from the blue in the visible (wavelength of 400 nm) to the thermal radiation spectrum in the mid-infrared (wavelength of a few tens of micrometers). The study, which is the first investigation of the optical properties of $SmNiO_3$ and the first demonstration of the material in photonic device applications, was published online in *Advanced Materials*.

"The performance of $SmNiO_3$ is record-breaking in terms of the magnitude and wavelength range of optical tuning," Yu says. "There is hardly any other material that offers such a combination of properties that are highly desirable for optoelectronic devices. The reversible tuning between the transparent and opaque states is based on electron doping at room temperature, and potentially very fast, which opens up a wide range of exciting applications, such as 'smart windows' for dynamic and complete control of sunlight, variable thermal emissivity coatings for infrared camouflage and radiative temperature control, optical modulators, and optical memory devices."

Some of the potential new functions include using $SmNiO_3$'s capability in controlling thermal radiation to build "intelligent" coatings for infrared camouflage and thermoregulation. These coatings could make people and vehicles, for example, appear much colder than they actually are and thus indiscernible under a thermal camera at night. The coating could help reduce the large temperature gradients on a satellite by adjusting the relative thermal radiation from its bright and dark side with respect to the sun and thereby prolong the lifetime of the satellite. Because this phase-transition material can potentially switch between the transparent and opaque states with high speed, it may be used in modulators for free-space optical communication and optical radar and in optical memory devices.

Researchers have long been trying to build active optical devices that can dynamically control light. These include Boeing 787 Dreamliner's "smart windows," which control (but not completely) the transmission of sunlight, rewritable DVD discs on which we can use a laser beam to write and erase data, and high-data-rate, long-distance fiber optic communications systems where information is "written" into light beams by optical modulators. Active optical devices are not more common in everyday life, however, because it has been so difficult to find advanced actively tunable optical materials, and to design proper device architectures that amplify the effects of such tunable materials.

When Shriram Ramanathan, associate professor of materials science at Harvard, discovered $SmNiO_3$'s giant tunable electric resistivity at room temperature, Yu took note. The two met at the IEEE Photonics Conference in 2013 and decided to collaborate. Yu and his students, working with Ramanathan, who is a co-author of this paper, conducted initial optical studies of the phase-transition material, integrated the material into nanostructured designer optical interfaces—"metasurfaces"—and created prototype active optoelectronic devices, including optical modulators that control a beam of light, and variable emissivity coatings that control the efficiency of thermal radiation.



Zhaoyi Li and Nanfang Yu

"$SmNiO_3$ is really an unusual material," says Zhaoyi Li, the paper's lead author and Yu's Ph.D. student, "because it becomes electrically more insulating and optically more transparent as it is doped with more electrons—this is just the opposite of common materials such as semiconductors."

It turns out that doped electrons "lock" into pairs with the electrons initially in the material, a quantum mechanical phenomenon called "strong electron correlation," and this effect makes these electrons unavailable to conduct electric current and absorbing light. So, after electron doping, $SmNiO_3$ thin films that were originally opaque suddenly allow more than 70 percent of visible light and infrared radiation to transmit through.

"One of our biggest challenges," Zhaoyi adds, "was to integrate $SmNiO_3$ into optical devices. To address this challenge, we developed special nanofabrication techniques to pattern metasurface structures on $SmNiO_3$ thin films. In addition, we carefully chose the device architecture and materials to ensure that the devices can sustain high temperature and pressure that are required in the fabrication process to activate $SmNiO_3$."

Yu and his collaborators plan next to run a systematic study to understand the basic science of the phase transition of $SmNiO_3$ and to explore its technological applications. The team will investigate the intrinsic speed of phase transition and the number of phase-transition cycles the material can endure before it breaks down. They will also work on addressing technological problems, including synthesizing ultra-thin and smooth films of the material and developing nanofabrication techniques to integrate the material into novel flat optical devices.

