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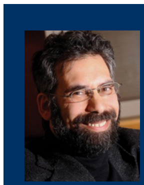
APAM NEWS

School of Engineering & Applied Science, Columbia University
Department of Applied Physics & Applied Mathematics
with Materials Science & Engineering



Message from the Chair

Dear APAM Community,

Greetings and best wishes for the New Year. This newsletter highlights the exceptional activities and accomplishments of our students, faculty, scientists, and alumni throughout the Fall semester. Faculty and students from all three APAM programs—Applied Physics, Material Science, and Applied Mathematics—have been engaged in a wide range of scientific and engineering endeavors. Here, we spotlight innovations in advanced photonics and lasers, new designs for fusion power plants, and a wide range of exciting advances in both hard and soft materials.

This semester also saw an extraordinary list of honors for faculty and researchers in all three programs, emphasizing their leadership roles and the interdisciplinary strengths of our department. Highlights include prestigious fellowships and prizes in Applied Physics, Applied Mathematics, and Material Sciences from the APS, the Materials Research Society, the American Meteorological Society, and others. Congratulations to all of our awardees.

As we prepare for another exciting year, I'm thrilled to welcome several new faculty members to APAM. Prof. Ben Zhu has joined the Plasma Physics/Fusion group and brings extensive expertise in computational Plasma Physics, high-performance computing and AI. And Curtiss Lyman joins the Applied Math group with a focus on the mathematics of quantum materials and condensed matter physics. Both will greatly enrich our community and promise to bring exciting new discoveries and innovations.

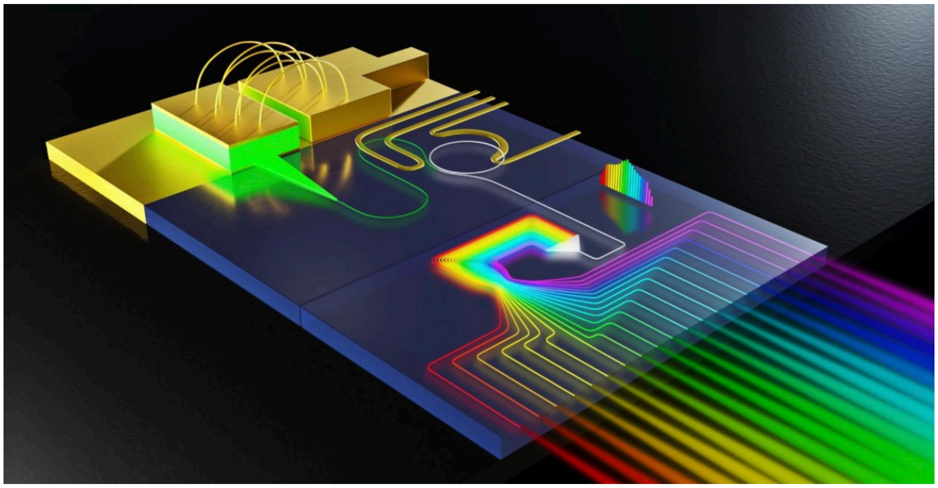
Finally, we warmly congratulate Prof. Michael E. Mauel on his retirement after forty years of dedicated service and his transition to Professor *Emeritus* of Applied Physics. We also congratulate Prof. Simon Billinge, Professor *Emeritus*, on his appointment as Director of the California Nanosystems Institute (CNSI) in the Materials Department at UC Santa Barbara. We thank them both for their invaluable contributions to the department and wish them well in their new endeavors. And they should know they are always welcome in the department—once APAM, always APAM.

I encourage you to explore the full newsletter to learn more about these accomplishments and many others. Together, we are shaping the future of science and engineering. Wishing everyone a year filled with continued achievements, growth, and discovery.

Best,

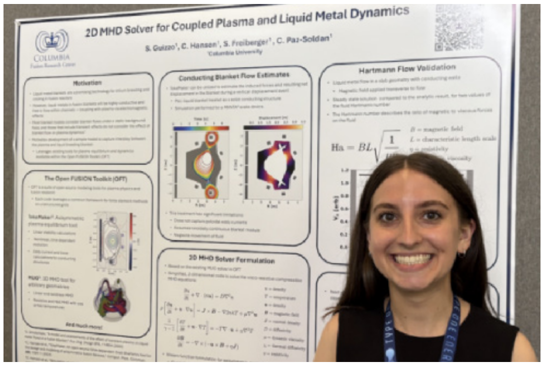
**Marc Spiegelman,
APAM Department Chair**

Cover image: This illustration shows the diffractive element in the high-power microcomb source separating comb lines spectrally. See page for 7 for more details.



STUDENT NEWS

Columbia Students Presented at 2025 Symposium on Fusion Engineering (SOFE) Conference



Sophia Guizzo (above) presented computational work on a magnetohydrodynamic solver for plasma and conducting breeder blanket dynamics

Columbia Fusion Research Center students and faculty attended the 2025 Symposium on Fusion Engineering (SOFE) conference, hosted at MIT from June 23–26. SOFE 2025 brings together researchers, engineers, industry professionals, and students from around the world to advance fusion energy by sharing the latest developments in engineering, materials, plasma science, and technology.

Graduate students **Eliot Felske** and **Chirag Khurana** presented the initial design of the Columbia Tritium Extraction Experiment (CTEX), a novel hydrogenic isotope extraction experiment being developed for fusion fuel cycle R&D. Graduate student **Sophia Guizzo** presented computational work on a magnetohydrodynamic solver for plasma and conducting breeder blanket dynamics, focused on better understanding plasma dynamics when surrounded by conducting tritium breeding blankets in future fusion devices.

Recent undergraduate alumnus and new graduate student **Dylan Schmeling** presented recent developments in the design and construction of the Columbia Stellarator Experiment (CSX), highlighting the in-house fabrication of non-planar, high-temperature superconducting magnets. Undergraduate student **Maxwell Epstein** presented a tokamak control method using Raspberry Pi Pico microcontrollers. Undergraduate alumni **Hope Hersom** and **Pricilla Dua** presented the recent operation and design of the Pellets at Columbia (PAC) experiment, a device focused on the interactions between plasmas and cryogenic fuel pellets.

Professor Carlos Paz-Soldan chaired a workforce development session and participated in a panel for the Women in Fusion luncheon. The contributions to the conference highlight a broadening of research scope for the Columbia Fusion Research Center, expanding further into the realm of fusion technology and engineering.

Afra Ashraf Receives Bakhmeteff Fellowship

Afra Ashraf is a second year PhD student researching how to use climate models to best make decisions under uncertainty. She is working on building a framework to quantify the "value of information" from climate models beginning with the Lorenz system as a simplified model of chaos that captures key features of the climate's unpredictability. Before graduate school, she studied physics at Barnard College, researching atmospheric variability in brown dwarfs and hot exoplanets. In her free time, she enjoys playing chess and baking.

Inaugural Hackathon Hosted by Columbia Fusion Research Center

Originally published by Columbia Fusion Research Center

Columbia Fusion Research Center students, researchers and faculty hosted the 2025 Perturbed Equilibrium Hackathon July 28–30. The concentrated effort of the hackathon laid the foundations for a new, open source Julia code that will reproduce the major functionalities of the Generalized Perturbed Equilibrium Code (GPEC) package with improvements in speed, numerical robustness and flexibility for future expansion of physics capabilities.

The event, organized by Research Scientist **Dr. Nikolas Logan** and hosted by the Fusion Research Center, provided the opportunity for Columbia undergraduate and graduate students to work alongside fusion industry researchers from General Fusion, Brennan Fusion Research and General Atomics to learn and contribute high impact work. Participation from Princeton University and Seoul National University greatly accelerated progress as well, establishing new and strengthening existing collaborations within the 3D magnetohydrodynamics (MHD) tokamak physics community.

Daily scrums included presentations from Dr. Meneghini (General Atomics) on "How to use the Integrated Modelling & Analysis Suite (IMAS) in Julia", Dr. Lyons (General Atomics) on "Best Practices and Speed Optimization in Julia", and Prof. Park on "Next steps: Physics extension priorities". Getting down into the code, Columbia students **Matthew Pharr** and **Rithik Banerjee** led a team to reproduce the capabilities of Dr. Chance's fortran Vacuum code in Julia, students **Jake Halpern** and **Meg Fairborn** worked on the fundamental Euler-Lagrange integration scheme to calculate stability by reproducing the Direct Criterion of Newcomb (DCON) while students **Daniel Burgess** and **Evan Bursch** concentrated on establishing the initial axisymmetric equilibrium representations about which 3D MHD perturbations are assessed.

The code produced by these team efforts lays the foundation for modeling the MHD stability and response to 3D fields of modern day tokamaks as well as future reactors. The event served to efficiently establish a broad developer base for the new premier 3D MHD modeling suite, connecting university students and private industry researchers in what we are sure will prove to be lasting and productive collaborations.

Above & below: Columbia Fusion Research Center students, researchers and faculty hosted the 2025 Perturbed Equilibrium Hackathon July 28–30. Guest speakers included researchers from General Fusion, Brennan Fusion Research, and General Atomics

Columbia University Students, Scientists, and Faculty Present at the 2025 Annual Meeting of the APS Division of Plasma Physics

By Michael Mauel

Columbia University students, scientists, and faculty arrived in Long Beach, CA to present their research results and interact with colleagues at the 67th Annual Meeting of the American Physical Society (APS) Division of Plasma Physics from November 17-21, 2025. Columbia plasma physicists presented over a hundred presentations to an international audience of more than 2,200 participants.

Highlights of the meeting were those invited presentations, representing the most exciting results achieved during the past year. **Matthew Tobin**, doctoral student working with Dr. **Steve Sabbagh** (PhD '90), presented "Avoidance of Disruptions due to Vertical Displacement Events via Novel Real-Time Stability Assessment." Tobin described how fast profile measurements can improve forecaster performance for real-time disruption avoidance while minimizing impacts to tokamak fusion performance. Dr. **Jeff Levesque** (PhD '12) presented "Disruption dynamics during the first operation of a Runaway Electron Mitigation Coil (REMC) on a tokamak," which has been successfully installed and benchmarked on Columbia University's HBT-EP tokamak. Dr. **Antoine Baillod**, working with Prof. **Elizabeth Paul**, lectured about "Design and optimization of the Columbia Stellarator eXperiment," where Baillod presented an example how stellarator physics objectives can be achieved with tight engineering constraints, including the use of non-insulated high-temperature superconducting coils. Prof. **Gerald Navratil** presented "Observation of Burning Plasma Dynamics in DIII-D" and reported on novel experiments in the DIII-D tokamak that reproduced the dynamics that will occur in future burning plasma devices for fusion energy. These experiments uncovered fascinating collective dynamics and established a test-bed for simulating fusion burn dynamics and testing burn control techniques needed for long pulse high fusion gain experiments.

The meeting also included two tutorial presentations targeting a wide audience and inspiring early career scientists. Prof. **Lorenzo Siron**i, Columbia's Department of Astronomy, introduced "Relativistic Magnetic Reconnection in Astrophysical Plasmas," and explained how modern high-performance computation reveals the physics underlying plasma physics near black holes and neutron stars. Prof. **Piero Martin**, from the University of Padova, spoke of the "Fusion history lessons for our times," based on his Columbia University course developed while on his sabbatical visit in Spring 2025 and reminded students that "best of our science and collaboration is needed for the goal of fusion energy."

In keeping with the meeting's goals to promote education and partnerships, the meeting had a special session for undergraduate students and a conference-within-a-conference to provide the APS Division of Plasma Physics community a comprehensive look across a range of private fusion companies to advance the physics and technology for a fusion pilot plant.

In the undergraduate session, **Sonia Sobel** (visiting from Carleton University) presented her research titled "Energy-resolved Detection of Hard X-Rays on the HBT-EP Tokamak." **Amelia Koff** (visiting from Davidson College) presented her work titled "Attainable Plasma Configurations for the Columbia University Tokamak for Education using TokaMaker." From Columbia University, **Beruktawit Gebreamlak** presented "High-Temperature Superconducting Non-Planar Coil Development: From Design to Cryogenic Testing," and **Thomas Wang** presented "Coupling ThinCurr and GPEC to Assess the Stability Implications of Induced Currents in Fusion Devices." **Michael Campagna** (visiting from William and Mary) presented their work "Effect of symmetry breaking on neoclassical flow damping in the Columbia Stellarator eXperiment."

Prof. **Carlos Paz-Soldan**, Dr. **Ian Stewart** (PhD '21), and Prof. Stephanie Diem (from University of Wisconsin), organized a two-day conference featuring all eight fusion companies participating in the U.S. Department of Energy Milestone program and representing public-private investment in fusion energy. The program also included a select number of international participants, and the conference highlights included presentations from Columbia University alumni Dr. **Benjamin Levitt** (PhD '24 and Zap Energy Inc.) and Dr. **Ryan Sweeney** (PhD '17 and Commonwealth Fusion Systems) and from current APAM doctoral student **Sophia Guizzo**.

An important tradition of the APS Annual Meeting of the Division of Plasma Physics is the Columbia University Plasma Physics Group Reunion Dinner. (See photo above) A record number of students, scientists, and alumni celebrated the many contributions, the traditions of learning, and broad avenues of progress launched from Columbia University Plasma Physics.

