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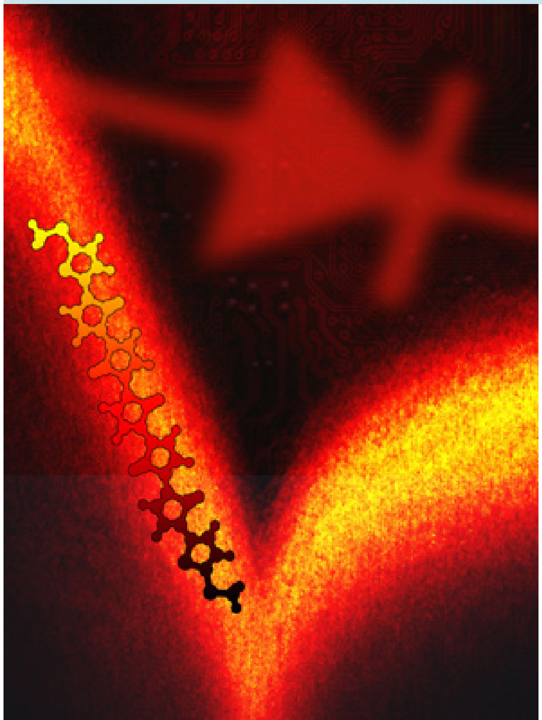
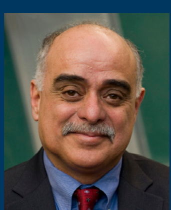
APAM NEWS

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,

We are pleased to send you this compilation of good news. You will see that many APAM students, faculty, and staff have worked above and beyond the call of duty to garner honors and kudos from all over the world. Our new course, MSAE E8235, which covered the state-of-the-art material characterization techniques available at the Brookhaven National Laboratory, was a success. This course was taught by BNL scientists who drove down once a week and is a harbinger of much closer cooperation/collaboration between our institutions. Our new faculty members are settling in and working hard. In closing, I can say that we at APAM are happy about our hard work and achievements in 2015. We will work harder and achieve more in 2016. I wish all members of the APAM Community Happy Holidays and a happy, healthy, and prosperous New Year.

Best regards,

I. Cevdet Noyan
Chair, APAM

In This Issue

The cover image, courtesy of Prof. Latha Venkataraman, depicts a molecule used to create the first single-molecule diode. Diodes are fundamental building blocks of integrated circuits; they allow current to flow in only one direction. (See page 10 for details.)

Focus on Egleston Scholars

Neel Rakholia, Applied Mathematics '16, from Rajkot, India, was named an Egleston Scholar. He is an Applied Mathematics major who minors in Computer Science and Operations Research. He has worked with Dr. Tess Russo at the Columbia Water Center (CWC) to analyze and model changes in groundwater levels in a region in India. On campus, he is involved with the Columbia chapter of Nourish International. He is also a part of Residential Incubator - a program intended to foster entrepreneurial spirit in college students. Neel has also represented India at several events including the International Junior Science Olympiad in 2009, World Robot Olympiad the following year, and International Conference for Sustainable Energy in Israel.

Larry Xiao, Applied Mathematics '17, from Plano, TX, was named an Egleston Scholar. He spent two years studying at the Texas Academy of Math and Science (TAMS), where he discovered his interest in the intersection of engineering and social entrepreneurship. During his time at TAMS, Larry did research in a materials science lab, investigating the chemical modification of natural fibers in polymer-based composites. As a result of his work, he has been recognized as a semi-finalist in the Intel STS Competition while also holding multiple publications in international journals. His experiences in the lab have helped him realize that his passions lie elsewhere, enabling him to pursue his interests in other academic fields. At Columbia, Larry is majoring in Applied Mathematics with the hope of creating a positive social impact for those who are less fortunate.

Graduate Student Award Winners

Bernard Lipat, an Applied Mathematics graduate student, was awarded a NASA Earth and Space Science Fellowship beginning September 2015. There were 391 applications in Earth Science Research, 64 of which were selected for award. The title of his proposal was "Quantifying and Understanding Linkages between Clouds and the General Circulation". Lipat's advisors are George Tselioudis (NASA GISS & APAM) and Lorenzo Polvani (APAM) and the goal of his research project is to understand the natural co-variability of clouds and the general circulation of the atmosphere as a step toward predicting their coevolution under anthropogenic forcing. Lipat says, "Due to the wide range of physical scales involved, clouds cannot be fully resolved in climate models and so are parameterized. Model biases in cloud processes of the current climate are strongly linked to model uncertainty in predictions of future climate. To study how clouds and the general circulation affect one another, I am performing observational analysis which will inform model evaluation and experiments."

Bosky Ravindranath and **Yong Hum Na,** students in the Medical Physics Program, who are also Medical Physics Residents (one at MSKCC and one at CU), were winners of the 2015 RAMPS Young Investigator Symposium. Ravindranath is currently a special student and Na is a student in the Certificate Program. Medical Physics students in the APAM Department can present results of research conducted independently or as part of APPH E6650, Research Project. RAMPS, The Radiological and Medical Physics Society of New York, is the local AAPM chapter based at MSKCC.

Harlin BS'08 Featured in *Engineering News*

by Jennifer Ernst Beaudry, originally published by Columbia Engineering News

Ky Harlin BS'08 is using what he learned at Columbia Engineering to bring Condé Nast into the future.

As vice president of growth and data science since March, Harlin is charged with both collecting data about site visitors and analyzing it for trends and insights that can help the venerable publication giant grow its burgeoning digital business. That includes analyzing data to make sure publications are tailoring their posts to channels like Facebook or Twitter where they'll be best received, advising on the kinds of stories that are driving visitors to the site (and the ones that keep them there), and even working with the magazines' online presences to tweak their presentation to maximize each user's experience.

"Condé Nast has all these incredible brands that people know and trust and are authoritative, but their print publications still drive the majority of their business in terms of revenue," he said. "However, we know that ultimately, people are going to spend the majority of their time consuming content digitally. My function is basically to help us use data to grow that audience."

And to do it, Harlin is relying not only on his years at Internet news media king BuzzFeed—he's putting into practice what he learned as an applied mathematics major at SEAS.

"I think my generation, going into college, was told by people who are four to five years older, 'You don't use anything you learned at school in a real job.' But I feel totally the opposite. What I did at Columbia was perfectly suited to what I do."

Harlin first encountered data science via a guest speaker in the applied mathematics majors' seminar. This led to research in medical imaging at Invicro, a company that provides imaging services to pharmaceutical companies, after graduation. Associate Professor Chris Wiggins—now also the chief data scientist at the *New York Times*—teaches the applied math seminar and later connected Harlin with a consulting opportunity at BuzzFeed.

And working at BuzzFeed gave Harlin a front-row seat to the uses of data science.

"When I started at BuzzFeed, [founder] Jonah Peretti was very visionary. He realized that data was going to be huge in the future," Harlin said. "Tech companies were doing it, but not many media companies. I was the first guy there doing it, so I learned it through trial and error."

It's that hands-on experience that Condé Nast wanted to tap. In his position—the first of its kind at the publisher—Harlin reports to EVP and Chief Digital Officer Fred Santarpia as part of a newly formed digital division that signals the company's focus on driving their online business.

"They're two very different companies. BuzzFeed was born on the web, and, in a sense, that made what I do much simpler, because they were creating content with a digital focus in mind from the beginning," he said. "But the two companies are ultimately trying to do the same thing. While Condé Nast has built its company and brands through print magazines, we still employ a lot of the same strategies in terms of growing our digital presence."

And it's paying off. Harlin said Condé Nast's Comscore numbers—the industry standard for measurement of web traffic data—have started showing growth: "Good stuff is happening. Three of the first four months since I joined have been our biggest in history."

Sheshadri Named Junior Fellow of Simons Society

Aditi Sheshadri, a postdoctoral research scientist working with Prof. Lorenzo Polvani, was named a Junior Fellow of the Simons Society of Fellows. She will receive three years of support from the foundation, including a yearly stipend, research allowance, and fringe benefits funds.