"This work is one crucial step towards realizing the major goal of my research lab, which is to make an optical interface a functional optical device," Yu notes. "We envision replacing bulky optical devices and components with 'flat optics' by utilizing strong interactions between light and two-dimensional structured materials to control light at will. The discovery of this phase-transition material and the successful integration of it into a flat device architecture are a major leap forward to realizing active flat optical devices not only with enhanced performance from the devices we are using today, but with completely new functionalities." **(Continued on page 11)**

Steven Sabbagh & John (Jack) Berkery
photo by Elle Starkman

Berkery & Sabbagh Receive the Landau-Spitzer Award

Dr. John (Jack) Berkery and **Dr. Steven Sabbagh** of the APAM Department, along with European colleagues Yueqiang Liu of the Culham Centre for Fusion Energy, UK (CCFE) and Holger Reimerdes of the École Polytechnique Fédérale de Lausanne, Switzerland (EPFL) were awarded the 2016 Landau-Spitzer Award, presented jointly every two years by the American Physical Society and the European Physical Society (APS and EPS).

The Award is given to an individual or group of researchers for outstanding theoretical, experimental, or technical contributions in plasma physics, and for advancing the collaboration and unity between the European Union and the United States. The Award also merited an invitation to speak about the research at the 43rd EPS Conference on Plasma Physics in Leuven, Belgium.

The Award carries the citation "For seminal joint research providing key understanding and quantitative verification of global mode stability in experimental high performance tokamak plasmas, based on drift-kinetic MHD theory, and made possible by strong and essential partnership between Europe and the USA." The research for which the award was given comprises nearly a decade of published effort on kinetic resistive wall mode theory validation and understanding, which included experiments on the NSTX and DIII-D tokamak devices.

Dr. Berkery is a research scientist and Dr. Sabbagh is a senior research scientist and adjunct professor of applied physics at APAM. Both are on long-term assignment at the Department of Energy's Princeton Plasma Physics Laboratory (PPPL) in Princeton, NJ. Their joint research includes the physics of macroscopic stability of magnetically confined fusion plasmas and their control by active means, non-resonant alteration of the plasma rotation profile created by applied three-dimensional magnetic fields, and the prevention of disruptions in tokamak plasmas.

Dr. Berkery received his B.S. degree in Mechanical Engineering from Cornell University in 1999, and his Ph.D. in Mechanical and Aerospace Engineering from Princeton University in 2005. Dr. Berkery works on the National Spherical Torus Experiment Upgrade (NSTX-U), where he is the leader of the Macroscopic Stability topical science group. He is a member of the American Physical Society (APS) and has been invited by selective committees to give talks on his research at APS Division of Plasma Physics meetings. Additionally, he has presented his work at over 20 other conferences, including internationally in Israel, Ireland, Germany and Taiwan. Dr. Berkery has been the first author on over a dozen scientific papers on his research including two in *Physical Review Letters* and one that has been recognized as one of the most cited articles of 2014 by *Physics of Plasmas*.

Dr. Sabbagh received his B.S. degree from Columbia in 1984, M.S. in 1985, M.Phil. in 1988, and Ph.D. in 1990. He presently directs, organizes, and conducts research in a collaboration between Columbia and PPPL as principal investigator for research on magnetohydrodynamic plasma stability on NSTX-U and the Korea Superconducting Tokamak Advanced Research (KSTAR). He is co-leader of the NSTX-U Core Science Group that manages one-third of the topical science groups that conduct research on the device. He has a prolific publication history, including over 310 papers and 6,450 citations. He has merited a number of awards including the Kaul Foundation Prize for Excellence in Plasma Physics Research and Technology Development (awarded by Princeton University), the International Atomic Energy Agency Nuclear Fusion Award, and the IEEE Nuclear and Plasma Sciences Society Graduate Scholarship Award. He was elected a Fellow of the American Physical Society in 2010.