Image: Alumni, current students, faculty, and researchers attended the 2025 Columbia University Plasma Physics Group Reunion Dinner

Materials Science Undergrad Research News: Current undergraduate, **Lauren Grae** (Mat Sci BS '27), shared, "This past July, I was published in *APL* as a co-author under my P.I., **Prof. Katayun Barmak**. For the past two years as a member of the Barmak lab I helped develop a machine learning program to autonomously trace grain boundaries. I constructed the training and validation for our model by hand tracing hundreds of brightfield TEM scans of aluminum thin films. This data's resulting trained model, which operates on a UNet machine learning architecture to semantically segment its inputs, is compared to an alternative proposed dynamic segmentation method in the paper. My tracings themselves are also included as figures in the publication. "

Patrick, M. J., Field, C. R., Grae, L. H. L., Rickman, J. M., Field, K. G., & Barmak, K. (2025). A comparative analysis of YOLOv8 and U-Net image segmentation approaches for transmission electron micrographs of polycrystalline thin films. APL Machine Learning, 3(3), Article 036105. https://doi.org/10.1063/5.0274266

Katayun Barmak

Barmak Named 2026 MRS Fellow

Katayun Barmak, the Philips Electronics Professor of Applied Physics and Applied Mathematics in the APAM Department, has been named to the 2026 class of Materials Research Society (MRS) Fellows. Barmak was recognized "For outstanding contributions to our understanding of solid state phase transformations and structure evolution of metallic films for electronic and magnetic applications, and for dedicated service to the materials community."

The MRS Fellow ("FMRS") title honors members for exceptional research achievements and significant contributions to advancing materials research globally. Each year, the number of new Fellows is limited to just 0.2% of the society's regular membership, making it a highly selective distinction reserved for those with sustained engagement in MRS activities.

According to the organization, the large number of strong nominations received annually makes the selection process highly competitive, underscoring both the prestige of the program and the excellence within the materials community. The newly elected class of MRS Fellows will be formally recognized at the 2026 MRS Spring Meeting, scheduled for April 26-May 1, 2026, in Honolulu, Hawai'i.

Prof. Barmak probes the nature of materials in order to understand their properties and how to engineer them. Such work aids the development of new and improved materials for engineered systems. She investigates the differences in materials structure at macro-, micro-, and nano-scales and uncovers the impact these differences have on a material's properties and ultimately the performance of engineered systems they are made for. In her work in Columbia Nano Initiative's new Electron Microscopy lab, she studies matter at magnifications not possible with optical microscopes. Her areas of particular interest are materials synthesis, structure and phase transformations.

Barmak obtained her BA (First Class Hons.) in materials science in 1983 and a MA in natural sciences, metallurgy, and materials science in 1987 from the University of Cambridge in England. She earned a SM in metallurgy in 1985 and a PhD in materials science in 1989 from Massachusetts Institute of Technology. She joined Columbia Engineering in 2011 as the Philips Electronics Professor of Applied Physics and Applied Mathematics and Materials Science Engineering and became Director of the Materials Science and Engineering Program in 2013. Previously, she was a professor in the Department of Materials Science and Engineering at Carnegie Mellon University from 1999-2011 and served on the faculty at Lehigh University from 1992-1998, where she also co-directed the Thin Film Laboratory. Prior to her appointment at Lehigh, Barmak spent three years at IBM T.J. Watson Research Center and IBM East Fishkill development laboratory and was a visiting scientist at the IBM T. J. Watson Research Center from 1998-2004.

Gaeta Wins 2026 Arthur L. Schawlow Prize in Laser Science

By Allison Elliott, Originally published by Columbia Engineering

The pioneer in nonlinear photonics has been recognized by the American Physical Society for his groundbreaking work.

Alexander Gaeta

Alexander Gaeta, the David M. Rickey Professor of Applied Physics and Materials Science at Columbia Engineering, has won the American Physical Society's (APS) 2026 Arthur L. Schawlow Prize in Laser Science "for groundbreaking innovations in the fields of quantum and nonlinear optics."

Gaeta's research group focuses on how laser light interacts with matter, particularly how light of one color can interact with material to create new colors. These interactions can help uncover ultrafast processes in physics and enhance communications, computing, and navigation, as well as chemical sensing and security.

"I'm honored to be recognized in this way by the APS and am extremely grateful to all my students and postdocs for their many research contributions over the past 30 years," said Gaeta, who is also a professor of electrical engineering at Columbia. "We continue to be inspired more than ever to continue to push the boundaries of what's possible for nonlinear photonics and laser science and to have impact on fundamental science and engineering."

The Gaeta Group's research spans ultrafast nonlinear optics, nanophotonics, nonlinear propagation in fibers and bulk media, the generation and processing of quantum light fields, and stimulated scattering processes. The team works closely on the development of silicon photonic devices with Eugene Higgins Professor of Electrical Engineering Michal Lipson's group to generate new light frequencies including those that create optical frequency "combs"--discretely spaced colors that can have a wide range of applications from extremely accurate clocks and optical communications to sensing of chemical and biological agents. Gaeta also co-founded Xscape Photonics, Inc. with current CEO Vivek Raghunathan, and fellow Columbia professors Lipson, Charles Batchelor Professor of Electrical Engineering Keren Bergman, and research scientist Yoshi Okawachi. The startup, which focuses on reducing the power consumption of AI data centers using photonic interconnects, raised $44 million in a round of venture funding in 2024.

"We congratulate Alex on this well-deserved recognition of his groundbreaking work in nonlinear photonics," said Shih-Fu Chang, Dean of Columbia Engineering. "The future of high-performance computing, sustainable devices and technologies, and much more, relies on the gains made by pioneering researchers like Alex."

Gaeta received his BS, MS, and PhD in optics from the University of Rochester in Rochester, NY. He joined Columbia Engineering as the David M. Rickey Professor of Applied Physics and Materials Science in 2015. Prior to Columbia, he was the Samuel B. Eckert Professor of Engineering at Cornell University and Chair of the School of Applied and Engineering Physics from 2011 to 2014. He is the founding editor-in-chief of the journal Optica, as well as a Fellow of Optica, American Physical Society (APS), and Institute of Electrical and Electronics Engineers (IEEE), and a Thomson Reuters Highly Cited Researcher. He received the 2019 Charles H. Townes Medal and the 2023 Stephen D. Fantone Distinguished Service Award.

Gaeta Named Vice President of Optica's 2026 Board of Directors: Alexander Gaeta has been elected as the 2026 Optica Vice President of the board of directors. Gaeta has dedicated nearly 40 years to research in quantum and nonlinear photonics. His long-standing relationship with Optica dates back to his days as a graduate student and has encompassed various volunteer roles. Notably, Gaeta was the founding Editor-in-Chief of the journal *Optica*, contributed as a General Co-Chair for the CLEO and Frontiers in Optics + Laser Science conferences, and previously served on the board of directors from 2008 to 2010. Currently, he is the Chair of the Strategic Planning Council.

Renata Wentzcovitch

Wentzcovitch Wins AIRAPT 2025 Bridgman Award

Professor **Renata Wentzcovitch** has been named the recipient of the 2025 Bridgman Award, a distinguished honor presented by the International Association for the Advancement of High Pressure Science and Technology (AIRAPT). This prestigious award, given every two years, recognizes outstanding research achievements in the physics, chemistry, and technology of high-pressure science.

Wentzcovitch, Professor of Materials Science and Applied Physics and Professor of Earth and Environmental Science at Columbia Engineering, is the first woman ever to receive the Bridgman Award since its inception. She was selected in recognition of her transformative contributions to materials simulations at high pressures and temperatures. In the nomination letter, her development of key computational methods that have become essential tools in the field was highlighted:

"Her work represents a new chapter in high-pressure research with the development of the first principles variable cell shape molecular dynamics methods. The impact of her methods was immense, and it was especially valuable for investigating minerals with complex crystal structures at extreme conditions. She has developed a version of this approach that allowed the determination and discovery of complex equilibrium structures at arbitrary pressures. She also pioneered high-temperature quasiharmonic calculations, which opened the door to studying materials at planetary interior conditions. Her contributions make her an internationally recognized leader in materials simulations at extreme conditions."

Prof. Wentzcovitch will officially receive the award, a gold medal, at the 29th AIRAPT Meeting in Matsuyama, Japan. As part of the honor, she will also deliver the Bridgman Lecture, named after Nobel laureate Percy W. Bridgman, a pioneer in high-pressure physics.

This milestone not only recognizes a stellar scientific career but also marks a historic moment for representation in high-pressure science. academic community and its tradition of excellence in research and scholarship.

Kui Ren

Ren Wins 2025 Feng Kang Prize for Computational Mathematics

Kui Ren, Professor of Applied Physics and Applied Mathematics, is the recipient of the 2025 Feng Kang Prize, the most prestigious honor in computational mathematics awarded in China.

Presented biennially by the Institute of Computational Mathematics and Scientific and Engineering Computing of the Chinese Academy of Sciences, the Feng Kang Prize recognizes exceptional achievements by Chinese mathematicians in the broad field of scientific computing. The prize is named after Feng Kang, a pioneering figure in computational mathematics.

He was recognized for his "contributions in computational and theoretical understanding of inverse problems for PDEs and mathematical imaging." The award includes a monetary prize of 20,000 Chinese Yuan and will be presented during the General Assembly of the China Society for Computational Mathematics, held in Changsha from August 17-21, 2025.

Ren received his B. from Nanjing University in China and his PhD in Applied Mathematics from the APAM Department at Columbia University in May 2006. He moved to the University of Chicago as a L.E. Dickson Instructor in 2007 and, in 2008, he joined the faculty at the University of Texas at Austin in the Department of Mathematics and the Oden Institute for Computational Engineering and Sciences where he became a tenured professor. Ren returned to Columbia Engineering in 2018 and joined the Applied Mathematics faculty in the APAM Department. He is also now a member of the Columbia Data Science Institute, the Initiative for Computational Science and Engineering, and the Artificial Intelligence@Columbia.

His research involves several aspects of applied and computational mathematics. His recent work includes theoretical and numerical analysis of inverse problems related to partial differential equations with applications in biomedical imaging; mathematical modeling and computation of the propagation of high-frequency acoustic/electromagnetic waves in random media; numerical and mathematical studies of random graphs and networks; as well as numerical algorithms for kinetic modeling of electrostatics and charge transport in semiconductor devices.

Congratulations to Prof. Ren on this well-deserved recognition of his outstanding contributions to the field of computational mathematics. As both an alumnus and a faculty member of Columbia University, his international recognition highlights the global impact of Columbia's academic community and its tradition of excellence in research and scholarship.

Simon Billinge

Billinge Moves On to New Leadership Role

APAM bids a fond farewell to Professor *Emeritus* **Simon Billinge**, expressing deep gratitude for his many years of service, leadership, and collaboration at Columbia Engineering. Beginning January 2026, he will join the Materials Department at UC Santa Barbara and serve as the new Director of the California Nanosystems Institute (CNSI).

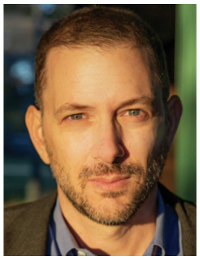
Billinge joined Columbia in 2008 as Professor of Applied Physics, Applied Mathematics, and Materials Science, also holding a Scientist appointment at Brookhaven National Laboratory. Over his distinguished career, he has published more than 350 papers, mentored generations of students, and helped shape the direction of materials science research at Columbia.

A graduate of Oxford University and the University of Pennsylvania, Billinge began his career at Los Alamos National Laboratory before joining the faculty at Michigan State University, where he rose to full professor in 2003. His many honors include the 2025 Gregori Aminoff prize of the Royal Swedish Academy of Sciences and being named a Carnegie Corporation Great Immigrant. He is a Fellow of the APS and the Neutron Scattering Society of America, and serves as Section Editor for *Acta Crystallographica Section A*. Renowned for pioneering advances in atomic pair distribution function (PDF) analysis, Prof. Billinge's research has transformed the study of local structure in disordered and nanoscale materials, with applications spanning energy, catalysis, environmental remediation, and pharmaceuticals.

APAM extends its warmest thanks to Prof. Billinge for his remarkable contributions and wishes him every success in this exciting new role!

Zhang Named RCSA Scialog Fellow: Assistant Professor of Applied Physics, **Xueyue (Sherry) Zhang**, has been named a Scialog Fellow in Quantum Matter and Information by the Research Corporation for Science Advancement (RCSA). The Scialog program brings together early-career researchers across physics, chemistry, materials science, and engineering to foster new collaborations and advance fundamental research in quantum science and technology. Zhang and her lab leverage the unique advantages of qubit-photon interactions to advance the frontiers of quantum science and technology. They focus on introducing new capabilities, such as high levels of connectivity, into superconducting circuits and solid-state spin platforms by integrating these qubits with microwave waveguides and silicon photonics.

Sobel Receives 2026 AMS Joanne Simpson Tropical Meteorology Research Award



Adam Sobel

Adam Sobel has received the 2026 Joanne Simpson Tropical Meteorology Research Award by the American Meteorological Society. This prestigious award honors his groundbreaking contributions to the field of tropical meteorology.

Joanne Simpson (1923-2010) was a pioneer of 20th century atmospheric science who made important contributions to our understanding of cumulus clouds, hurricanes, and the tropical atmospheric circulation. She was the first woman to be awarded a PhD in meteorology in the U.S., and played a critical role in the Tropical Rainfall Measuring Mission, the first satellite mission to measure precipitation from space using radar.

Prof. Sobel was recognized "for advancing understanding of tropical meteorology through transformative approaches, including the weak temperature gradient approximation and moisture-mode theory." His innovative research has significantly deepened scientific insight into the dynamics of tropical weather and climate systems.

As a professor of Applied Physics and Applied Mathematics, and of Earth and Environmental Sciences, Sobel's work focuses on the physics of climate and weather, with a particular emphasis on the tropics. In recent years, his research has increasingly addressed the societal risks posed by extreme weather events and climate change.