Dr. Sheshadri has a bachelor's degree in mechanical engineering from the R. V. College of Engineering in Bangalore, India, and a master's degree in aeronautics and astronautics from the Massachusetts Institute of Technology in Cambridge, Massachusetts. She graduated from MIT with a Ph.D. in Atmospheric Science in June 2015. Her doctoral thesis advisor was Prof. R. Alan Plumb.

Sheshadri's research interests are in atmosphere and ocean dynamics, climate variability, and general circulation. She is particularly interested in stratospheric dynamics and stratosphere-troposphere interactions, as well as natural modes of variability of the climate system and their possible relation to its response to external forcing. Her doctoral work focused on the dynamics and variability of the stratospheric polar vortices in both hemispheres, and the impact of their variability on surface weather and climate. Her recent work has been aimed at understanding the dramatic collapse of the stratospheric westerlies that occur in the wintertime northern hemisphere and at the end of winter in both hemispheres. These events have implications for surface climate, since they result in persistent perturbations to surface weather. Another focus has been the investigation of mechanisms linking Southern Hemisphere tropospheric climate changes to the ozone hole. At Columbia, she will continue to study the circulation of the troposphere and stratosphere, eddy-mean flow feedbacks, modes of variability of the midlatitude jet and storm tracks, the role of interactive chemistry in modeling stratosphere-troposphere interactions, and the role of the stratosphere in setting the state of climates of the past.

Berkery and Sabbagh Coauthor Highly Cited Plasma Physics Research Paper

by Jesse Adams, originally published by Columbia Engineering News

Jack Berkery and **Steven A. Sabbagh** (Ph.D. '90, Plasma Physics), both research scientists in the APAM Department, coauthored one of the 20 most cited papers in *Physics of Plasmas*, the premiere journal of plasma physics research, in 2014. The paper, "Benchmarking kinetic calculations of resistive wall mode stability," showcases a multiyear effort that benchmarks leading fusion plasma stability analyses, and includes calculations for the International Thermonuclear Experimental Reactor (ITER), the world's largest tokamak project currently under construction in France. Berkery and Sabbagh (also an adjunct professor in APAM) are part of a Columbia research team collaborating on the National Spherical Torus Experiment—Upgrade (NSTX-U) at the U.S. Department of Energy's Princeton Plasma Physics Laboratory.

Öztürk Receives Best Student Poster & Young Scientist Award

Hande Öztürk, a postdoctoral research scientist in the Noyan group, received a "Best Student Poster Award" at the 64th Annual Conference on Applications of X-ray Analysis in Westminster, CO. Öztürk's poster, "D-44 Relating Particle Sampling Statistics and Intensity Statistics in Powder Diffraction Experiments with Nanocrystalline Powders," featured her recent work with her advisor, Prof. I.C. Noyan, as well as H. Yan and J. Hill, from Brookhaven National Lab. Öztürk also received a Young Scientist Award for £254.00 GBP from the Organizing Committee of the 7th Size-Strain conference on Diffraction Analysis of the Microstructure of Materials (SS-VII) to participate in the conference at the University of Oxford, United Kingdom.

Alumni Reports

Hubert Hugh Burke (Ph.D. '95, Solid State Physics) has a limited term appointment to the faculty in the Physics & Astronomy Department at Trent University (Peterborough) at the rank of assistant professor. He continues to look for a permanent faculty appointment at a Canadian University and to seek financing for 'A Very Canadian Film' - a story told in six independent feature length films by Burke.

Gabriel Ganot (Ph.D. '12, Materials Science and Engineering), a consultant at Exponent Engineering and Scientific Consulting, visited APAM this September to present a talk at the MSE Colloquium. Ganot appeared in the official NFL Deflategate report mentioned in *The New York Times* article, "Tom Brady Probably Knew Footballs Were Doctored, N.F.L. Finds." "Exponent analyzed pressure data collected at halftime on the day of the AFC Championship Game, and conducted a series of experiments designed to evaluate the impact of environmental and other conditions on the air pressure levels of footballs to determine whether the reduction in air pressure levels recorded during the AFC Championship Game was more likely the result of environmental and natural factors as opposed to human intervention." See page 35 of the official report for more references to Exponent and Ganot.

Ruth Griswold Abrams (B.S. '05, Applied Mathematics) and John Klinger (B.S. '70, Applied Physics) attended the Alumni Department Luncheon during the SEAS Reunion Weekend in May 2015.

Paul Koch (Ph.D. '64, Plasma Physics) writes, "I finished my degree in plasma physics fifty years ago, and am long retired. However, my scientific curiosity is unabated." Please see "Cortical Activity Waves are the Physical Carriers of Memory and Thought," which I presented at the IEEE conference on neural engineering in Montpelier France in Spring 2015. "I believe this work opens many possibilities for future research in a field that will be increasingly funded, and is quite suitable for APAM students," says Koch.

Richard Robinson (Ph.D. '04, Solid State Physics) has been promoted to associate professor with indefinite tenure, effective July 1, 2015, in the Materials Science Department at Cornell University. Robinson's lab works on nanomaterials synthesis and device integration. His group is researching the fundamental science of how to program and process nanoscale building blocks into functional architectures, and the structure-property relationships of the resulting nanostructured materials.

New APAM Faculty Members: Gaeta, Quenneville-Bélair, and Yang

Alexander L. Gaeta is the David M. Rickey Professor of Applied Physics and of Materials Science. He received his B.S., M.S., and Ph.D. degrees from the University of Rochester in 1983, 1985, and 1991, respectively. After receiving his doctoral degree in optics, he remained at the University of Rochester for two years as a postdoctoral research associate. He then joined the faculty of the School of Applied and Engineering Physics at Cornell University, rising through the academic ranks and named the Samuel B. Eckert Professor of Engineering.

His research interests include ultrafast nonlinear optics, nanophotonics, nonlinear propagation in fibers and bulk media, photonic crystal fibers, coherent interactions of laser light with matter, the generation of non-classical light fields, and stimulated scattering processes. The author or coauthor of more than 200 publications, he is currently the editor-in-chief of the Optical Society of America's journal *Optica*, and has served on the editorial boards of *Laser Physics Letters* and *New Journal of Physics*. While at Cornell, he served as the Chair of the School of Applied and Engineering Physics and Director of the Center for Nanoscale Systems from 2007-2012, and was a four-time recipient of the College of Engineering Teaching Award. Prof. Gaeta has received numerous honors in recognition of his research over his career, including Young Investigator Awards from the Office of Naval Research in 1993 and the Army Research Office in 1995. He is a fellow of the Optical Society of America and of the American Physical Society.

Vincent Quenneville-Bélair is the new Chu Assistant Professor of Applied Mathematics. He received his B.Sc. with first class honors in mathematics and physics from McGill University in 2008. He pursued his graduate studies at the University of Minnesota, receiving his M.Sc. in applied mathematics in 2011, M.CS. (master of computer science) in 2014, and Ph.D. in applied mathematics in 2015, studying gravitational wave propagation using the finite element method with Prof. Douglas N. Arnold.

His research interests are in numerical analysis and scientific computation with applications to physics and wave propagation. In particular, he designed and analyzed new mixed finite elements by adapting the recently developed Finite Element Exterior Calculus (FEEC) framework to abstract Hodge wave equations. This framework enables him to borrow key ideas from Reissner-Mindlin plate bending and elasticity with weakly imposed symmetries to maintain stability of the method. The stability of a discretization often relies on deep connections between fundamental branches of mathematics: the FEEC mimics these connections for the numerical method to achieve similar stability to that of the original equations. The recent development of FEEC has had a transformative impact on electromagnetism and related computational problems, and he expanded it to general relativity.

Yuan Yang is a new assistant professor of Materials Science and Engineering. He received a B.S. degree in physics from Peking University in 2007 and Ph.D. degree in materials science and engineering from Stanford University in 2012, under the supervision of Prof. Yi Cui. He comes to Columbia University from the Department of Mechanical Engineering at MIT, where he was a postdoctoral researcher working with Prof. Gang Chen.