The prevention of disruptions in fusion tokamak devices is the new "grand challenge problem" in fusion plasma stability research. The research meriting this Award is a new paradigm and key foundation toward reaching this goal. Drs. Berkery and Sabbagh are now applying this knowledge and are naturally evolving their national and international research through an assessment and a quantitative reduction of disruptions in tokamak plasmas based on this improved physics understanding.

Sabbagh to Lead $3 Million International Grant on Sustained Tokamak Operation

Dr. Sabbagh will lead a new joint international grant from the US Department of Energy (DOE) to study high performance tokamak plasma disruption prediction and avoidance in the long-pulse Korea Superconducting Tokamak Advanced Research (KSTAR) located in Daejeon, South Korea. APAM associate research scientist **Dr. Young-Seok Park** will be lead researcher on the project for Columbia. This effort, which directly addresses one of two Tier 1 (highest priority) elements of the US magnetic fusion program as defined by the DOE, is a joint international effort comprised of three US institutions (Columbia, PPPL, and MIT) and the National Fusion Research Institute in Daejeon, South Korea. Dr. Sabbagh is lead principal investigator (PI) for the overall project and institutional PI for Columbia, with Dr. Steven D. Scott and Dr. Earl S. Marmar as institutional PIs for PPPL and MIT, respectively. The present grant covering three years totals $3.3 million for all three institutions, 53% of which will fund Columbia researchers. Drs. Sabbagh and Park will conduct the research full time at PPPL in close coordination with Dr. Sabbagh's present Columbia group research on this topic on the US DOE National Spherical Torus Experiment - Upgrade (NSTX-U), including **Dr. John (Jack) Berkery** and **Dr. James Bialek** of APAM, and two newly-appointed APAM post-doctoral researchers. The project also aims to bring in an APAM student.

The prediction and avoidance of tokamak disruptions, which stop plasma operation in the device, comprise a present "grand challenge" problem facing magnetic fusion in this leading magnetic confinement system. The research is of critical importance to the field, and while challenging, the goals of this exciting research are tractable and rewarding.

The present expanded research effort is enabled by the prudent guidance and strong support of the DOE to create joint research efforts, including national and international partners, to tackle such high priority research issues. The present work builds on the successful, award-winning Columbia APAM group effort at PPPL to allow analysis of data from multiple tokamak devices, leveraging the advanced, unique capabilities of the high performance, long pulse superconducting KSTAR device (at high aspect ratio) and low aspect ratio ("spherical") plasmas in NSTX-U. These devices represent the greatest range of aspect ratio of high performance tokamaks in the world today, allowing plasma theory to be validated over a wide range of this important device parameter. The devices also have world-class diagnostics and multi-megawatt auxiliary heating systems. The present research is the natural progression of past research by Columbia APAM scientists, evolving the research by directly applying the plasma stability, transport, and control physics knowledge gained in the past decade to disruption event characterization and forecasting (DECAF). **(Continued on p. 11)**

In Memoriam: Professor Leon Lidofsky (1924 - 2016)

Following service in the United States Navy during World War II, **Leon Lidofsky** completed his undergraduate education at Tufts University and then pursued doctoral studies at Columbia, earning a Ph.D. in Physics in 1952. In 1960, he joined the faculty of the School of Engineering and Applied Science where he was a founding member of the Division of Nuclear Science and Engineering as well as one of the nine founding members of the Department of Applied Physics and Applied Mathematics. In addition, he was a founding member of the graduate Program in Medical Physics.

Professor Lidofsky's fields of specialization included nuclear physics, radiation transport and shielding, application of computers to nuclear research, and nuclear safety. He later extended the reach of his research to include radiation imaging and other applications of radiation in medicine. Of the thirty doctoral dissertations he sponsored, nine were directly in or related to the field of medical physics.