Over the past six months, Sobel has delivered a series of invited talks across the U.S. and Europe, including two sponsored named lectures. His engagements began in April with the Ogura Lecture at the University of Illinois, Urbana-Champaign, followed in June by participation in the Columbia University–National Technical University of Athens Workshop on Infrastructure and Energy Sustainability in a Changing Climate in Athens, Greece. He continued his speaking schedule with a July visit to Stony Brook University, the Zurich Insurance Advisory Council for Catastrophes meeting in Zurich, Switzerland, in September, and a talk at ETH Zurich later that month. In October, Sobel presented at the Institute at Brown for Environment and Society in Providence, Rhode Island (video available online). His recent series of talks concluded in November with the Werner A. Baum Lecture at Florida State University in Tallahassee.

To learn more about Sobel and his work, check out his podcast Deep Convection at https://deep-convection.org and visit his new Substack at deepconvection.substack.com.

Wiggins Receives Honorary Doctorate from Niagara University

Niagara University awarded **Chris Wiggins** an Honorary Doctor of Humane Letters degree during its 2025 graduate commencement ceremony. Wiggins, a trailblazer in data science and a thought leader in digital transformation, also delivered the keynote address to the graduating class. Wiggins is widely recognized as one of a select group of data scientists at the forefront of digital innovation in the United States. Since 2014, he has served as Chief Data Scientist at *The New York Times*, while also holding prominent academic roles at Columbia University. He is a founding member of the executive committee of Columbia's Data Science Institute and serves as an associate professor in the APAM Department.

Michele Simoncelli receives the 2025 Charles Haenny Prize in Physics

Prof. Hugo Dil (right), Head of the Prize Committee, presents the 2025 Charles Haenny Prize to Prof. Michele Simoncelli (left)

Michele Simoncelli, Assistant Professor in the APAM Department, is the recipient of the 2025 Charles Haenny Prize for Physics, which recognizes research of "excellent scientific quality and internationally competitive, while also respectful of humanity and its environment". The prize was awarded to Simoncelli in Lausanne, Switzerland, with the following citation: "For the development of novel microscopic and mesoscopic theories of thermal transport that find direct application in a better understanding of heat transport and a reduction of energy consumption in various fields."

The Charles Haenny Prize is awarded by the Institute of Physics of EPFL and the Société Académique Vaudoise (SAV). It is supported by an endowment from Charles Haenny, who demonstrated in 1939 that nuclear fission emits neutrons—a cornerstone for nuclear chain reactions—and later signed with Halban, Joliot, and Kowarski the first French patent on nuclear energy. Very concerned about ethical issues, he warned of nuclear energy's dangers and, after retiring in 1972, established the Groupe Université-Tiers Monde questioning the objectives of scientific research when dealing with development challenges. In 1996, he created the Charles Haenny Prize Fund to recognize discoveries in physics that benefit humanity from the scientific, environmental, and ethical perspectives.

The award recognizes Simoncelli's early-career contributions, which started during his PhD in Nicola Marzari's group at EPFL, then moved to the Theory of Condensed Matter (TCM) group at the University of Cambridge, and now continue in Simoncelli's group at Columbia University. Examples include: First, the development of a unified theory of thermal transport in crystals and glasses, and its application to find hybrid crystal–glass refractory materials that reduce energy consumption and carbon footprint in steel furnaces. Second, the development of a theoretical framework to shed light on how to induce and amplify non-diffusive transport of heat and charge, proposing approaches and proof-of-concept experiments to address overheating in electronic devices. Third, the explanation of how atomic composition and structure influence heat-shield performance in applications from eco-friendly jet engines to nuclear-fusion reactors.

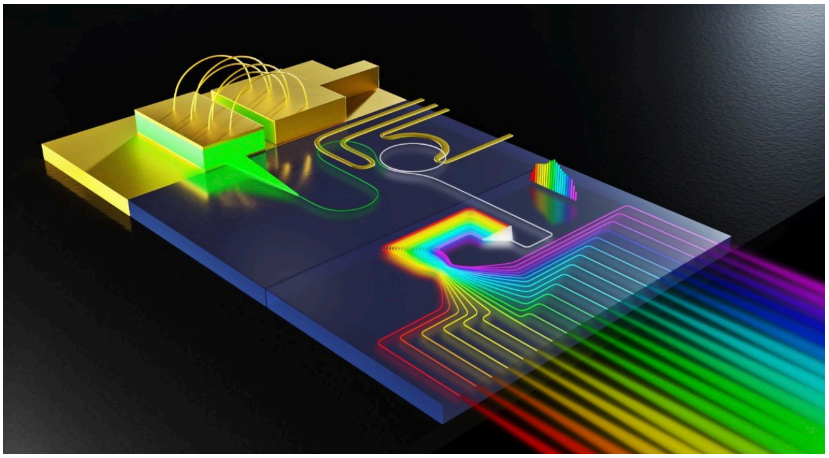
After the ceremony, Simoncelli said: "Haenny's story, his commitment to ethically conscious research, and his vision for how science should address development challenges are truly inspiring. The award—a double-pan balance with atomistic physics on one side and the Earth on the other—exemplifies Haenny's values: combining scientific excellence with social responsibility, integrity, and environmental stewardship. It sits on my desk, serving as daily motivation and inspiration to continually strive in pursuit of Haenny's values."

At Columbia, the Simoncelli group develops the theoretical and computational framework to understand, quantitatively describe, and control quantum transport phenomena in solids and liquids involving, e.g., charge, heat, light and spin, their possible synergies or conflicts, and related macroscopic signatures. The ambition is twofold: first, to evolve current materials for eco-friendly storage and management of information or energy, and second, to innovate on existing applications or even conceive new ones, in collaboration with experimentalists and industry. In Spring 2026, Simoncelli will teach the state-of-the-art AI-based atomistic simulation techniques used by his group in the course 'Atomic Foundation Models' (APPH4990E).

Powerful and Precise Multi-color Lasers Now Fit on a Single Chip

Researchers at Columbia Engineering have developed a compact light source that generates dozens of high-power wavelengths, paving the way for a new generation of data center hardware and portable sensing technologies.

By Grant Currin, Originally published by Columbia Engineering



This schematic illustration shows the diffractive element in the high-power microcomb source separating comb lines spectrally.

A few years ago, researchers in **Michal Lipson**'s lab noticed something remarkable.

They were working on a project to improve LiDAR, a technology that uses lightwaves to measure distance. The lab was designing high-power chips that could produce brighter beams of light.

"As we sent more and more power through the chip, we noticed that it was creating what we call a frequency comb," says Andres Gil-Molina, a former postdoctoral researcher in Lipson's lab.

A frequency comb is a special type of light that contains many colors lined up next to each other in an orderly pattern, kind of like a rainbow. Dozens of colors — or frequencies of light — shine brightly, while the gaps between them remain dark. When you look at a frequency comb on a spectrogram, these bright frequencies appear as spikes, or teeth on a comb. This offers the tremendous opportunity of sending dozens of streams of data simultaneously. Because the different colors of light don't interfere with each other, each tooth acts as its own channel.

Today, creating a powerful frequency comb requires large and expensive lasers and amplifiers. In their new paper in *Nature Photonics*, Lipson, Eugene Higgins Professor of Electrical Engineering and professor of Applied Physics, and her collaborators show how to do the same thing on a single chip.

"Data centers have created tremendous demand for powerful and efficient sources of light that contain many wavelengths," says Gil-Molina, who is now a principal engineer at Xscape Photonics. "The technology we've developed takes a very powerful laser and turns it into dozens of clean, high-power channels on a chip. That means you can replace racks of individual lasers with one compact device, cutting cost, saving space, and opening the door to much faster, more energy-efficient systems."

"This research marks another milestone in our mission to advance silicon photonics," Lipson said. "As this technology becomes increasingly central to critical infrastructure and our daily lives, this type of progress is essential to ensuring that data centers are as efficient as possible."

Cleaning up messy light: The breakthrough started with a simple question: What's the most powerful laser we can put on a chip?

The team chose a type called a multimode laser diode, which is used widely in applications like medical devices and laser cutting tools. These lasers can produce enormous amounts of light, but the beam is "messy," which makes it hard to use for precise applications.

Integrating such a laser into a silicon photonics chip, where the light pathways are just a few microns — even hundreds of nanometers — wide, required careful engineering.

"We used something called a locking mechanism to purify this powerful but very noisy source of light," Gil-Molina says. The method relies on silicon photonics to reshape and clean up the laser's output, producing a much cleaner, more stable beam, a property scientists call high coherence.

Once the light is purified, the chip's nonlinear optical properties take over, splitting that single powerful beam into dozens of evenly spaced colors, a defining feature of a frequency comb. The result is a compact, high-efficiency light source that combines the raw power of an industrial laser with the precision and stability needed for advanced communications and sensing.

The paper's co-authors, Gaeta (left) and Lipson, pictured in the Gaeta lab at Columbia University. Credit: Columbia Engineering

Why it matters now: The timing for this breakthrough is no accident. With the explosive growth of artificial intelligence, the infrastructure inside data centers is straining to move information fast enough, for example, between processors and memory. State-of-the-art data centers are already using fiber optic links to transport data, but most of these still rely on single-wavelength lasers.

Frequency combs change that. Instead of one beam carrying one data stream, dozens of beams can run in parallel through the same fiber. That's the principle behind wavelength-division multiplexing (WDM), the technology that turned the internet into a global high-speed network in the late 1990s.

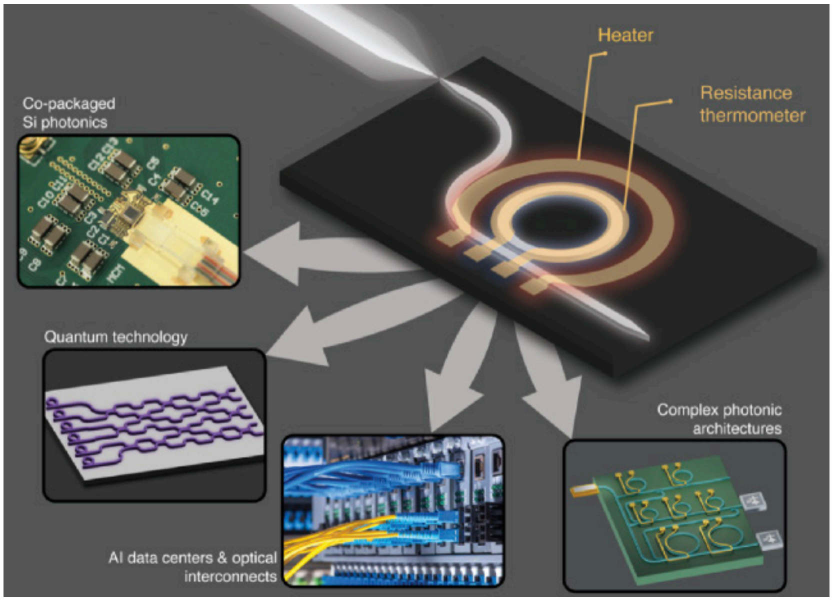
By making high-power, multi-wavelength combs small enough to fit directly on a chip, Lipson's team has made it possible to bring this capability into the most compact, cost-sensitive parts of modern computing systems. Beyond data centers, the same chips could enable portable spectrometers, ultra-precise optical clocks, compact quantum devices, and even advanced LiDAR systems.

"This is about bringing lab-grade light sources into real-world devices," says Gil-Molina. "If you can make them powerful, efficient, and small enough, you can put them almost anywhere." **Read more: Gil-Molina, A., Antman, Y., Westreich, O. et al. High-power electrically pumped microcombs. *Nat. Photon*. 19, 1270–1274 (2025). https://doi.org/10.1038/s41566-025-01769-z**

Columbia Researchers Take the Temperature of Integrated Photonics

A thin resistor routinely used in photonic devices can also act as a thermometer—a simple feature that could help integrated photonics reach its full potential.

By Ellen Neff, Originally published by Columbia Engineering



A conceptual illustration of a microresonator stabilized using an integrated platinum resistance thermometer, and its potential applications. Credit: Sai Kanth Dacha. [Image for data center sourced from Adobe Stock Images (user Xiaoliangge, image 100999003). Picture of co-packaged device courtesy of Kaylx Jang]

Integrated photonics has become a multi-billion-dollar industry, but it is feeling the heat—literally.

An increasingly important component in data centers, photonic devices move and process data using light instead of electricity. The physical nature of light gives this approach several advantages, including higher bandwidth and lower latency. One limitation on even wider adoption has been the hardware's sensitivity to temperature. If photonic devices become a little too hot or a little too cold, their exquisitely tuned photonic properties can be disrupted. Today's state-of-the-art computing facilities prevent that problem with large electronic temperature sensors.

But, it turns out, a thermometer has been part of photonic chips all along.

In a new paper published in *Nature Photonics*, researchers at Columbia Engineering have discovered that the thin-film metallic resistor routinely used to thermally tune photonic devices to the desired resonance frequency can also measure temperature. That simple, intrinsic detail may eliminate the need for bulky and costly external temperature sensors and help integrated photonics reach its full potential.

"One of the key challenges for the broad adoption of silicon photonics in many applications is mitigating the high sensitivity of photonic devices to thermal variations. The technology we have developed here offers a straightforward approach that is foundry compatible and may find near-term applications in large-scale photonic integrated circuits for data communications and quantum information processing," said **Alexander Gaeta**, David M. Rickey Professor of Applied Physics and Materials Science and professor of electrical engineering at Columbia Engineering.

Finding a built-in solution

When researchers and engineers shrunk electronics down to nanometer scales, it changed the world. Scientists studying photonics hope to do the same: light moves faster than electrons and can carry more information while consuming less energy. But as powerful as light is, the photons that make it up are fragile. Tiny changes in temperature can throw light out of phase and change the resonance frequency of the photonic structure.