His research interests include the exploration of novel materials and chemistry for advanced energy storage, thermal harvesting and management, investigation of fundamental structure-property correlations, and chemical processes in energy materials and devices. He received an MRS Postdoctoral Award (2015), a Chinese Government Award for Outstanding Self-financed Students Abroad (2012), the Cubicciotti Award with Honor Mention of the Electrochemical Society (2010), and the O. Cutler Shepard Award of Stanford University (2010).

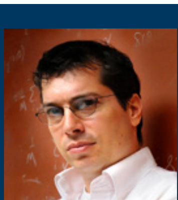
Osgood Receives 2015 IEEE Photonics Society Quantum Electronics Award

originally published by Columbia Engineering News

Richard M. Osgood, Eugene Higgins professor *emeritus* of electrical engineering and professor *emeritus* of applied physics, received the 2015 IEEE Photonics Society Quantum Electronics Award for "seminal contributions to novel laser systems, laser-surface photochemistry, and integrated linear and nonlinear Si waveguides." He was presented with the award at the 2015 IEEE Photonics Conference held in Reston, Virginia, in October. "I am particularly honored to receive this award," said Osgood, "since quantum electronics, which encompasses lasers, laser physics and chemistry, and their applications, had its origins many years ago with Professor Townes at Columbia! It is also a stellar example of the importance of basic science to the growth of technology in our country."

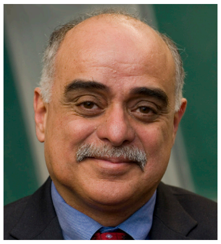
Volpe Receives Excellence in Fusion Engineering Award

Francesco Volpe, associate professor of applied physics, is the recipient of the 2015 Excellence in Fusion Engineering Award given by Fusion Power Associates (FPA). He received the award at the FPA 36th annual meeting and symposium, Strategies to Fusion Power, which took place in Washington, DC, from December 16-17, 2015. He was selected for his contributions "to fusion science and engineering in many areas, including MHD instability and control and RF heating. The FPA Board especially acknowledged the leadership role he is playing in innovations for stellarator and tokamak-torstron hybrid configurations." Prof. Volpe follows in the footsteps of Prof. Michael Mauel who received this award in 2000.



Wiggins Receives NOA Grant

Chis Wiggins, an associate professor of applied mathematics and the Chief Data Scientist at *The New York Times*, received an NOA Grant for the Columbia University Center for Topology of Cancer Evolution and Heterogeneity. The Center - a member of the National Cancer Institute's Physical Sciences in Oncology Network - is a multidisciplinary, multi-institutional research center that supports research combining mathematical and experimental techniques for the study of cancer. Their team includes experts in cancer genomics, the genetics of brain tumors, developmental biology, single-cell genomics, machine learning, and topological data analysis.



Noyan Receives Jenkins Lifetime Achievement Award

originally published by Columbia Engineering News

I.C. "Cev" Noyan, chair of the APAM Department and a professor of materials science and engineering and of earth and environmental engineering, was honored by the International Centre for Diffraction Data with its Jenkins Lifetime Achievement Award, the most prestigious honor for scientists who advance the use of x-rays in materials analysis.

The award, which was presented at the 64th Annual Conference on Applications of X-ray Analysis in Colorado this past August, recognized Noyan's contributions to the development of residual stress measurements and their applications in materials science and for his teaching and research in neutron and x-ray diffraction methods for analyses of micro- and nano-scale structures. The biennial award is named for Ron Jenkins, a leader and pioneer in the field of x-ray analysis.

"It is a great honor to receive this recognition and it is especially meaningful because I had known Ron Jenkins for almost 20 years. He was a great diffractionist, an excellent teacher, and had a wonderful sense of humor. I truly treasure the memory of our arguments."

Since 1978, Noyan has been advancing the study of the mechanical response of crystalline materials over various length scales using diffraction. He was one of the first researchers to combine the theory of micromechanics with that of x-ray and neutron diffraction. His x-ray and neutron characterization techniques for non-destructive analysis of structures have applications that range from suspension bridge cables to nanostructures and integrated circuitry. He and his research group also work on the theory of scattering, especially fine-tuning the measurement of diffraction data and quantifying uncertainties.

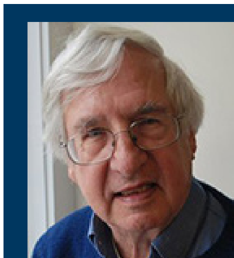
A fellow of the American Physical Society, Noyan's early research work was at IBM, where he received two IBM Outstanding Technical Achievement Awards for research and development of computer and packaging structures, an IBM Research Division Award for research on diffusion barriers, and 11 IBM Invention Plateaus for filed patents. He is also coauthor of the monograph, Residual Stress: Measurement by Diffraction and Interpretation (Materials Research and Engineering).

Du Wins MURI Grant

originally published by Columbia Engineering News

Qiang Du, the Fu Foundation Professor of Applied Mathematics, is part of a team who recently won a highly competitive Department of Defense (DoD) MURI (Multidisciplinary University Research Initiative) grant to develop mathematical theory and algorithms for data-driven fractional partial differential equations (PDEs) that can be used to model anomalous transport behavior in crowded and turbulent environments.

The team is led by Brown University, and includes researchers from Rice Univ., Michigan State Univ., and the University of South Carolina, as well as Columbia. The 5-year $6 million ARO (Army Research Office) grant was awarded for the DoD's "MURI Topic 6: Fractional Order Methods for Sharp Interface Flows;" the project is titled "Fractional PDEs for Conservation Laws and Beyond: Theory, Numerics and Applications." A member of Columbia's Data Science Institute, Du works on developing mathematical tools and numerical algorithms for applications in physical, biological, materials, data, and information science. His research is supported by multiple federal funding agencies, including another MURI award, a 5-year $7.5 million grant funded by the Air Force Office of Scientific Research for "MURI Center for Material Failure Prediction through Peridynamics."



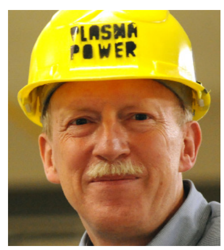
Scholz Receives the Harry Fielding Reid Medal

Christopher Scholz, professor of earth and environmental sciences and applied physics and applied mathematics, has been named the recipient of the Seismological Society of America's (SSA) top honor – the Harry Fielding Reid Medal.

"Professor Scholz studies the physics of earthquakes using experiments, theory, and observations. The author of more than 250 papers, his monograph, "The Mechanics of Earthquakes and Faulting" (2002) is considered the authoritative work on that subject. He has studied earthquakes extensively in Japan, New Zealand, southern Africa, the western U.S., and the island arcs of the Pacific. His experiences in one such field study is retold in "Fieldwork, a Geologist's Memoir of the Kalahari" (1997). "Stick-Slip", a novel about the next great earthquake and tsunami in Cascadia was published in 2014.

The Seismological Society of America, established over a century ago, is an international scientific organization dedicated to the 'advancement of seismology and its applications in understanding and mitigating earthquake hazards and in imaging the structure of the Earth.'