Professor Lidofsky taught numerous courses, including *Radiation Shielding*, *Computer Techniques in Radiation Shielding*, *Nuclear Physics*, *Nuclear Engineering Design*, *Environmental Aspects of Nuclear Power*, and *Controlled Fusion Reactor Technology*. He established the Gussman Computer Lab, and was the principal investigator of an IBM project to develop a school-wide undergraduate course, *Engineering Design with Interactive Computer Graphics*. In 1988, he received the Great Teacher Award, an award he valued greatly. The award citation reads in part, "The Columbia community is proud to have you as one of its most insightful and compassionate faculty members."

In addition to his service to the University, Professor Lidofsky served on government committees at the NRC and the U.S. Atomic Energy Commission. He was a consultant for APS Study Groups, Ebasco Services, IBM, Memorial Sloan-Kettering Cancer Center, Schlumberger Doll, and The Mount Sinai School of Medicine, among others. He was a fellow of the American Physical Society, a visiting research fellow at the University of Amsterdam, and a member of the American Nuclear Society. He also served as a media expert on questions of nuclear safety.

At Professor Lidofsky's retirement dinner, held in November 1992, his doctoral thesis advisor, Chien-Shiung Wu, Professor Emeritus of Physics, was the guest speaker; his colleagues praised his distinguished career in nuclear science; his students remembered him as a brilliant and dedicated teacher who was always available to help with any professional or personal matters. As one of his protégés wrote, "All the grad students I knew adored him, in fact everybody did. He was always around, always available to anybody for anything." In 2004, his Columbia "family," together with his wife Elly, gathered to celebrate his 80th birthday. We all remember him, and we will miss him.

APAM Staff News: The Department bid a fond farewell to two dedicated, long-term staff members this summer: **Nick Rivera**, from the Plasma Lab, and **Dina Amin**, the former Department Administrator. Nick retired after 32 years of service and Dina is now a Senior Project Officer in the office of Sponsored Projects Administration. We warmly welcome **Stella Lau** as the new APAM Department Administrator. She previously worked in the SEAS Dean's office, Columbia's Office of the Treasurer and Controller, and Columbia's Department of Psychiatry. Stella also spent several years as the Administrator Director in the Department of Psychiatry at the Research Foundation of Mental Hygiene and, most recently, she was the Director of Finance and Operations at the Kew-Forest School.

Sabbagh to Lead $3 Million Int'l Grant (continued from p. 10)

The new grant is organized into three elements:

1) Analysis of the chains of events leading to disruptions in a long pulse, high performance superconducting tokamak, and forecasting the onset of such events. This effort includes the important effort of collecting the present set of excellent diagnostic data on KSTAR into more advanced plasma equilibrium, stability, and transport analyses required to support DECAF analysis.

2) Improvements and additions to certain key diagnostics required for equilibrium, stability, and transport analysis, especially the addition of a background light polychrometer for the KSTAR Motional Stark Effect (MSE) diagnostic, built by our PPPL and MIT partners. An existing 10 channel system will be shipped to KSTAR to improve the present MSE system on the device, especially as the pulse length goes beyond 50 seconds, and the auxiliary heating power is doubled to 12 MW within 3 years. Research under the present grant by PPPL and MIT will also build 15 additional polychrometer channels to fully support the present MSE system on KSTAR.

3) Instability control for disruption avoidance will be implemented and supported in KSTAR in a manner similar to the successful research conducted by the Columbia group at PPPL over the past decade. Control efforts will feature multi-sensor control, and advanced algorithms including a physics model-based state-space controller to maintain global MHD stability.

This effort will produce exciting, new, and greatly needed data in conjunction with our strong international partners at NFRI, utilizing and building or collaborative research and extending the reach of Columbia APAM researchers around the globe.