Changes in ambient temperature can disrupt photonics, as can the presence of co-packaged electrical circuits. Electrical circuits are notorious for generating heat—that's part of why laptops and phones get hot and why data centers consume so much energy in the form of air conditioning—but combining electrical and photonic circuits on the same chip is a major goal of the integrated photonics industry.

It is possible to keep track of a photonic chip's temperature, but it's been a complicated process that required external equipment—an impediment to shrinking photonic devices down to similar sizes as the electronic chips that underlie so many of today's technologies.

In a step toward overcoming that hurdle, researchers at Columbia found a new use for a component that is already common in many integrated photonic devices. For over a decade, many in the field have been incorporating a thin film of platinum into their hardware. The platinum acts as a resistor: controlling the voltage applied to the resistor changes the resonance frequency (i.e., the color of light resonant with the photonic structure). Platinum has also long been used, in its bulk form, as a temperature sensor in some of the most extreme environments, like the surface of Mars and the inside of nuclear reactors.

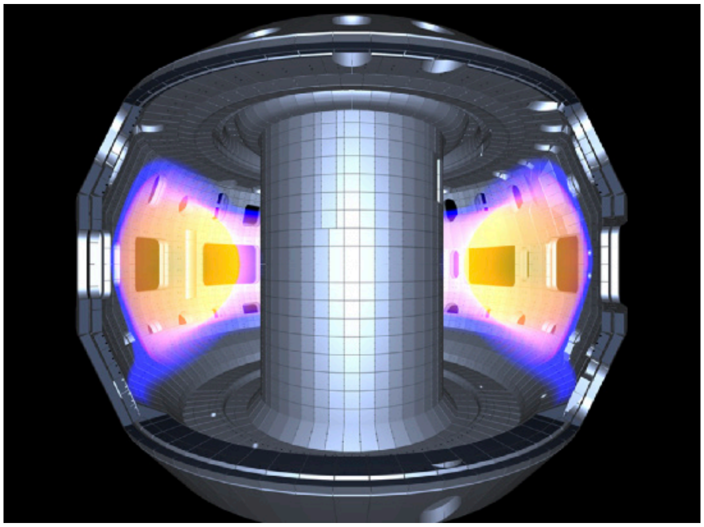
A few years ago, when **Sai Kanth Dacha** joined Gaeta's lab as a postdoctoral research scientist, he made the connection between these apparently unconnected uses for this material.

"One day, we changed the heat source on one of our chips and decided to observe the resistance of the platinum," explained Dacha, who is the lead author on the work. "It changed—a lot."

The platinum connection

Most bulk resistors are Ohmic, with a straight-line relationship between current and voltage over a large range of voltages. The thin-film Platinum resistor used in this work is not. "Its behavior mirrors that of a tungsten filament lamp," explained Dacha, a well-known example of a thin film of metal that exhibits non-Ohmic behavior. "Eventually, tungsten filaments heat up so much that their properties change—that's why they glow."

Dacha and his colleagues discovered that the integrated Platinum resistors follow a similar voltage-current curve, which they realized hinted at a strong temperature dependence of resistance and the ability to serve as a temperature readout. "It's actually very simple. I'm surprised no one has seen it before," Dacha said. "We can now directly measure temperature in real time and stabilize as needed." **(Continued on the following page)**



Negative triangularity plasma produced in the DIII-D tokamak during an experimental campaign dedicated to exploring this innovative scenario. Image courtesy of Lawrence Livermore National Laboratory

Inverted Plasma Shape Shows Promise for Future Fusion Power Plant Design

Negative triangularity exhibits high core fusion performance & good power handling, pointing to a compelling approach for future fusion pilot plants.

Originally published by Fusion Energy Sciences

The Science: Tokamak devices magnetically bottle plasma for fusion, which scientists are working to harness as a new energy source. To maximize a tokamak's power output, plasma pressure, current, and density must all be high at the same time. Tokamaks must be able to confine the plasma while limiting how much heat reaches the interior walls of the device. Scientists at the DIII-D National Fusion Facility are exploring a new approach to tokamak operation called negative triangularity. In this method, the plasma is in an inverted "D" shape with the curve pointing to the inner wall. Recent results show that negative triangularity can produce stable plasmas that exceed the conditions required for future fusion power plants. These findings indicate that this approach has promise for the design of future fusion power plants that could produce electricity and/or heat.

The Impact: The results of these studies surprised the fusion community. The fact that the device reached plasma stability while also achieving high density, current, and pressure with high confinement is promising. Researchers thought it would actually be less stable than comparative approaches. These findings suggest a potential innovative design path for future plants. The results also indicate that negative triangularity may solve the core-edge integration issue. This is the question of how to keep the edge of the plasma cool while maintaining a hot core. This problem is a key challenge for fusion power plant operation. The conditions observed in this study exceeded the predicted needs for fusion pilot plants. These observations strongly support further investigation into this unique approach to tokamak operation.

Summary: Scientists continue to address science and technology challenges for tokamak-based fusion energy production. In 2023, the DIII-D National Fusion Facility, a Department of Energy Office of Science User Facility, completed a dedicated experimental campaign focused on assessing operation with a negative triangularity plasma shape. The results reported here are the first in a series of publications on the promising potential of negative triangularity for fusion power.

Two key areas of effort along the path to fusion commercialization are achieving high core performance and good power handling. Researchers predict that the needed core performance requires high plasma current, pressure, and density, all of which can be negatively affected by plasma instabilities. Although the research community expected negative triangularity to be less stable than conventional triangularity, research at the DIII-D National Fusion Facility found surprisingly low levels of instability with simultaneous achievement of high pressure, density, and current during negative triangularity operation. Researchers observed the confinement to be very good under these conditions. Additionally, the necessary power handling for fusion pilot plants will require dissipative divertor conditions that reduce heat flux and electron temperature at the interior walls to minimize device damage over time. For the first time, negative triangularity plasmas achieved high confinement with divertor detachment and an instability-free edge, suggesting a solution for core-edge integration. Researchers are investigating divertor detachment in negative triangularity plasmas and its dependence on power and current using state-of-the-art simulation tools to confidently extrapolate to future design points. These features collectively indicate the promising potential of negative triangularity and support further investigation of this regime for development as a fusion pilot plant design.

Video - Quantum at Columbia: 100 Years On

A century ago, European physicists developed the theory of quantum mechanics—a momentous occasion marked in 2025 as the International Year of Quantum Science and Technology by the United Nations. Quantum mechanics changed the way scientists think about the world we live in, and its counterintuitive rules continue to ripple into a new century. Columbia physicist I.I. Rabi was instrumental in bringing quantum mechanics to campus. Today, collaborative teams of Columbia engineers, physicists, and chemists continue a quantum legacy decades in the making. Watch how quantum got its start at Columbia and how it influences research today.

Columbia Researchers Take the Temperature of Integrated Photonics (continued from the previous page)

In the paper, the team documented the usefulness of this integrated thermometer as a means to stabilize microscopic photonic cavities. By frequency locking a commercial distributed feedback (DFB) laser to such a cavity, they demonstrated a crucial component of optical communication networks that require compact light sources. They were able to keep the laser within a picometer of the desired wavelength for over two days. "That's better performance than some commercial telecommunication systems. And the beauty of it is that the cavity stabilization requires no photodetection at all," said Dacha.

They note the thermometer is platform-agnostic and should work with different materials and chip configurations. For example, it should help stabilize silicon ring modulators, a highly efficient method for switching light on and off that was pioneered by co-author Michal Lipson, Eugene Higgins Professor of Electrical Engineering and Professor of Applied Physics, and is now used in commercial applications by companies such as NVIDIA. Keeping tabs on temperature is also critical for emerging quantum devices, which require extremely low temperatures; an integrated thermometer may help shrink the size of the necessary cryochambers.

"So far, thermal issues have been a major unsolved problem in the field. We hope our work is one of the first big steps to realizing large-scale photonic devices capable of operating in real-world environments in a resource-efficient way," said Dacha.

Dacha, S.K., Zhao, Y., McNulty, K.J., Bhatt, G.R., Lipson, M. & Gaeta, A. Frequency-stable nanophotonic microcavities via integrated thermometry. *Nat. Photonics* (2025). https://doi.org/10.1038/s41566-025-01789-9

The Race to Fusion Energy

@Columbia Engineering Climate Week NYC 2025

Carlos Paz-Soldan

The **Columbia Fusion Research Center**, together with the **Fusion Industry Association**, recently brought together a diverse group of experts, policymakers, and industry leaders to discuss how cooperation and competition define the current global fusion landscape. Established earlier this year, the center leverages Columbia's long-standing tradition of fusion research and aims to be a significant force in turning fusion into a practical energy source.

On September 24, 2025, an event called "The Race to Fusion Energy" was held at International House as part of Climate Week at Columbia Engineering 2025. This afternoon session explored the role of international collaboration in advancing the global effort to commercialize fusion energy, a highly anticipated technology with the potential to provide nearly limitless, carbon-free power.

A Global Conversation on the Future of Fusion

The program opened with remarks from George Deodatis, Vice Dean for Research at Columbia Engineering, and **Carlos Paz-Soldan**, Associate Professor of Applied Physics and Applied Mathematics and Founding Director of the Columbia Fusion Research Center, along with Andrew Holland, CEO of the Fusion Industry Association. Dr. Najat Mokhtar, Deputy Director General and Head of the Department of Nuclear Sciences and Applications at the International Atomic Energy Agency (IAEA), also presented.

Fireside Chats and Industry Insights

The event also included a fireside chat between Marco Margheri, Head of U.S. Relations and Chairman of New Energies U.S. at Eni, and Andrew Holland of the FIA. The chat was then followed by an international fusion industry panel, moderated by Holland, featuring Jennifer Ganten, Chief Global Affairs Officer, Commonwealth Fusion Systems, Warrick Matthews, CEO, Tokamak Energy, Francesco Sciortino, Co-Founder & CEO, Proxima Fusion, and Greg Twinney, CEO, General Fusion.

Networking, Reception, and Lab Tours

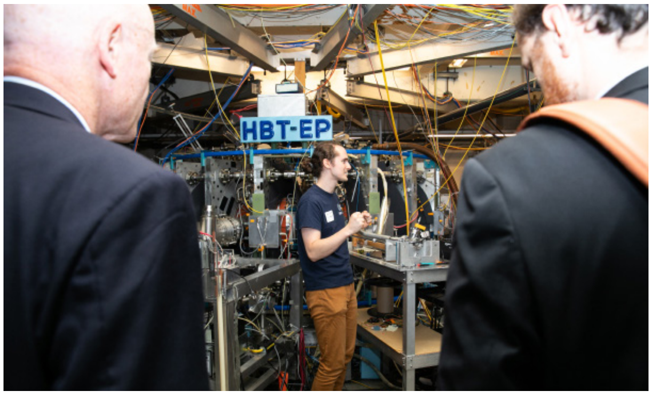
Following the panel discussions, attendees gathered for a reception in the Hall of History and participated in guided tours of the Columbia Fusion Research Center, where faculty and students showcased cutting-edge experiments advancing plasma physics and fusion confinement research.

"This is one of the first university centers focused on supporting the fusion industry's growth," said Carlos Paz-Soldan, associate professor of applied physics and applied mathematics and director of the Fusion Research Center. "We're not just pursuing academic milestones — we're working closely with companies to accelerate their progress and guide our academic work."

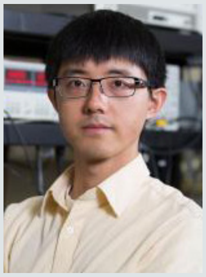
The event was made possible partially through the generous support of Commonwealth Fusion Systems, Proxima Fusion, General Fusion, and Tokamak Energy.

(Above) A diverse group of experts, policymakers, and industry leaders to discuss how cooperation and competition define the current global fusion landscape

(Above) The event was held at International House as part of Climate Week at Columbia Engineering 2025



(Above) APAM graduate students led a tour of the Columbia Fusion Research Center



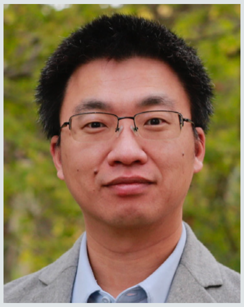
Yu Featured in Harvard University News

Nanfang Yu, an associate professor of applied physics, was recently highlighted in a Harvard University News article titled "Hidden in plain sight: A century-old museum specimen turns out to be a landmark in evolution." The piece recounts the rediscovery of a fossil long misidentified as a caterpillar, worm, or millipede, now recognized as Palaeocampa anthrax, the earliest known nonmarine lobopodian. Advanced imaging and FTIR spectroscopy by Yu revealed nearly 1,000 toxin-secreting spines, showing how this tiny freshwater creature defended itself and filling a key gap in early animal evolution. The find confirms that France's Montceau-les-Mines site was nonmarine and broadens our understanding of lobopodian diversity. It also highlights the value of revisiting century-old museum collections, where overlooked specimens—like this one, "literally hiding in plain sight" near Stephen Jay Gould's office—can still yield major evolutionary insights.

Knecht, R.J., McCall, C.R.A., Tsai, CC. et al. Palaeocampa anthrax, an armored freshwater lobopodian with chemical defenses from the Carboniferous. *Commun Biol* 8, 1080 (2025). https://doi.org/10.1038/s42003-025-08483-0

New APAM Faculty Members

APAM is pleased to announce the appointment of two new faculty members. We're thrilled to welcome them to our community and look forward to the impact their expertise and research will bring to the department and beyond.