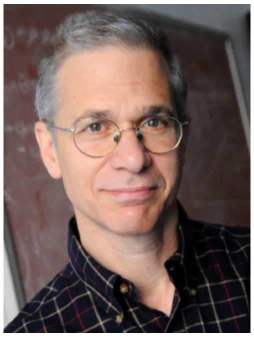
The Harry Fielding Reid Medal of the Seismological Society of America is awarded for outstanding contributions in seismology and earthquake engineering. It is awarded no more frequently than once in any calendar year. The award will be presented to Professor Scholz at the Society's Annual Meeting in Reno, Nevada in April 2016." - originally published by Earth & Environmental Sciences News



Mauel Delivers Plenary Lecture at APS Meeting

Michael Mauel, Professor of Applied Physics, delivered the plenary lecture on "The Physics of the Laboratory Magnetosphere" during the Annual Meeting of the APS Division of Plasma Physics November 16, 2015 in Savannah, GA. This meeting attracts more than 2000 leading plasma physicists from around the world to discuss the latest breakthroughs and scientific studies concerning the physics of ionized matter, called "plasma". Mauel described research conducted by students and scientists at Columbia University, MIT, Dartmouth College, and University of Tokyo that have characterized a new regime of high-temperature magnetically-confined plasma called "laboratory magnetospheres." Laboratory magnetosphere gives students opportunities to explore the physics of space with precision laboratory instruments. The laboratory magnetosphere consists of a large plasma is confined by a small, magnetically levitated, superconducting current ring. Mauel's plenary lecture reviewed the observations from the levitated dipole experiments at MIT and at the University of Tokyo, showed the importance of advanced supercomputer simulations to describing complex plasma dynamics, and introduced opportunities to apply the new physics of the laboratory magnetosphere to explore turbulent transport processes within a large quasi-steady magnetized plasma torus.

The presentation reviewed the contributions of 19 doctoral dissertations including the work from Thomas Roberts, Ph.D. Columbia University, (2015); Matthew Worstell, Ph.D. Columbia University (2013); Matt Davis, Ph.D. Columbia (2013); Brian Grierson, Ph.D. Columbia (2009); Eugenio Ortiz, Ph.D. Columbia (2007); Ben Levitt, Ph.D. Columbia (2004); Dmitry Maslovsky, Ph.D. Columbia (2003); and Harren Warren, Ph.D. Columbia (1994).



Weinstein Named Simons Foundation Math+X Investigator

by Holly Evants, originally published by Columbia Engineering News

Michael Weinstein, professor of applied mathematics and professor of mathematics, has been named a Simons Math+X investigator by the Simons Foundation. The five-year $1.5 million award, renewable for an additional five years, is a program established by the foundation in 2014 to encourage novel collaborations between mathematics and other fields in science or engineering. As Simons Math+X Investigator at Columbia, Weinstein will lead collaborations centered between the Engineering School's Applied Mathematics Program and Columbia's Department of Mathematics, with links to engineering and the sciences, in the mathematics of waves in novel media, such as those arising in optics and photonics and in condensed matter physics.

"This is a tremendous honor for me, and a very exciting opportunity for Columbia," Weinstein says. "The award will catalyze activities at the intersection of fundamental and applied mathematics, and with science and engineering fields, where wave phenomena are central. I am excited to be leading this initiative."

A revolution in researchers' ability to fabricate new material structures that can manipulate the flow of wave-energy, together with major advances in theory, has led to a myriad of possibilities for transport and processing of information with applications from communication to computation.

"In principle, the behavior of all waves—electro-magnetic, optical, quantum, gravitational, acoustic, seismic, etc.—is predictable, and the design of systems to control wave phenomena is deducible from the partial differential equations (PDEs) of mathematical physics," Weinstein notes. "However the complexity of these systems is such that the equations are not solvable in any explicit sense. Rather, we make progress through theoretical insights derived from the mathematical structure of these equations and their approximations, and computer simulation."

Weinstein, whose research bridges areas of fundamental and applied mathematics, physics, and engineering, is known for his deep and influential mathematical analyses of wave phenomena in diverse and important physical problems. These have included phenomena such as the focusing of intense beams in nonlinear optics, as well as the dynamics of pulses in optical fibers, solitary waves in fluids, and matter-waves in Bose-Einstein condensates. Weinstein was elected a SIAM Fellow (Society for Industrial and Applied Mathematics) in 2010 and a fellow of the AMS (American Mathematical Society) in 2014.

A recent focus of Weinstein and his collaborators has been "cloaking" and other types of control of wave-energy by "metamaterials." Metamaterials are composite material micro-structures, some fabricated and some, so far, only theorized by researchers that have emergent properties not achievable in naturally occurring materials. Experimentalists have demonstrated cloaking, the rendering of objects invisible to detection, using metamaterials. Weinstein observes that it is a mathematical analysis of the equations of electromagnetism that leads to a prescription for the optical properties of metamaterials that enables the cloaking effect.

Weinstein is also studying the flow of energy in topological insulators. These novel structures offer exciting possibilities for extremely robust energy transport in photonic and electronic systems, and are potentially important building blocks of nanoscale components in communication and computing systems. He and his colleagues are exploring the remarkable properties of metamaterials and topological insulators, using a combination of sophisticated mathematical theory and computer simulation.

Weinstein notes that there are deep mathematical questions in, for example, PDEs, analysis, geometry, topology, and stochastic processes that lie at the core of these phenomena, and answering them will inform future applications across disciplines. "And there is also the reciprocal effect of central questions arising in applications inspiring new mathematical directions," he adds. "This is an exciting time for research at the nexus of mathematics, applied science, and engineering. The convergence of fundamental mathematics and applications is a compelling invitation to mathematicians to important intellectual terrain. Columbia has an outstanding community of fundamental and applied mathematicians, and we have terrific potential to become a very strong center in these areas."

Conference on Waves, Spectral Theory & Applications - A Celebration for Weinstein's 60th Birthday

by James Lee-Thorp

In honor of his 60th birthday, past and present colleagues and students of Prof. Michael Weinstein, including APAM alumni **Braxton Osting (Ph.D. '11), Gideon Simpson (Ph.D. '08)** and **Jeremy Marzuola (Postdoctoral Research Scientist)**, gathered together at Princeton University on September 10-11, 2015, for a conference on Waves, Spectral Theory and Applications.

The conference focused on a dozen talks by mathematicians, physicists and engineers, who spoke on subjects to which Prof. Weinstein has made important contributions. The speakers were a mix of both early career and accomplished researchers with whom Prof. Weinstein has collaborated closely. The talks covered a wide range of topics, including, to mention but a few, spectral theory, partial differential equations, photonics, seismic wave detection, betting against the financial market and insect locomotion. More so than anything, this range of topics served as a reflection of Prof. Weinstein's varied academic contributions.

One of the early career speakers was Prof. Braxton Osting from the University of Utah. Before sharing his recent results on graph theory algorithms – obtained in part using methods related to his doctoral work under Prof. Weinstein – Prof. Osting took the time to thank Prof. Weinstein for being incredibly generous with his time and putting great investment into Prof. Osting's early career; a sentiment that was echoed by other past and current students of Prof. Weinstein.

Many of the talks began with personal anecdotes and happy recollections of previous collaborations, and all speakers underlined Prof. Weinstein's infectious desire to learn about new fields. It was particularly touching on the last day to hear Prof. Weinstein's academic advisor, Prof. George Papanicolaou of Stanford University, speak of his immense personal pride at the range and influence of Prof. Weinstein's work.

For more information, see https://sites.google.com/site/wavesandspectraltheory/home

Columbia Engineers Develop New Approach to Modeling Amazon Seasonal Cycles

The following story by Holly Evants, originally published by Columbia Engineering News, features the research of Prof. Adam Sobel, Prof. Pierre Gentine (former APAM Chu Assistant Professor and current Professor of Earth and Environmental Engineering), Usama Anber (Sobel's Ph.D. student at LDEO) and Shuguang Wang (APAM associate research scientist). Image courtesy of lbl.gov

With the rise of CO_2 in Earth's atmosphere, understanding the climate of tropical forests—the Amazon in particular—has become a critical research area. A recent NASA study showed that these regions are the biggest terrestrial carbon dioxide sinks on our planet, absorbing 1.4 billion metric tons of CO_2 out of a total global terrestrial absorption of 2.5 billion. Climate scientists have typically been relying on general circulation models (GCMs) to simulate the tropical climate to learn more about its processes. But these models exhibit biases over tropical continents, showing peak evaporation and photosynthesis rates in the wrong season, as well as rain too early in the day.

A team led by Pierre Gentine, professor of earth and environmental engineering, and **Adam Sobel**, professor of applied physics and applied mathematics and of earth and environmental sciences, has developed a new approach, opposite to climate models, to correct climate model inaccuracies using a high-resolution atmospheric model that more precisely resolves clouds and convection (precipitation) and parameterizes the feedback between convection and atmospheric circulation. This study is published in the August 31 online Early Edition of *Proceedings of the National Academy of Sciences (PNAS)*.