Yu's Team Discovers New Optical Material (continued from p. 9)

Yu's team included Ramanathan, his Harvard Ph.D. student You Zhou, and his Purdue postdoctoral fellow Zhen Zhang, who synthesized the phase-transition material and did some of the phase transition experiments (this work began at Harvard and continued when Ramanathan moved to Purdue); Drexel University Materials Science Professor Christopher Li, Ph.D. student Hao Qi, and research scientist Qiwei Pan, who helped make solid-state devices by integrating $SmNiO_3$ with novel solid polymer electrolytes; and Brookhaven National Laboratory staff scientists Ming Lu and Aaron Stein, who helped device nanofabrication. **Yuan Yang**, Assistant Professor of Materials Science and Engineering in the APAM Department, was consulted during the progress of this research.

The study was funded by DARPA YFA (Defense Advanced Research Projects Agency Young Faculty Award), ONR YIP (Office of Naval Research Young Investigator Program), AFOSR MURI (Air Force Office of Scientific Research Multidisciplinary University Research Initiative) on metasurfaces, Army Research Office, and NSF EPMD (Electronics, Photonics, and Magnetic Devices) program.

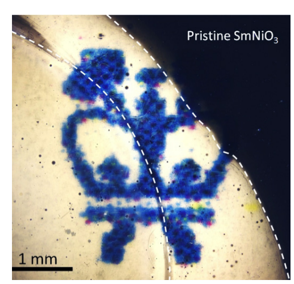
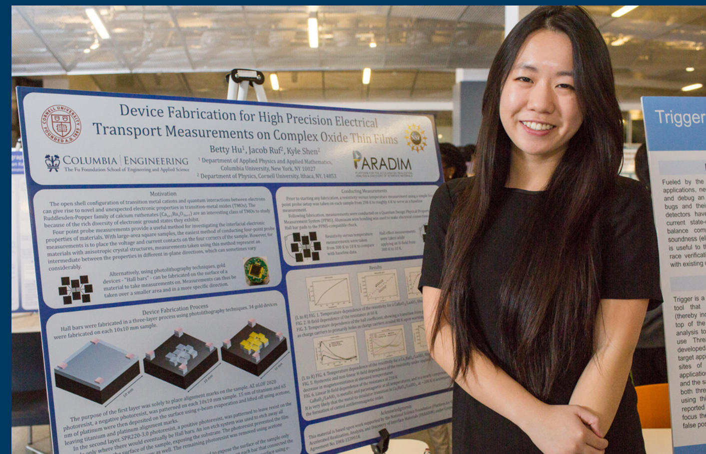


Image: Prototype of a smart window. The picture shows a layer of phase-transition material $SmNiO_3$ placed on top of the SEAS logo. The transparency of the material can be controlled by electron doping under ambient conditions. Pristine $SmNiO_3$ is opaque; partial phase-transition makes the material translucent, and complete phase-transition makes it transparent.

2016 Undergraduate Research Symposium

Applied Physics undergrads, Betty Hu '19, Derek Tropf '17, and Shangzhou Xia '18, participated in the 5th Annual SEAS Undergraduate Research Symposium on October 6, 2016, in Carleton Commons. The event was hosted by SEAS Undergraduate Student Affairs and Global Programs, the Engineering Student Council, and the Columbia Undergraduate Scholars.

Betty Hu was supervised by Prof. Kyle Shen and was sponsored by Cornell University's PARADIM (Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials); Derek Tropf was supervised by Dr. Yong Chu, as part of a Science Undergraduate Laboratory Internship (SULI) at the National Synchrotron Light Source II (NSLS-II) at Brookhaven National Laboratory; and Shangzhou Xia, who was supervised by Prof. Yuan Yang in the APAM Department, was jointly sponsored by the Egleston Scholar Program and the Yang group.



Betty Hu, SEAS '19, Applied Physics
"Device Fabrication for High Precision Electrical Transport Measurements on Complex Oxide Thin Films"

Derek Tropf, SEAS '17, Applied Physics
"Development of Automated Batch Workflow and Real Time Large Data Processing for X-ray Fluorescence Tomography"

Shangzhou Xia, SEAS '19, Applied Physics
"Measuring the Thermal Conductivity of Lithium-ion Battery Anodes Using a Simple Differential Steady-state Method"

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