Ben Zhu

Ben Zhu has joined the APAM department as an Assistant Professor of Applied Physics and Applied Mathematics.

Ben Zhu is a theoretical and computational physicist whose research advances our understanding of fusion and laboratory plasmas. His work focuses on magnetic fusion energy (MFE), with particular emphasis on the nonlinear dynamics of magnetized plasmas across multiple spatial and temporal scales. Zhu investigates phenomena such as plasma instabilities, turbulence, transport barriers, bifurcation processes, and particle and heat exhaust in magnetic confinement devices including tokamaks and stellarators. His research integrates both fluid and kinetic theories, employing high-performance computing and advanced numerical methods to model boundary plasma behavior. Zhu is also at the forefront of applying machine learning and artificial intelligence (ML/AI) to plasma physics, developing neural-network-based kinetic closures and surrogate models for tokamak control and predictive modeling.

Zhu received his BS degree in Applied Physics from the University of Science and Technology of China in 2008, his MS degree in Applied Science from the University of California, Davis in 2009, and his PhD in Physics from Dartmouth College in 2017. His doctoral work explored the interplay between turbulence, transport, and spontaneously generated shear flows at the tokamak edge using global three-dimensional two-fluid electromagnetic simulation. After serving as a research associate at Dartmouth College, he joined Lawrence Livermore National Laboratory (LLNL) in 2018 and became a staff scientist in 2020. He was honored with the U.S. Department of Energy (DOE) Early Career Award in 2024.

Curtiss Lyman

Curtiss Lyman has joined the APAM department as a limited-term Assistant Professor of Applied Physics and Applied Mathematics.

Lyman's research focuses on partial differential equations arising from condensed matter physics and the study of quantum materials. Recently, he has been interested in how Floquet-Bloch theory, spectral theory, and representation theory can be applied to reduce the dimension of such problems when symmetries are involved, and the impact this has on the physical behavior of the corresponding waves.

Lyman teaches APMA 2000E: Multivariable Calculus, which he is very excited about, as an analogous class is what initially convinced him to pursue a career in mathematics. Outside of academia, Lyman loves board games, sailing, and his chocolate lab Zelda, and would love to talk to you about them.

Columbia Connected to New York Quantum Network

Entangled photons will soon make their way instantaneously across the growing network, which now extends 70 miles from Long Island to Morningside Heights.

By Ellen Neff, Originally published by Columbia Engineering

Under perfect traffic conditions, the drive from Columbia University in Manhattan to Brookhaven National Laboratory on Long Island will take over an hour; try to leave during a Friday rush hour, and the time can easily double (or even triple). But as of today, information traveling to and from these research institutions will soon be instantaneous, with Columbia's connection to the quantum network that is growing across New York.

The SCY-QNet, funded in part by the National Science Foundation National Quantum Virtual Laboratory (NQVL) program, will connect 10 locations, including Stony Brook University, Columbia, Yale, Brookhaven, and Qunnect, a quantum networking start-up. The effort is directed by Professor Eden Figueroa at Stony Brook and includes research teams across the New York metro area that have been tapping into "dark fibers" to build one of the largest quantum networks in the United States. The second phase of this grant, providing $4M in funding, was recently awarded to a team composed of Columbia, Yale, and Stony-Brook researchers.

"This state-of-the-art quantum network connecting regional partners is a physical manifestation of a long-standing and growing intellectual collaboration among our institutions," said Jeannette Wing, executive vice president for research and professor of computer science at Columbia. "Our collective strengths in science and engineering are pushing the frontiers in quantum information science, transforming vision to reality. I can't wait to see what we will light up with entangled photons as a means to communicate."

Columbia Connected to New York Quantum Network: Follow the growing quantum network, which stretches via fibers from Brookhaven National Laboratory and Stony Brook University on Long Island into Columbia in Manhattan and, via lasers over Long Island Sound, to Yale University in Connecticut.

On September 30, Columbia's hookup was completed: photons, the quantum particles that make up light, can now be distributed and detected from Long Island to Morningside Heights. Entangled photons, one of the cornerstones of quantum science that enable instant information transfer, will soon follow.

The network will link different quantum devices, including quantum sensors and computers, that are under development at the partner institutions into a nascent quantum internet. At Columbia, it now reaches three labs: those of Gil Zussman, Sebastian Will, and Alexander Gaeta:

The Glue: Gil Zussman, Kenneth Brayer Professor of Electrical Engineering, provided access to the optical fibers needed to transport entangled photons; these fibers were originally deployed for the NSF COSMOS testbed. Seed funding from Columbia Engineering and the Data Science Institute allowed the team to expand the network to Qunnect in Brooklyn. An expert in classical networking and communications, Zussman will also help develop new protocols and standards to efficiently send information along the quantum network.

The Device: Sebastian Will, associate professor of physics and co-PI on the NQVL grant, is developing quantum devices that will send and receive information via the entangled photons transmitted along the network. His lab has been pioneering techniques to trap individual atoms into arrays that can serve as quantum bits, or qubits—a rapidly evolving approach to quantum computing, one of the goals of the NQVL collaboration.

The Translators: Alex Gaeta, David M. Rickey Professor of Applied Physics and Materials Science and professor of electrical engineering along with Michal Lipson, Eugene Higgins Professor of Electrical Engineering and professor of applied physics (and a co-PI on the NQVL grant), will make sure the devices at the network's nodes, like Will's atomic arrays, can "talk" with the entangled photons, which will be transmitted along the network's fibers at a different wavelength than the devices can understand. Experts in quantum optics, Gaeta and Lipson have created quantum frequency converters that can change the wavelength of photons without breaking the entangled states that are essential to the network.

"At Columbia, we are combining our expertise in networks, optics and photonics, and atomic physics to tackle open questions in quantum networking," said Will. "Now the fun can really begin."

Consider the Chemistry of Your Quantum Materials, Say Researchers at Columbia

Atomic orbitals, not just crystal lattices, can yield frustrated materials with quantum results

By Ellen Neff, Originally published by Columbia Quantum Initiative

Chemistry and physics are combining forces at Columbia, and it's leaving everyone frustrated—in a good way. New work, published in *Nature Physics*, describes a new two-dimensional material capable of complex quantum behaviors that arise from its underlying chemistry, rather than its atomic structure.

Aravind Devarakonda

"It's a classic Columbia story—multiple groups in physics and chemistry came together to work on this new material, and we found exciting new results about how electrons move," said Professor **Aravind Devarakonda**, an applied physicist at Columbia Engineering.

The material, Pd_5AlI_2, exhibits what's known as frustration of electron motion. It's metallic, air-stable, and can be peeled into atom-thin layers, and it represents a simple new starting point in the search for flat bands. These are unique electronic structures that could one day lead to new quantum technologies like better superconductors, rare-earth-free room-temperature magnets, and more.

A New Way of Thinking About Frustration

Many quantum phenomena, like superconductivity and unique forms of magnetism, arise when electrons behave in ways that contradict the laws of classical physics, which declare that these elementary particles repel each other. But there are circumstances in which electrons can be forced to pair up. One means is by introducing frustration.

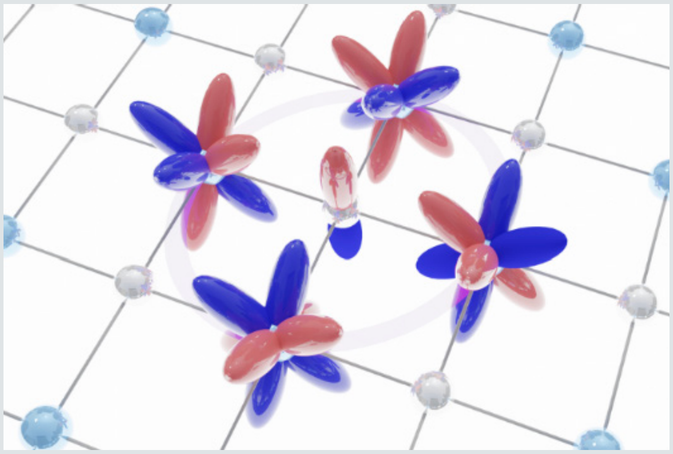
Frustration occurs when the electrons in a material can't find a stable place to settle with respect to each other's energies. To date, this has been due to geometry: crystals made up of triangles or squares create a physical conflict between electrons and trap them together. Et voila, collective quantum behaviors can manifest…at least in theory; materials with frustrated geometries are rare.

Pd_5AlI_2 brings frustration into the mix by way of its chemistry, rather than its crystal structure alone. "We've found an entirely new way to think about frustration, one that combines how chemists think about chemical bonds with how physicists think about crystal lattices," said Columbia chemist Xavier Roy, whose lab made the new metal.

At a glance, Pd_5AlI_2 's lattice looked pretty straightforward, said Devarakonda, who led the work as a Simons Fellow working with Roy and Columbia physicist Cory Dean. Two members of Roy's group, graduate student Christie Koay (now a postdoctoral researcher at Princeton Chemistry) and postdoctoral researcher Daniel Chica, created it for Dean, who was looking for an air-stable metal that could be peeled into atom-thin layers.

During preliminary measurements, Devarakonda recognized a curious electronic feature that is characteristic of a geometrically frustrated structure called a Lieb lattice. Lieb lattices are made up of squares—and their unusual behavior had yet to be studied outside of theoretical models.

Devarakonda showed the data to theoretical physicist Raquel Queiroz, who made the connection between his observation and Pd5AlI2's chemistry: its orbitals, a fundamental concept in chemistry that determines where an electron can roam around its originating atom, combine into a checkerboard pattern that mimics the geometry of the Lieb lattice, but now, in a real material.



Atomic orbitals (red & blue), which determine how far electrons can move around their originating atom in a material, can trap those electrons in place—a new source of frustration that researchers can now tap to create quantum behaviors. Credit: Aravind Devarakonda

"That was our Eureka moment," said Devarakonda. "The lattice may be simple, but it's because of the orbitals that it becomes so interesting."

The signal that Devarakonda observed was a coveted electronic flat band. Flat bands are electronic structures that force electrons to all share the same energy, an inherently unstable position that can give rise to unusual quantum behaviors, like superconductivity.

Towards a Frustrated Future

The team continues to probe and prod Pd5AlI2 and similar frustrated materials—Devarakonda, for example, is literally pulling on samples to introduce strain—in efforts to coax out and ultimately control these behaviors. They are excited by the prospects of this new source of frustration.

As a layered crystal, they successfully peeled it down to a single atomic layer in the current publication; this raises the possibility of combining it with other 2D materials to create entirely new kinds of physics, a focus of Dean's lab. The fact that Pd_5AlI_2 is metallic, one of the first to stably exist while so very thin, also means that he will be able to shrink the stacked structures he creates even further.

Devarakonda also points to potential applications, like creating new quantum sensors and high-temperature magnets. Because the electrons are held in place, it may be possible to record their properties, like the direction they are spinning, to sense changes in their environment. At a larger scale, most magnets found in, for example, electric motors or wind turbines, require rare-earth elements; insights from Pd5AlI2 could help reduce reliance on increasingly difficult and expensive materials.

However, Pd_5AlI_2 isn't exactly cheap. So the team plans to incorporate AI techniques to more rapidly identify crystals that might have orbital frustration hiding within their chemical bonds.

"The possibility of frustrated hopping from orbitals was articulated theoretically, but now we have a concrete example. We're now trying to see what other combinations of elements can come together to frustrate electrons," said Devarakonda. "There are so many models that people have come up with over the decades, but now we can use our newfound insights about lattices and orbitals to chase them from a different angle."

Aravind Devarakonda, Christie Koay, Daniel Chica, et al. Frustrated electron hopping from the orbital configuration in a two-dimensional lattice. Nature Physics (2025). DOI: 10.1038/s41567-025-02953-2

Michele Simoncelli

Hybrid Crystal-Glass Materials from Meteorites Transform Heat Control

Michele Simoncelli combines a first-principles approach with machine learning to identify a unique material with distinctive thermal properties.

By Ellen Neff, Originally published by Columbia Engineering

Crystals and glasses have opposite heat-conduction properties, which play a pivotal role in a variety of technologies. These range from the miniaturization and efficiency of electronic devices to waste-heat recovery systems, as well as the lifespan of thermal shields for aerospace applications.

The problem of optimizing the performance and durability of materials used in these different applications essentially boils down to fundamentally understanding how their chemical composition and atomic structure (e.g., crystalline, glassy, nanostructured) determine their capability to conduct heat. **Michele Simoncelli**, assistant professor of applied physics and applied mathematics at Columbia Engineering, tackles this problem from first principles — i.e., in Aristotle's words, in terms of "the first basis from which a thing is known" — starting from the fundamental equations of quantum mechanics and leveraging machine-learning techniques to solve them with quantitative accuracy.

In research published on July 11 in the *Proceedings of the National Academy of Sciences*, Simoncelli and his collaborators Nicola Marzari from the Swiss Federal Technology Institute of Lausanne and Francesco Mauri from Sapienza University of Rome predicted the existence of a material with hybrid crystal-glass thermal properties, and a team of experimentalists led by Etienne Balan, Daniele Fournier, and Massimiliano Marangolo from the Sorbonne University in Paris confirmed it with measurements.

The first of its kind, this material was discovered in meteorites and has also been identified on Mars. The fundamental physics driving this behavior could advance our understanding and design of materials that manage heat under extreme temperature differences—and, more broadly, provide insight into the thermal history of planets.

A unified theory of thermal transport in atomically ordered crystals and disordered glasses

Thermal conduction depends on whether a material is crystalline, with an ordered lattice of atoms, or glassy, with a disordered, amorphous structure, which influences how heat flows at the quantum level–broadly speaking, thermal conduction in crystals typically decreases with increasing temperature, while in glasses it increases upon heating.