"Our new simulation strategy paves the way for better understanding of the water and carbon cycles in the Amazon," says Gentine, whose research focuses on the feedback between land and atmosphere. "Our approach should help us learn more about the role of deforestation and climate change on the forest."

Usama Anber, Sobel's Ph.D. student at Columbia's Lamont-Doherty Earth Observatory and the paper's first author, simulated the Amazon climate and demonstrated the key role that the morning fog layer plays on evaporation and surface radiation. This fog layer is induced by the large nighttime precipitation, missed by current climate models, which underestimated the effect of clouds and precipitation. The researchers found that the fog layer is an essential regulator of the Amazon climate: during the wet season, it artificially modifies the duration of daytime because it reflects sunlight during the early morning. During the dry season, with no fog layer to reflect sunlight, the smaller cloud cover allows plants to receive much higher radiation, increasing evaporation and photosynthesis rates, another process missed by the GCMs.

Columbia Engineers Develop New Approach, cont.

"Our study demonstrates that using coupled land-atmosphere models with resolved convection and parameterized large-scale dynamics produces very accurate results," Anber observes. "It is critical to our understanding of tropical climates."

The team, which also included **Shuguang Wang**, associate research scientist in the Department of Applied Physics and Applied Mathematics, plans next to examine CO_2 cycles to see if they can develop better predictions of climate changes.

"If we can improve our estimations of evaporation over land, then we can also improve water resources management, and weather and climatic forecasts," Gentine adds. "Working on the hydrologic and carbon cycles is exciting because it will help determine the fate of our planet."

Their study is supported by the Department of Energy, the National Science Foundation (NSF), and the Office of Naval Research.

Sobel's Eastern Canadian Tour

The Marine Environmental Observation Prediction and Response Network (MEOPAR) hosted an Eastern Canadian speaking tour for Prof. Adam Sobel in late August and early September. The tour, organized by MEOPAR, a federally funded research network on the theme of maritime risk, and sponsored by the Insurance Bureau of Canada, consisted of a series of talks about Hurricane Sandy and was based on his book, *Storm Surge*, winner of the 2014 Atmospheric Science Librarians International Choice Award and the 2016 Louis J. Battan author's award from American Meteorological Society.

"Like everywhere, the climate is changing up here, and people know it. My perception from the media is that Canada has as much denial as the United States does, but I have seen zero evidence of it during these past two weeks. Instead, I have heard about people's first-hand perceptions of the changes they're seeing on the ground. Those motivate concern about the enormous global challenge, and a genuine desire to reduce local greenhouse gas emissions and increase use of renewable energy." - from "New York, New Orleans, Charlottetown and Everywhere Else," originally published online in the *State of the Planet* (Earth Institute News). Read the full article online: http://tinyurl.com/nzr45bh

Sobel Featured in NY Transit Museum Exhibit

Sobel is featured in the New York Transit Museum's new exhibit, "Bringing Back the City: Mass Transit Responds to Crisis".

This exhibit, which opened on September 30, focuses on the preparation and response of transit employees to natural and man-made disasters including the 2003 Northeast Blackout, 9/11, Hurricane Sandy, and other severe weather events. Sobel, the only weather and climate scientist featured in this exhibit, can be seen on several video displays discussing Hurricane Sandy and climate change.

The New York Transit Museum is located at the corner of Boerum Place and Schermerhorn Street in Brooklyn Heights. For more information, see: http://web.mta.info/mta/museum/

Staying Cool: Saharan Silver Ants

by Holly Evants, originally published by Columbia Engineering News

Nanfang Yu, assistant professor of applied physics, and colleagues from the University of Zürich and the University of Washington, have discovered two key strategies that enable Saharan silver ants to stay cool in one of the hottest terrestrial environments on Earth. Yu's team is the first to demonstrate that the ants use a coat of uniquely shaped hairs to control electromagnetic waves over an extremely broad range from the solar spectrum (visible and near-infrared) to the thermal radiation spectrum (mid-infrared), and that different physical mechanisms are used in different spectral bands to realize the same biological function of reducing body temperature. Their research, "Saharan silver ants keep cool by combining enhanced optical reflection and radiative heat dissipation," is published June 18 in Science magazine.

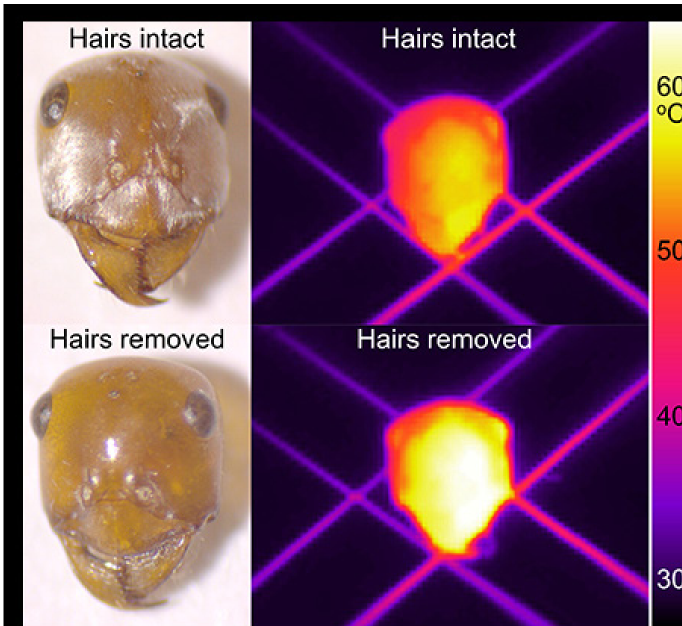
"This is a telling example of how evolution has triggered the adaptation of physical attributes to accomplish a physiological task and ensure survival, in this case to prevent Saharan silver ants from getting overheated," Yu says. "While there have been many studies of the physical optics of living systems in the ultraviolet and visible range of the spectrum, our understanding of the role of infrared light in their lives is much less advanced. Our study shows that light invisible to the human eye does not necessarily mean that it does not play a crucial role for living organisms."

The project was initially triggered by wondering whether the ants' conspicuous silvery coats were important in keeping them cool in blistering heat. Yu's team found that the answer to this question was much broader once they realized the important role of infrared light. Their discovery that there is a biological solution to a thermoregulatory problem could lead to the development of novel flat optical components that exhibit optimal cooling properties.

"Such biologically inspired cooling surfaces will have high reflectivity in the solar spectrum and high radiative efficiency in the thermal radiation spectrum," Yu explains. "So this may generate useful applications such as a cooling surface for vehicles, buildings, instruments, and even clothing."

Saharan silver ants (Cataglyphis bombycina) forage in the Saharan Desert in the full midday sun when surface temperatures reach up to 70°C (158°F), and they must keep their body temperature below their critical thermal maximum of 53.6°C (128.48°F) most of the time. In their wide-ranging foraging journeys, the ants search for corpses of insects and other arthropods that have succumbed to the thermally harsh desert conditions, which they are able to endure more successfully. Being most active during the hottest moment of the day also allows these ants to avoid predatory desert lizards. Researchers have long wondered how these tiny insects (about 10 mm, or 3/8" long) can survive under such thermally extreme and stressful conditions.

Using electron microscopy and ion beam milling, Yu's group discovered that the ants are covered on the top and sides of their bodies with a coating of uniquely shaped hairs with triangular cross-sections that keep them cool in two ways. These hairs are highly reflective under the visible and near-infrared light, i.e., in the region of maximal solar radiation (the ants run at a speed of up to 0.7 meters per second and look like droplets of mercury on the desert surface). The hairs are also highly emissive in the mid-infrared portion of the electromagnetic spectrum, where they serve as an antireflection layer that enhances the ants' ability to offload excess heat via thermal radiation, which is emitted from the hot body of the ants to the cold sky. This passive cooling effect works under the full sun whenever the insects are exposed to the clear sky.