In 2019, Simoncelli, Nicola Marzari, and Francesco Mauri derived a single equation that captures the opposite thermal-conductivity trends observed in crystals and glasses—and, most importantly, also describes the intermediate behavior of defective or partially disordered materials, such as those used in thermoelectrics for waste-heat recovery, perovskite solar cells, and thermal barrier coatings for heat shields.

Using this equation, they investigated the relationship between atomic structure and thermal conductivity in materials made from silicon dioxide, one of the main components of sand. They predicted that a particular "tridymite" form of silicon dioxide, described in the 1960s as typical of meteorites, would exhibit the hallmarks of a hybrid crystal-glass material with a thermal conductivity that remains unchanged with temperature. This unusual thermal-transport behavior bears analogies with the invar effect in thermal expansion, for which the Nobel Prize in Physics was awarded in 1920.

That led the team to the experimental groups of Etienne Balan, Daniele Fournier, and Massimiliano Marangolo in France, who obtained special permission from the National Museum of Natural History in Paris to perform experiments on a sample of silica tridymite carved from a meteorite that landed in Steinbach, Germany, in 1724. Their experiments confirmed their predictions: meteoric tridymite has an atomic structure that falls between an orderly crystal and disordered glass, and its thermal conductivity remains essentially constant over the experimentally accessible temperature range of 80 K to 380 K.

Upon further investigation, the team also predicted that this material could form from decade-long thermal aging in refractory bricks used in furnaces for steel production. Steel is one of the most essential materials in modern society, but producing it is carbon-intensive: just 1 kg of steel emits approximately 1.3 kg of carbon dioxide, with the nearly 1 billion tons produced each year accounting for about7% of carbon emissions in the U.S. Materials derived from tridymite could be used to more efficiently control the intense heat involved in steel production, helping to reduce the steel industry's carbon footprint.

Future: from AI-driven solutions of first-principles theories to real-world technologies

In this new PNAS paper, Simoncelli employed machine-learning methods to overcome the computational bottlenecks of traditional first-principles methods and simulate atomic properties that influence heat transport with quantum-level accuracy. The quantum mechanisms that govern heat flow through hybrid crystal-glass materials may also help us understand the behavior of other excitations in solids, such as charge-carrying electrons and spin-carrying magnons. Research on these topics is shaping emerging technologies, including wearable devices powered by thermoelectrics, neuromorphic computing, and spintronic devices that exploit magnetic excitations for information processing.

Simoncelli's group at Columbia is exploring these topics, structured around three core pillars: the formulation of first-principles theories to predict experimental observables, the development of AI simulation methods for quantitatively accurate predictions of materials properties, and the application of theory and methods to design and discover materials to overcome targeted industrial or engineering challenges.

Simoncelli, M., Fournier, D., Marangolo, M., Balan, E., Béneut, K., Baptiste, B., Doisneau, B., Marzari, N., & Mauri, F. (2025). Temperature-invariant crystal–glass heat conduction: From meteorites to refractories. *Proceedings of the National Academy of Sciences*, 122(28), e2422763122. https://doi.org/10.1073/pnas.2422763122

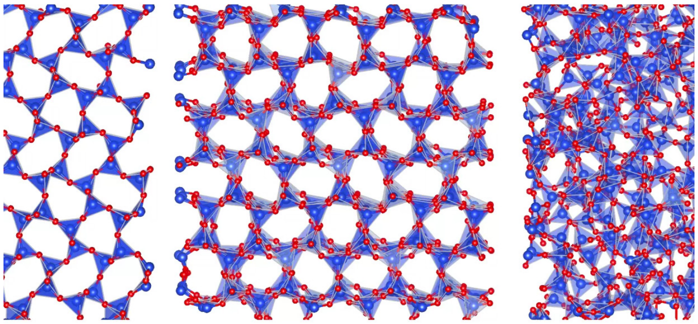
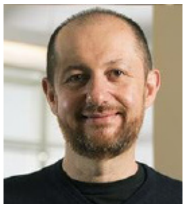


Image: The article discusses how increasing disorder in the atomic structure of materials influences macroscopic heat conduction — a critical property for heat-management technologies. The materials studied include crystalline meteoritic tridymite (left), a tridymite phase featuring crystalline bond order and amorphous bond geometry (center), and completely amorphous silica glass (right). Red represents oxygen (O), blue represents silicon (Si), and common SiO4 tetrahedral arrangements are highlighted in shaded blue. Credit: Simoncelli Lab

Need a New 3D Material? Build It With DNA

A new approach breaks down complicated designs into modular building blocks for easy assembly from the bottom up.

By Ellen Neff, Originally published by Columbia Engineering



Oleg Gang

When the Empire State Building was constructed, its 102 stories rose above midtown one piece at a time, with each individual element combining to become, for 40 years, the world's tallest building. Uptown at Columbia, **Oleg Gang** and his chemical engineering lab aren't building Art Deco architecture; their landmarks are incredibly small devices built from nanoscopic building blocks that arrange themselves.

"We can build now the complexly prescribed 3D organizations from self-assembled nanocomponents, a kind of nanoscale version of the Empire State Building," said Gang, professor of chemical engineering and of applied physics and materials science at Columbia Engineering and leader of the Center for Functional Nanomaterials' Soft and Bio Nanomaterials Group at Brookhaven National Laboratory.

"The capabilities to manufacture 3D nanoscale materials by design are critical for many emerging applications, ranging from light manipulation to neuromorphic computing, and from catalytic materials to biomolecular scaffolds and reactors," said Gang.

In two papers, one released in *Nature Materials* and a second on April 11 in *ACS Nano*, Gang and his colleagues describe a new methodology for fabricating targeted 3D nanoscale structures via self-assembly that can find use in a variety of applications, and they provide a design algorithm for others to follow suit. And it's all based on the most basic biomolecular building blocks: DNA.

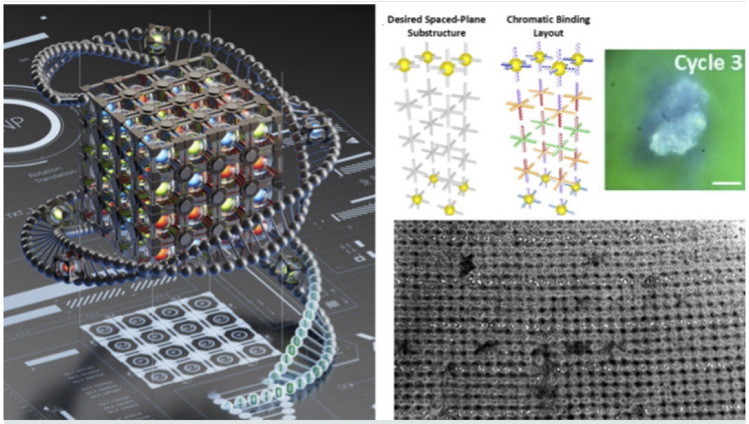
One pot stop for new materials: When it comes to small-scale fabrication of microelectronics, conventional approaches are based on top-down strategies. One common approach is photolithography, which uses powerful light and intricate stencils to etch circuits. But mainstream lithographic techniques struggle with complex, three-dimensional structures, while additive manufacturing, better known as 3D printing, cannot yet fabricate features at the nanoscale. In terms of workflow, both methods fabricate each feature one by one, in serial. This is an intrinsically slow process for building 3D objects.

Taking his cues from bio-systems, Gang builds 3D materials and devices from the bottom up via self-assembly processes that are directed by DNA. He has been refining his method through collaborations with other scientists to build, for example, extremely small electronics that they need for their work.

Two months ago, he and his former student, **Aaron Michelson**, now a staff scientist at Brookhaven National Laboratory's Center for Functional Nanomaterials, delivered a prototype for collaborators at the University of Minnesota interested in creating 3D light sensors integrated onto microchips. They built the sensors by growing DNA scaffolds on a chip and then coating them with light-sensitive material.

That device was just the first of many. In their latest paper in *Nature Materials*, Gang and his team establish an inverse design strategy for creating the desired 3D structures from a set of nanoscale DNA components and nanoparticles. The study presents four additional applications of their "DNA origami" approach to material design: a crystal-like structure comprised of one-dimensional strings and two-dimensional layers; a mimic of the materials found commonly in solar panels; another crystal that spins in a helical swirl; and, for collaborator Nanfang Yu, professor of applied physics at Columbia Engineering, a structure that will reflect light in particular ways for his goal of one day creating an optical computer.

Using advanced characterization techniques, such as synchrotron-based x-ray scattering and electron microscopy methods, at Columbia and Brookhaven National Laboratories, the team confirmed that the resulting structures matched their designs and revealed the designed considerations for improving structure fidelity.



Artistic rendering of the assembly of designed 3D hierarchically ordered nanoparticle structures using DNA-programmable bonds (left). The desired structure and its design with optical reflection properties, and an image of formed material with reflective characteristics (top right). Electron microscopy image of the realized structure with nanoparticles arranged in lines, separated at half-wavelength of light (bottom right). Credit: Oleg Gang

Each of these unique structures assembled itself in water wells in Gang's lab. This type of material formation is parallel in its nature since the components come together during the assembly process, meaning significant time- and cost-savings for 3D fabrication compared with traditional methods. The fabrication process is also environmentally friendly as the assembly occurs in water.

This assembly methodology, coupled with liquid robotics automatization on which I am working now at BNL, opens new possibilities for establishing 3D nano-manufacturing for a broad range of applications", said Brian Minevich, co-first author on the paper, who was a PhD student in Gang's lab and now is a postdoctoral fellow at BNL.

"This is a platform that is applicable to many materials with many different properties: biological, optical, electrical, magnetic," said Gang. The end result simply depends on the design.

DNA design, made easy: DNA folds predictably, as the four nucleic acids that make it up can only pair in particular combinations. But when the desired structure contains millions, if not billions of pieces, how do you come up with the correct starting sequence?

Gang and his colleagues solve this challenge with an inverse structural design approach. "If we know the big structure with the function that we want to create, we can dissect that into smaller components to create our building blocks with structural, binding, and functional attributes required to form the desired structure," said Gang.

The building blocks are strands of DNA that fold into a mechanically robust eight-sided octahedral shape, which Gang refers to as a voxel, with connectors at each corner that link each voxel together. Many voxels can be designed to link up into a particular repetitive 3D motif using DNA encoding, similar to how jigsaw puzzle pieces form a complex picture. The repetitive motifs, in turn, are also assembled in parallel to create the targeted hierarchically organized structure. Collaborator Sanat Kumar, the Michael Bykhovsky and Charo Gonzalez-Bykhovsky Professor of Chemical Engineering at Columbia, provided a computational verification of Gang's inverse design approach.

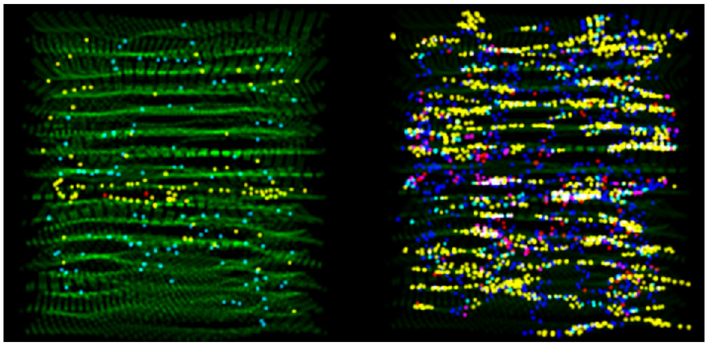
To enable the inverse design strategy, the researchers must figure out how to design these DNA-based nanoscale "jigsaw puzzle pieces" with the minimal number needed to form the desired structure. "You can think of it like compressing a file. We want to minimize the amount of information for the DNA self-assembly to be most efficient," said first author Jason Kahn, a staff scientist at BNL and previously a postdoc at Gang's group. Dubbed Mapping Of Structurally Encoded aSsembly, or MOSES, this algorithm is like nano-scale CAD software, Gang adds. "It will tell you what DNA voxel to use to make a particular, arbitrarily defined 3D hierarchically ordered lattice."

(Continued on page 15)

Columbia Scientists Explain How Atomic Disorder Controls Heat

Research led by Michele Simoncelli establishes a new framework that links atomic-scale disorder to heat conduction, paving the way for the theory-driven design and discovery of more efficient heat-shielding materials

By Ellen Neff, Originally published by Columbia Quantum Initiative



Left, irradiated graphite analyzed with conventional structural descriptors. Right, the new framework developed by the researchers exposes previously hidden variability in the material's atomic structure. More generally, it clarifies how atomic structure influences physical properties and enables the design of materials with targeted performance. Credit: Kamil Iwanowski

Carbon is an exceptionally versatile element that plays a crucial role in numerous industrial applications. It moderates reactions in nuclear power plants (e.g., graphite moderator blocks in fission reactors); as a fundamental electrode material in batteries and supercapacitors, it underpins modern energy storage; and in the form of heat spreaders and thermal interface materials, it enhances the performance and reliability of electronic devices and power modules. Optimizing these applications requires an understanding of how carbon, in its different forms, transports heat.

In a paper published on December 4 in *Physical Review X*, Columbia researchers Kamil Iwanowski and **Michele Simoncelli**, along with their University of Cambridge colleague Gábor Csányi, introduce a mathematical descriptor and a physical framework that together provide a quantitative explanation for how the amount of disorder in the atomic structure of materials influences their capability to transport heat.