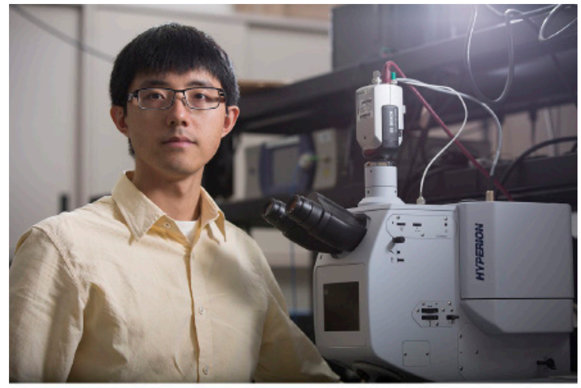
(Above) Thermodynamic figure comparing the temperature of ant head with and without hairs. The hair coating helps reduce body temperature substantially (via enhanced reflection of solar radiation and enhanced thermal radiation). (Below) Saharan silver ants forage in the midday sun and look like droplets of mercury rolling on the desert surface — Images courtesy of Norman Nan Shi and Nanfang Yu

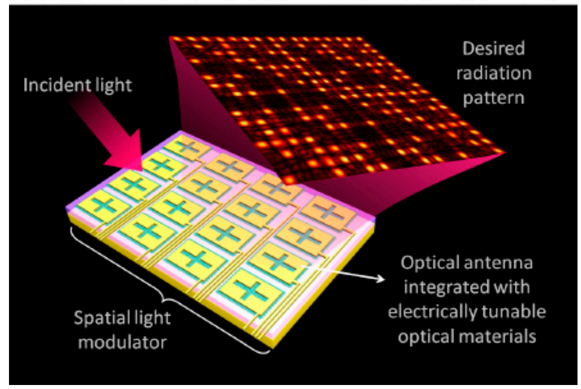
"To appreciate the effect of thermal radiation, think of the chilly feeling when you get out of bed in the morning," says Yu. "Half of the energy loss at that moment is due to thermal radiation since your skin temperature is temporarily much higher than that of the surrounding environment."

The researchers found that the enhanced reflectivity in the solar spectrum and enhanced thermal radiative efficiency have comparable contributions to reducing the body temperature of silver ants by 5 to 10 degrees compared to if the ants were without the hair cover. "The fact that these silver ants can manipulate electromagnetic waves over such a broad range of spectrum shows us just how complex the function of these seemingly simple biological organs of an insect can be," observes **Norman Nan Shi**, lead author of the study and Ph.D. student who works with Prof. Yu. **(continued on page 9)**

Yu Receives DARPA Young Faculty Award

by Holly Evants, originally published by Columbia Engineering News





Nanfang Yu has won the prestigious DARPA (Defense Advanced Research Projects Agency) Young Faculty Award (YFA). The award will provide ~$250k per year up to three years to support his work on metasurface-based flat optical modulators.

"We are looking to demonstrate a new class of planar optical devices called spatial light modulators that are able to mold optical wavefronts into complex shapes and with fast speed," Yu says. "I am very pleased to receive this significant recognition, which will advance my lab's research on 'flat optics'—using strong interactions between light and 2D-structured materials to control light at will."

Spatial light modulators (SLMs) consist of two-dimensional arrays of "optical antennas" that have sub-wavelength dimensions and are able to actively control the properties of the scattered light waves. These high-speed and light-weight optoelectronic devices are crucial for light detection and ranging, or LIDAR, a technology useful for a wide range of applications, including remote sensing, navigation, and surveillance. SLMs that control mid-infrared light will be particularly helpful in enabling pilots, for instance, to see through strongly scattering optical media such as fog, smoke, and dusty haze.

"Demonstrating high-frame-rate infrared SLMs is an extremely challenging subject," Yu notes. A high performance optical system requires three key components: light sources, modulators, and detectors. Over the past couple of decades, there have been major advancements in the development of both infrared light sources and detectors, but progress towards fast, electrically tunable infrared SLMs remains limited.
Yu and his PhD students Zhaoyi Li and Adam Overvig plan to realize large modulation of light with high speed by using a hybrid structure of optical antennas integrated with optical materials with electrically tunable optical refractive indices. His key concept is to use tunable materials to shift the optical resonances of the optical antennas so that the properties of the scattered light from the antennas can be altered significantly. "The SLMs will consist of a 2D array of such tunable optical antennas, individually controlled by electronics, to generate arbitrary optical wavefronts with desired phase, amplitude, and polarization profiles," he explains.

"For the long term, we want to replace all common optical devices and components with their advanced 'flat' counterparts, and to substantially miniaturize optical instruments and enhance their performance," Yu explains. "We will realize this ambition by designing light-matter interaction at the deep subwavelength scale and by learning from design 'rules' discovered in nature."

Prof. Yu's team's report, "Keeping cool: Enhanced optical reflection and heat dissipation in silver ants," was published online in *Science* and was also picked up by numerous other media sources including *The New York Times, The Washington Post, Christian Science Monitor, New Scientist, Nature World News, Times Gazette, Wired, iflscience, Benchmark Reporter, The Hoops News, Headlines & Global News, Tech Times, Microscopy & Analysis, University Herald, Neatorama, Pioneer News,* and *Slash Gear.*

Staying Cool: Saharan Silver Ants (continued from page 8)

Yu and Shi collaborated on the project with Rüdiger Wehner, professor at the Brain Research Institute, University of Zürich, Switzerland, and Gary Bernard, electrical engineering professor at the University of Washington, Seattle, who are renowned experts in the study of insect physiology and ecology. The Columbia Engineering team designed and conducted all experimental work, including optical and infrared microscopy and spectroscopy experiments, thermodynamic experiments, and computer simulation and modeling. They are currently working on adapting the engineering lessons learned from the study of Saharan silver ants to create flat optical components, or "metasurfaces," that consist of a planar array of nanophotonic elements and provide designer optical and thermal radiative properties.

Yu and his team plan next to extend their research to other animals and organisms living in extreme environments, trying to learn the strategies these creatures have developed to cope with harsh environmental conditions.

"Animals have evolved diverse strategies to perceive and utilize electromagnetic waves: deep sea fish have eyes that enable them to maneuver and prey in dark waters, butterflies create colors from nanostructures in their wings, honey bees can see and respond to ultraviolet signals, and fireflies use flash communication systems," Yu adds. "Organs evolved for perceiving or controlling electromagnetic waves often surpass analogous man-made devices in both sophistication and efficiency. Understanding and harnessing natural design concepts deepens our knowledge of complex biological systems and inspires ideas for creating novel technologies."

The study was supported by the National Science Foundation under the Electronics, Photonics, and Magnetic Devices program (ECCS-1307948) and Physics of Living Systems program(PHY-1411445), and the Air Force Office of Scientific Research (AFOSR) Multidisciplinary Research Program of the University Research Initiative (MURI) program (FA9550-14-1-0389).

Research was also carried out in part at the Center for Functional Nanomaterials, Brookhaven National Laboratory.

One Step Closer to a Single-Molecule Device

by Holly Evants, originally published by Columbia Engineering News

Under the direction of **Latha Venkataraman**, associate professor of applied physics, researchers have designed a new technique to create a single-molecule diode, and, in doing so, they have developed molecular diodes that perform 50 times better than all prior designs. Venkataraman's group is the first to develop a single-molecule diode that may have real-world technological applications for nanoscale devices. Their paper, "Single-Molecule Diodes with High On-Off Ratios through Environmental Control," was published May 25 in *Nature Nanotechnology*.

"Our new approach created a single-molecule diode that has a high (>250) rectification and a high "on" current (~0.1 micro Amps)," says Venkataraman. "Constructing a device where the active elements are only a single molecule has long been a tantalizing dream in nanoscience. This goal, which has been the 'holy grail' of molecular electronics ever since its inception with Aviram and Ratner's 1974 seminal paper, represents the ultimate in functional miniaturization that can be achieved for an electronic device."