"Technologies ranging from nuclear fusion to solar cells depend on the properties of materials whose atomic structure lies between that of well-studied, perfectly ordered (periodic) crystals and completely disordered (amorphous) glasses. Imperfect "real-world" materials can thus be seen as the "unconventional shades of gray" of condensed-matter physics," said Simoncelli, assistant professor of applied physics and applied mathematics at Columbia. "Here we introduce a framework to quantitatively describe, understand, and engineer their physical properties and functionalities. We look forward to using this framework in collaboration with experimentalists and industry to improve current heat-management materials or even to design new ones." Their framework is applicable to a wide range of solid materials, and it solves a 76-year-old problem in physics.

In 1949, Bell Labs physicist Charles Kittel proposed a phenomenological model connecting a material's thermal conductivity (the physical measure of heat conduction) to "obstacles" that disturb the microscopic vibrations of its atoms. In this picture, heat flows easily when these obstacles are far apart, and much less efficiently when they are closer together. Experiments suggested that this characteristic distance is determined by imperfections in how atoms are arranged, but for decades, it remained unclear how reliable this connection was.

"We solve this problem by demonstrating fundamental physical relations between variability in the arrangements of atoms, their microscopic vibrational patterns, and the length scales over which vibrations transport heat," said Iwanowski, the first author of the paper and graduate student in Simoncelli's research group at Columbia, which he established earlier this year.

Simoncelli's group is interested in carbon for its applications, especially in green energy technologies, and because it is a realistic example of a network solid that can have high variability in the way atoms are connected. In fact, carbon can bond with two, three, or four other carbon atoms. That results in considerable structural diversity, several imperfections, and potential networks of bonds. What remained an extremely challenging problem was quantifying these features and relating them to macroscopic properties.

In the current work, the team modeled the properties of 23 different forms of carbon at the quantum mechanical level and quantified their structural disorder using their newly introduced Bond-Network Entropy (BNE) growth descriptor, which measures the number of different local bond networks that connect the atoms. They further established clear links between structural disorder, motifs of atomic vibrations, and overall thermal conductivity.

Although they focused on carbon here, the theoretical and computational framework they developed is applicable to a wide range of network solids, where atoms are bonded through strong covalent bonds. From here, they are working to relate it to experimental measurements and thinking about future applications. For example, materials in fusion reactors are exposed to neutron irradiation, which induces defects in their bond network. The framework allows scientists to quantitatively predict how the neutron-irradiation-induced changes in atomic structure affect a material's macroscopic properties. This will ultimately enable predictions about the durability and reliability of materials that operate under extreme conditions.

"Having a quantitatively accurate theory that predicts how materials behave in extreme environments is incredibly useful, as it allows us to replace very expensive and challenging experiments with fast and accurate simulations. This will greatly accelerate the development of more efficient materials," said Iwanowski.

Kamil Iwanowski, Gábor Csányi, and Michele Simoncelli. Bond-Network Entropy Governs Heat Transport in Coordination-Disordered Solids. *Physical Review X* (2025). https://doi.org/10.1103/w4p6-b9mp

Need a New 3D Material? Build It With DNA (continued from p.14)

From there, you can add diverse types of nano-"cargo" inside the DNA voxels that will imbue the final structure with particular properties. For example, gold nanoparticles were embedded to give unique optical properties, as demonstrated in Yu's experiments. But, as shown previously, both inorganic and bio-derived nanocomponents can be integrated into these DNA scaffolds. Once the device was assembled, the team also "mineralized" it. They coated scaffolds with silica and then exposed them to heat to decompose the DNA, effectively converting the original organic scaffolding into a highly robust inorganic form.

Gang continues to collaborate with Kumar and Yu to uncover design principles that will allow for the engineering and assembly of complex structures, hoping to realize even more complicated designs, including a 3D circuit intended to mimic the complex connectivity of the human brain. "We are well on our way to establishing a bottom-up 3D nanomanufacturing platform. We see this as a '"next-generation 3D printing"' at the nanoscale, but now the power of DNA-based self-assembly allows us to establish massively parallel fabrication," said Gang.

Kahn, J.S., Minevich, B., Michelson, A. et al. Encoding hierarchical 3D architecture through inverse design of programmable bonds. *Nat. Mater.* 24, 1273–1282 (2025). https://doi.org/10.1038/s41563-025-02263-1

Professor Michael E. Mauel Retires After Four Decades of Service

After a distinguished career at Columbia University, Professor Michael E. Mauel has retired and is now Professor Emeritus of Applied Physics.

Since joining the faculty in 1985, Mauel has shaped the fields of plasma physics and fusion energy research while inspiring generations of students through his exceptional teaching, mentorship, and leadership.

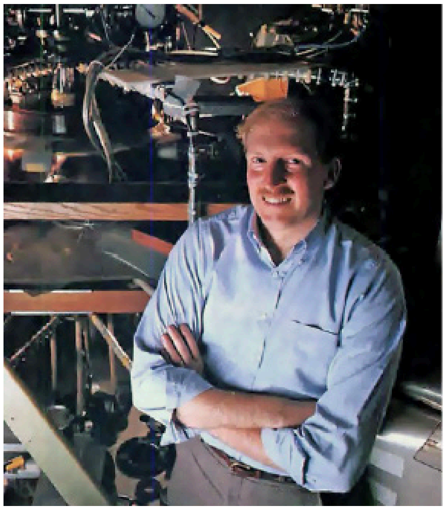
Mauel devoted his career to understanding how hot, ionized gas, called plasma, behave under the influence of strong magnetic fields and how these insights can be applied to controlled fusion energy, semiconductor manufacturing, and particle transport in the magnetospheres surrounding planets. He is best known for developing new methods to control plasma behavior for fusion energy, creating relativistic magnetically-trapped electrons with electromagnetic waves, and pioneering studies of high-temperature plasma confined by a strong dipole magnet.

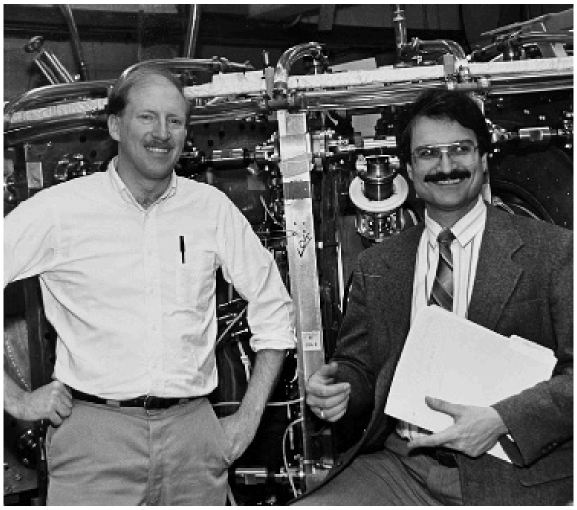
Mauel received his B.S. and Sc.D. from MIT, where he conducted research using microwaves to heat electrons trapped in magnetic mirror and tandem mirror fusion devices. Upon arriving at Columbia University, he worked alongside Professor Gerald Navratil to control high-pressure plasmas in tokamaks and worked with the late Akira Hasegawa, adjunct professor and scientist at Bell Laboratories, to explore the confinement of high-temperature plasma in laboratory magnetospheres, called "terrella." Highlights of Mauel's early research include (i) the first characterization of high-pressure plasma equilibrium from internal magnetic field measurements made within Columbia's HBT tokamak and within the large TFTR experiment at the Princeton Plasma Physics Laboratory and (ii) the discovery of how variations in plasma current profile can enhance fusion performance and create an internal barrier to plasma heat transport. Motivated by Hasegawa's theories and with the help of several talented graduate students, Mauel built the Collisionless Terrella Experiment (CTX) and investigated energetic particle transport and plasma turbulence confined by a strong dipole magnetic field. Among the CTX discoveries, students measured the natural "frequency chirping" of drift-resonant energetic particle instabilities, a phenomenon also found later in many magnetic fusion energy devices. The success of CTX experiments lead to the construction of the world's largest magnetically levitated dipole experiment, called LDX, as a joint project of MIT and Columbia University. Using a high current superconducting magnet, the LDX experiment gave dramatic confirmation of Hasegawa's dipole concept of stable high-pressure plasma confinement.

Following in the footsteps of colleagues Gerald Navratil and the late Robert Gross, founder of Columbia's Plasma Lab, Professor Mauel became a central force guiding expansion of the Department of Applied Physics and Applied Mathematics and guiding strategy for the national fusion research program. Mauel served as chair of the APAM Department from 2000 to 2006 and developed the strategic plan that united the three programs of today's Department: Applied Physics, Applied Mathematics, and Materials Science and Engineering. In 1996, Mauel helped to write a new strategic plan for the Department of Energy's Office of Energy Research titled *A Restructured Fusion Energy Sciences Program*. In 1999, he organized and co-chaired the first Fusion Summer Study, located at the Snowmass Conference Center where over 300 scientists and engineers gathered from all fusion disciplines and communicated a future of shared research goals.

Mauel chaired the American Physical Society's Division of Plasma Physics from 2002-2003; he chaired the U.S. Burning Plasma Council from 2010-2013; and he chaired the Plasma Science Committee of the National Research Council from 2012-2014. In 2006–2007, he served as a Jefferson Science Fellow in the Office of International Energy and Commodity Policy assisting U.S. diplomatic efforts to promote energy security. In 2017-2018, during a policy crossroad for the U.S. Fusion Energy Science Program, Mauel co-chaired the National Academies' Committee for *A Strategic Plan for U.S. Burning Plasma Research* that recommended a strategy supporting both participation in the ITER fusion device, located in France, and construction of a fusion pilot plant in the United States. Mauel's influence has been recognized with Certificates of Appreciation from both the U.S. Department of Energy and the U.S. Department of State, the 2020 Leadership Award by the Fusion Power Associates, and his appointment as lifetime associate of the U.S. National Academies.

(Continued on page 17)





(above left) Professor Mauel featured in Macworld magazine (1989)
(above right) Professors Mauel and Navratil with HBT-EP (1993)

(above left) Professors David Keyes, Mike Mauel, and C.K. Chu (2006)
(above right) Mauel, Mitsuru Kikuchi, and Ken Fowler at NAS Meeting at DIII-D (2018)

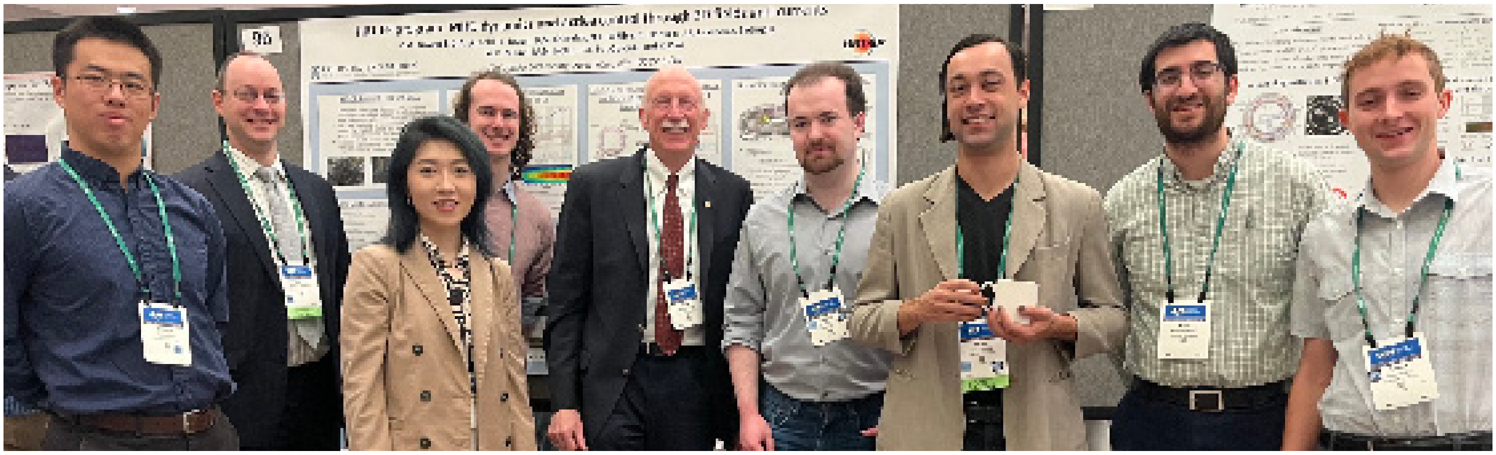
Professor Michael E. Mauel Retires After Four Decades of Service (continued from page 16)

"I have been enormously privileged to have worked with so many inventive students, scientists, and faculty colleagues," said Mauel. "The Department of Applied Physics and Applied Mathematics both energized and inspired me. I am grateful for what I have learned from my students and for the joy of research and discovery that I have shared with my colleagues." In 1994, Columbia Engineering undergraduates named him Teacher of the Year, and Mauel fondly recalls his time in the Plasma Lab, including non-academic pursuits like the running of the Brooklyn Half-Marathon.

Across his distinguished career, Professor Mauel combined imaginative scientific inquiry with a deep commitment to educating the next generation of physicists and engineers. His contributions strengthened Columbia Engineering's leadership in plasma physics and helped shape the pursuit of fusion science and clean energy technology.

We express our deepest gratitude to Professor Mauel for his decades of scholarship, service, and mentorship and extend our warmest wishes for a fulfilling and well-deserved retirement.