With electronic devices becoming smaller every day, the field of molecular electronics has become ever more critical in solving the problem of further miniaturization, and single molecules represent the limit of miniaturization. The idea of creating a single-molecule diode was suggested by Arieh Aviram and Mark Ratner who theorized in 1974 that a molecule could act as a rectifier, a one-way conductor of electric current. Researchers have since been exploring the charge-transport properties of molecules. They have shown that single-molecules attached to metal electrodes (single-molecule junctions) can be made to act as a variety of circuit elements, including resistors, switches, transistors, and, indeed, diodes. They have learned that it is possible to see quantum mechanical effects, such as interference, manifest in the conductance properties of molecular junctions.

Since a diode acts as an electricity valve, its structure needs to be asymmetric so that electricity flowing in one direction experiences a different environment than electricity flowing in the other direction. In order to develop a single-molecule diode, researchers have simply designed molecules that have asymmetric structures.

"While such asymmetric molecules do indeed display some diode-like properties, they are not effective," explains **Brian Capozzi**, a Ph.D. student working with Venkataraman and lead author of the paper. "A well-designed diode should only allow current to flow in one direction—the 'on' direction—and it should allow a lot of current to flow in that direction. Asymmetric molecular designs have typically suffered from very low current flow in both 'on' and 'off' directions, and the ratio of current flow in the two has typically been low. Ideally, the ratio of 'on' current to 'off' current, the rectification ratio, should be very high."

In order to overcome the issues associated with asymmetric molecular design, Venkataraman and her colleagues—Chemistry Assistant Professor Luis Campos' group at Columbia and Jeffrey Neaton's group at the Molecular Foundry and UC Berkeley—focused on developing an asymmetry in the environment around the molecular junction. They created an environmental asymmetry through a rather simple method—they surrounded the active molecule with an ionic solution and used gold metal electrodes of different sizes to contact the molecule.

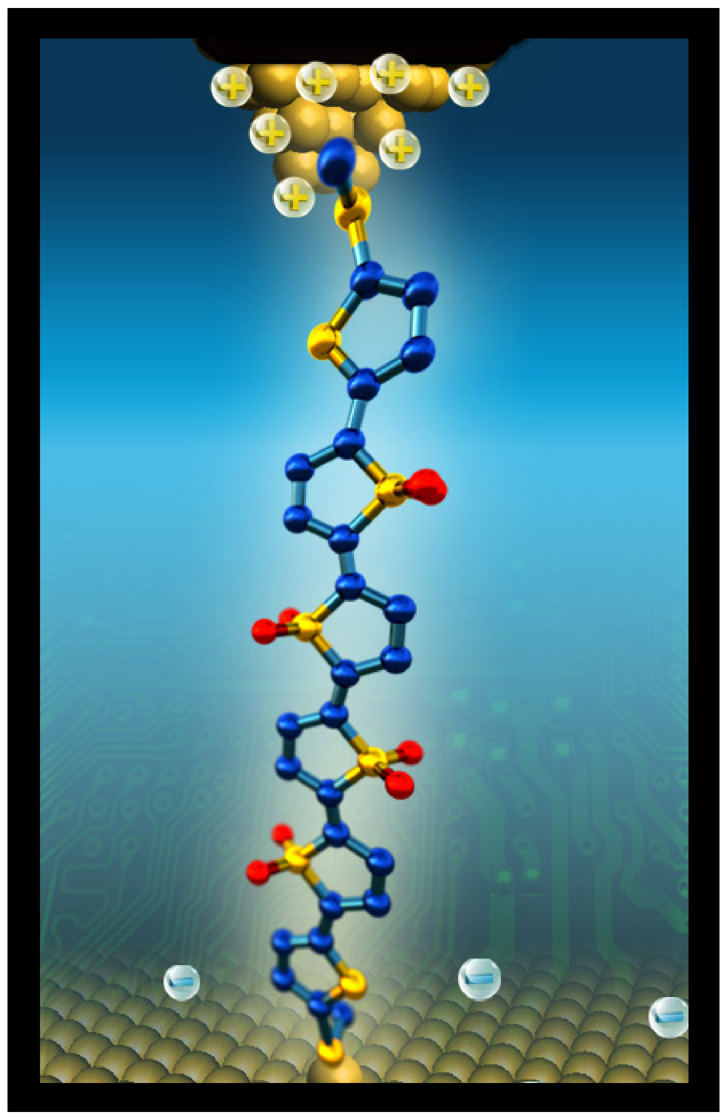
Their results achieved rectification ratios as high as 250:50 times higher than earlier designs. The "on" current flow in their devices can be more than 0.1 microamps, which, Venkataraman notes, is a lot of current to be passing through a single-molecule. And, because this new technique is so easily implemented, it can be applied to all nanoscale devices of all types, including those that are made with graphene electrodes.

"It's amazing to be able to design a molecular circuit, using concepts from chemistry and physics, and have it do something functional," Venkataraman says. "The length scale is so small that quantum mechanical effects are absolutely a crucial aspect of the device. So it is truly a triumph to be able to create something that you will never be able to physically see and that behaves as intended."

She and her team are now working on understanding the fundamental physics behind their discovery, and trying to increase the rectification ratios they observed, using new molecular systems.

The study was funded by the National Science Foundation, the Department of Energy, and the Packard Foundation.

Prof. Venkataraman was recently elected a Fellow of the American Physical Society (APS) for her outstanding contributions to physics. She will be recognized during the APS March Meeting in Baltimore, MD, at the DMP/DCMP Fellows and Awards Reception in March.



Billinge Featured in BNL Newsroom

The following article by Laura Mgrdichian, "Brookhaven Lab Study Explores Nanoscale Structure of Thin Films: Result opens new doors in thin-film research and provides early confirmation of the expected impact of the National Synchrotron Light Source II" was originally published by the BNL Newsroom.

The article highlights the recent research of Simon Billinge, professor of materials science and engineering, who holds a joint appointment at BNL, and his former postdoc, Kristen Jensen.

The world's newest and brightest synchrotron light source—the National Synchrotron Light Source II (NSLS-II) at the U.S. Department of Energy's Brookhaven National Laboratory—has produced one of the first publications resulting from work done during the facility's science commissioning phase.

Published July 7 in the online edition of the *International Union of Crystallography Journal* (a recently launched journal of the International Union of Crystallography), the paper discusses a new way to apply a widely used local-structure analysis tool—known as atomic pair distribution function (PDF) analysis—to x-ray scattering data from thin films, quickly yielding high-quality information on the films' atomic structure. The work creates new avenues for studies of nanocrystalline thin films.

This work shows that NSLS-II—a DOE Office of Science User Facility with ultra-bright, ultra-concentrated x-ray beams—is already proving to be a game-changer in studies of thin films, which play a vital role in a large number of technologies, including computer chips and solar cells.

Thin Film Challenges

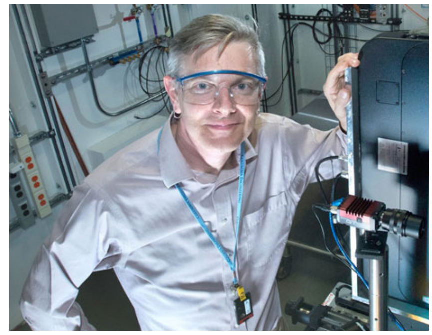
In applications and during experiments, thin films (defined as having thicknesses from just a few to more than 1000 nanometers, or billionths of a meter) are deposited onto a thick base, called a substrate, often made of crystalline wafers of silicon, silicon dioxide, or aluminum oxide. It is extremely difficult to study the structure of materials in this geometry because of the small amount of film material and large amount of substrate. To minimize the scattering of x-rays off the substrate, which tends to obscure the data from the tiny volume of sample, thin film x-ray studies are done using grazing incidence (GI) x-ray experiments.

In GI studies, the x-ray beam grazes the surface of the film such that it reflects off the substrate, allowing the beam to illuminate as much of the film as possible while minimizing penetration through the film into the substrate. However, the small angle of incidence makes GI studies notoriously difficult to carry out and introduces serious complexities in data analysis.

"Grazing-incidence diffraction experiments are tricky for crystalline materials, and have never successfully been done to obtain PDFs from films," said one of the paper's authors, **Simon Billinge**, a physicist with a joint position at Brookhaven and Columbia University's School of Engineering and Applied Science. "The experiments are too painstaking and the data analysis is extremely challenging."

Studying the 'Atomic Neighborhood'

PDF provides local atomic structural information – that is, data for neighborhoods of atoms – by yielding the distances between all pairs of atoms in the sample. These distances appear as peaks in the data. In recent years, PDF has become a standard technique in structural studies of complex materials and can be used for samples that are bulk or nanoscale, amorphous or crystalline.



The approach that Billinge and his colleagues devised leverages the high fluxes of photons coming from NSLS-II, which, together with novel data reduction methods recently developed in his group, creates data suitable for PDF analysis from a thin film. Essentially, it turns the standard GI experiment on its head: the beam is simply sent through the film from the back to the front.

Eric Dooryhee, the lead scientist for the NSLS-II X-Ray Powder Diffraction (XPD) beamline, where the work was done, explained, "The first group of NSLS-II beamlines is now successfully transitioning from technical commissioning, which began back in the fall of 2014 when we first produced x-ray light, towards science commissioning, where we benchmark and test the beamline capabilities on real samples. Extracting the thin film's tiny signal from the substrate's large signal in this normal-incidence geometry is extremely technically difficult. Nonetheless, I told Simon that XPD should be up to the challenge."

Preview of Future Breakthroughs

The group tested thin-film PDF (which they call tfPDF) with both crystalline and amorphous thin films, each about 360 nm thick. The collaboration includes the groups of Bo Iversen at Aarhus University in Denmark and Dave Johnson from the University of Oregon, who prepared the thin films.

The first sample studied was an amorphous iron-antimony film on an amorphous borosilicate substrate mounted perpendicular to the x-ray beam. In order to isolate the contribution from the film, the substrate contribution was first determined by measuring the scattering pattern from a clean substrate. The signal from the film is barely visible in the raw data on top of the large substrate contribution, but could be clearly extracted during data processing. This allowed for a reliable, low-noise PDF that can be modeled successfully to yield the quantitative atomic structure of the film.

The data led to high-quality PDFs for both amorphous and crystalline films—confirmed by comparison to control samples in a standard PDF setup. Based on the success of these first measurements, the Billinge group and the XPD team are now planning future experiments to watch the films crystallize in real time, in the beam.

"The discovery that we can get PDFs from samples in thin-film geometry so readily will revolutionize this area of science," said Kirsten Jensen, a postdoctoral researcher in Billinge's group. "The experiments don't take any specialized equipment or expertise beyond the beamline setup at XPD and are quick, opening the way to time-resolved in-situ studies of changes in film structure under processing as well as spatially resolved studies of nanostructured films in place."

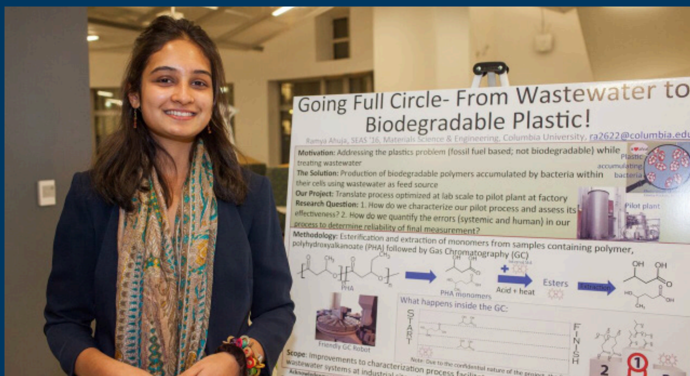
Added Billinge, "This is an exciting new result by itself, but it only gives us a glimpse of the possibilities that NSLS-II will present as the power ramps up over the next few years. This is the tip of the iceberg of what will be possible when NSLS-II is operating at full power."

NSLS-II is supported by the U.S. Department of Energy's Office of Science. Support for this study was also provided by the Villum Foundation Postdoc Program, the Sino-Danish Center, the National Science Foundation, and the Danish National Research Foundation.

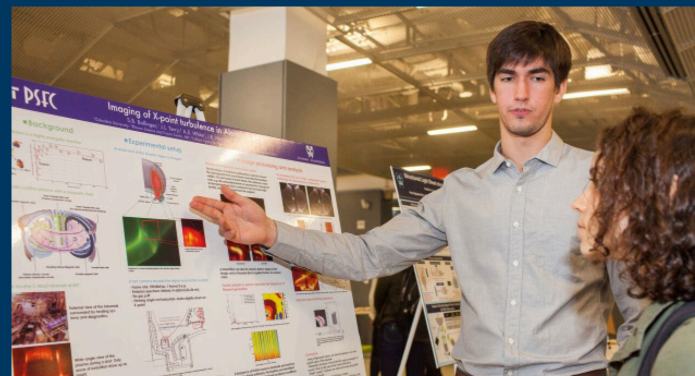
2015 Undergraduate Research Symposium

Five APAM majors, along with 26 other SEAS undergraduate students, presented their research at a symposium on October 14th in the newly redesigned Carlton Commons lounge. The annual event is sponsored by SEAS Undergraduate Student Affairs and Global Programs, the Engineering Student Council, and the Columbia Undergraduate Scholars Program.

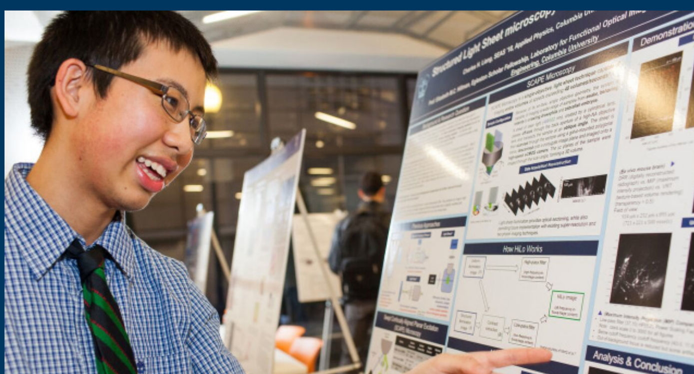
Not pictured: Lucas Zeppetello, SEAS '16, Applied Physics, presented a poster on "Determining the Effectiveness of the Menikoff-Kober Porosity Model on Lunar Crater Formation." Photos by Timothy Lee.



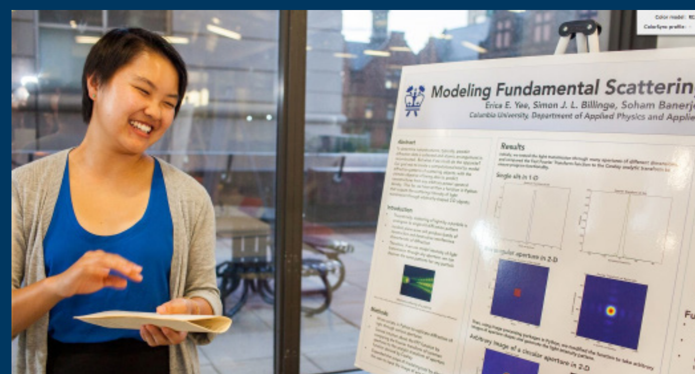
Ramya Ahuja, SEAS '16, Materials Science
"Going Full Circle - From Wastewater to Biodegradable Plastic!"



Sean Ballinger, SEAS '16, Applied Physics
"Imaging of X-point turbulence in Alcator C-Mod"



Charles H. Liang, SEAS '18, Applied Physics
"Structured Light Sheet Microscopy for High-speed, Volumetric Imaging"



Erica Yee, SEAS '17, Materials Science
"Modeling Fundamental Scattering Patterns"

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