(above) Professor Mauel with Jay Kesner, Darren Garnier, and Scientific Team of Levitated Dipole Experiment (2015)



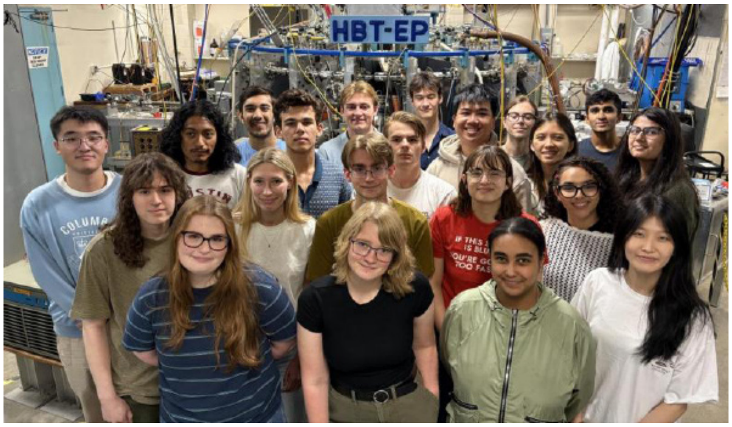
(above) Professor Mauel with HBT-EP Presentations at APS DPP Annual Meeting (2023)

(above) Professors Mauel and Navratil and Plasma Lab at finish of Brooklyn Half-Marathon (2010)

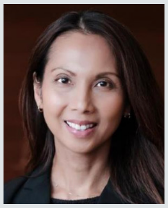
2025 Columbia Fusion Research Center REU News

The Columbia Fusion Research Center welcomed an undergraduate cohort of well over 20 undergraduate students participating in summer research with the Fusion Research Center. Columbia undergraduate students were also joined by an external cohort of six NSF-funded REU students hailing from universities across the country. Columbia students and REU students worked side-by-side on their respective projects. The undergraduate students (pictured on the right) participated in all aspects of research at the lab:

- 2 students worked on hard X-ray physics at the HBT-EP Tokamak experiment.
- 3 students worked on ablation physics and cryogenic technology at the Pellets at Columbia experiment.
- 4 students worked on superconducting magnet physics and technology at the Columbia Stellarator Experiment.
- 2 students performed plasma astrophysics calculations with Columbia Astrophysics Lab colleagues.
- 7 students contributed to the assembly of the Columbia University Tokamak for Education.
- 3 students performed calculations of tokamak stability and control.
- 3 students performed calculations of stellarator optimization and analysis.



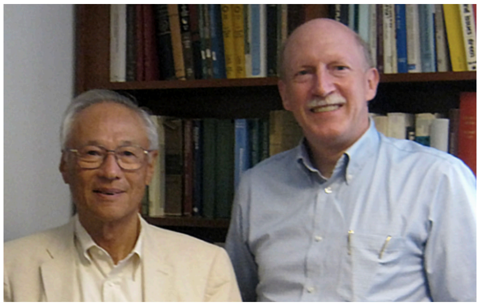
As part of the summer program, staff and faculty mentors provided a special colloquium on Fridays to introduce key research topics. Additionally, a graduate-student-led speaker series offered tutorial content in a less formal setting. Students presented their results at the annual student poster symposium in August. See the back cover for more details and photos.



Nguyen Joins APAM as New Career Placement Officer

Meet Kim Nguyen, the new Career Placement Officer for the APAM Department. In addition to this role, Kim serves as a Career Placement Advisor with Columbia Engineering's Graduate Career Placement Team. Her primary focus is on supporting students in creating clear career paths and successfully transitioning from the classroom to industry, research, and entrepreneurship. She offers personalized one-on-one advising, fosters employer and alumni partnerships, and guides students through every stage of their career journey. Kim is deeply passionate about helping others and thrives in environments where she can make a meaningful impact. She draws on her 30 years of experience as an executive recruiter and an executive in the Financial Services industry. Whether she is collaborating with cross-functional teams or offering direct guidance to students, Kim believes that understanding and compassion are at the heart of leadership and effective problem-solving. By leading with empathy, Kim aims to empower each student to confidently navigate their career path.

In Memoriam: Prof. Akira Hasegawa (1934-2025)



Akira Hasegawa and Mike Mauel in 2008

Dr. Akira Hasegawa, former adjunct professor in the APAM Department, peacefully passed away on June 22, 2025, with his beloved wife Miyoko by his side. Despite a diagnosis of myelodysplastic syndrome in June 2024 and a prognosis of just months, Akira defied expectations, celebrating his 91st birthday just days before he passed away.

Akira Hasegawa was born in Tokyo in 1934. He is a graduate of Osaka University and received his Ph. D. Degree from the University of California, Berkeley and, later, a Doctor of Science Degree from Nagoya University. After graduation, he was a post-doctoral scientist at Bell Laboratories and an associate professor in the Faculty of Engineering Science of Osaka University. In 1968, Hasegawa returned to Bell Laboratories where he made pioneering discoveries of plasma wave phenomena in the Earth's magnetosphere. While at Bell Labs, Hasegawa became an adjunct professor in 1971 Columbia University and was a source of inspiration and ideas to members of Columbia's plasma physics and fusion research program. In 1987 Hasegawa proposed confining a high-temperature plasma by a levitated superconducting dipole magnet. This invention lead to two successful demonstrations of high-pressure plasma confinement: at the Levitated Dipole Experiment (LDX) built jointly by Columbia University and MIT and at the "Ring Trap-1" device built at the University of Tokyo.

Professor Hasegawa is recognized for many discoveries in plasma physics and nonlinear optics. The American Physical Society awarded Hasegawa the 2000 James Clerk Maxwell Prize for "innovative discoveries and seminal contributions to the theories of nonlinear drift wave turbulence, Alfvén wave propagation in laboratory and space plasmas, and optical solitons and their application." In 2011, he was co-recipient of the 2011 Hans Alfvén Prize awarded by the European Physical Society "for laying the foundations of modern numerical transport simulations and key contributions on self-generated zonal flows and flow shear decorrelation mechanisms which form the basis of modern turbulence in plasmas." In the field of nonlinear optics and communications, Hasegawa derived the master equation for information transfer in optical fibers and was the first to proposed the use of solitons for optical communications. In 1995, Hasegawa received the Computers and Communications Prize from the NEC Foundation "for the discovery of soliton in optical fiber and the pioneering contributions made in the applications for ultra high speed optical fiber communication" and later the 1999 Quantum Electronics Award from the IEEE Photonics Society. In 2010, the Emperor of Japan bestowed Akira Hasegawa The Order of the Sacred Treasure, Gold Rays with Neck Ribbon for his innovative discoveries and fundamental contributions in the field of physics.

His final year was filled with joy—time with friends and family, favorite meals, nature's beauty, and deep gratitude for a life rich in purpose and love. He often reflected on how fortunate he was, thankful for the freedom to pursue his passion at Bell Labs and through his affiliations with several universities. Akira is survived by his wife, who lovingly cared for him until the end. He was also a father of three and a proud grandfather to five. Akira was surrounded by love in his final days. As he said, Shiawase datta — "I had a wonderful life."

Werkmeister Receives the 2026 APS Greene Dissertation Award

The American Physical Society (APS) has selected **Dr. Thomas Werkmeister** as the recipient of the 2026 Richard L. Greene Dissertation Award in Experimental Condensed Matter or Materials Physics. This award, one of the highest honors for recent Ph.D. graduates in the field, recognizes Werkmeister's outstanding doctoral research that has significantly contributed to advancements in experimental condensed matter physics, in particular his "pioneering investigation of unusual integer and fractional quantum Hall states in a graphene-based quantum Hall interferometer."

Werkmeister received his PhD in May 2025 from Harvard University, advised by Professor Philip Kim, and he is now a Simons Junior Fellow and Postdoctoral Research Scientist at Columbia University, mentored by Professor **Aravind Devarakonda** in the Department of Applied Physics and Applied Mathematics and Professor Cory Dean in the Department of Physics.

In his doctoral research, Werkmeister designed and fabricated interferometers from graphene, a two-dimensional (2D) lattice of carbon atoms, to measure the quantum phase accumulated by charged particles as they encircle a strong magnetic field, where he successfully measured the fractional charge and braiding phase of emergent "anyons" in fractional quantum Hall states.

Anyons are unusual particles hypothesized to exist in 2D space that, unlike conventional bosons or fermions, can be used to encode and manipulate quantum information through a pairwise exchange process termed "braiding". Braiding-based quantum processing has attracted considerable attention as a promising route towards fault-tolerant quantum computing. By experimentally demonstrating the existence of the simplest type of anyons in fractional quantum Hall states, Werkmeister's work opens the door for developing fault-tolerant qubits that leverage braided anyons in 2D materials.

Building on his groundbreaking Ph.D. work addressing long-standing questions surrounding fractional quantum Hall physics and topological order more broadly, Werkmeister is now developing expertise in the synthesis of novel quantum materials, in particular superconductors. He will incorporate these new materials into quantum devices that utilize their unique properties. Through this combination, he aims to advance the frontiers of fundamental physics and ultimately develop new technologies that take advantage of quantum coherence.

"I am deeply grateful for the mentorship of my Ph.D. adviser, Philip Kim, and for the very supportive and inspirational lab environment that he built. I also thank my many collaborators over the years, from whom I learned a great deal", says Werkmeister.

The award will be formally presented at the APS March Meeting in 2026, highlighting Werkmeister's remarkable contributions to science and his potential to lead future innovations in materials physics. This accolade underscores the American Physical Society's commitment to supporting emerging talents who push the boundaries of scientific knowledge.

Math Meets Industry" Roundtable

Columbia University's SIAM student chapter, in collaboration with APAM Career Placement, hosted *Math Meets Industry*, a lively roundtable event designed to introduce students to the diverse ways mathematics drives innovation across sectors. The session brought together alumni and industry professionals who shared insights into their day-to-day work, career journeys, and practical advice for students preparing for jobs and internships. The event offered students an opportunity to ask questions in an informal setting, learn about emerging roles in data science, AI, engineering, and technology, and gain perspective on how mathematical training translates into real-world impact.

Panelists included:

Yamini Ananth, BS '23, *Software Engineer in Machine Learning at Celonis*
Yamini earned a BA in Applied Math and Computer Science from Columbia University in 2023. She is a software engineer and researcher at Celonis in the CeloAI group. Yamini co-developed ETL Assistants, a flagship AI product suite at Celonis that leverages AI to speed up the customer data onboarding process. At Celonis, Yamini has also published research in machine learning and process mining at academic venues including ICML and ICPM.

Sadi Gulcelik, BS '23, *AI Engineer Intern, Pensa Systems & CU MSCS candidate*
Sadi earned a BA in Applied Mathematics from Columbia University in 2023. After graduation, he joined Bridgewater Associates as an Investment Engineer. He is currently pursuing a Master's in Computer Science at Columbia and works part-time as an AI Engineer at a retail technology startup. Upon completing his degree, he plans to return to the hedge fund space as a Quantitative Developer.

Francis Kamdem, MS '23, *Decision Scientist at CVS Health*
Francis is a Data Scientist with a Master's degree in Civil Engineering and Engineering Mechanics from Columbia University, specializing in the integration of data science and machine learning to optimize infrastructure systems. He is skilled with the ability to develop and deploy predictive models and optimization algorithms that enhance efficiency and decision-making in high-stakes environments. Francis is also experienced in leveraging statistical models to deliver actionable insights.

Abram Moats, BA '20, *Founder of ARDA Consulting*
Abram earned a BA in Applied Mathematics from Columbia College in 2020. He currently works as a senior data engineer at YPrime, a company focused on facilitating clinical trial research. In this role, he is primarily responsible for data architecture that enables visibility and transparency into clinical trial operations. He is also the founder of ARDA Consulting, a company that helps Chambers of Commerce provide technical services to their members. Abram is passionate about the processes that help us determine what is and is not important in life.

Emma Schecter, BS '20, *Deployment Strategist at Palantir Technologies*
Emma is a Deployment Strategist at Palantir Technologies in their Hospital Operations group. She graduated from Columbia in 2020 with a BS in Applied Math. Following graduation, she was a staff associate in the Applied Math department for a year and then a data scientist at Sony Music for 3 years. Now at Palantir, she works as a forward deployed engineer working to solve complex problems at various healthcare institutions.

The event underscored a shared message from all panelists: mathematical training provides a powerful foundation for tackling real-world challenges—and opens doors to an exciting range of careers. Students left the event inspired by the breadth of career possibilities rooted in mathematical thinking and grateful for the chance to build connections with professionals and alumni who once stood where they are today.

3rd Annual Summer Student Poster Symposium

Seventeen undergraduate students from the Columbia University Fusion Research Center participated in the third Annual Summer Student Poster Symposium, hosted by the APAM Department. The participants included students from the Summer@SEAS program, NSF-funded REU students, and continuing student members of the Fusion Research group, some of whom had been conducting research in the group for over a year.

The symposium was attended by faculty advisors in the plasma physics program, as well as research scientists, postdoctoral researchers, graduate students, master's students, and other undergraduate students. Participants Included:

Hanga Andras-Lentanovszky: Is There Alfvénic Turbulence at the Apex of Solar Coronal Loops?

Rithik Banerjee: Application of Single Stage Optimization to Generate "Banana Coil" Configurations for Upgrade on Columbia HBT Experiment

Alexander Boeckmann: Predicting HBT-EP Plasma Mode Amplitude and Phase with High Speed Image Data

Michael Campagna: Effect of Symmetry Breaking on Neoclassical Flow Damping in the Columbia Stellertor eXperiment *(winner of best poster prize)*

Emily Epstein: Power Supply Systems Development for the CUTE Tokamak

Beruktawit Gebreamlak: High-Temperature Superconducting Non-Planar Coil Development: From Design to Cryogenic Testing

Aiden Hightower: Methods for Improving the Design and Fabrication of Nonplanar HTS Magnets for the Columbia Stellerator eXperiment (CSX)

Amelia Koff: Attainable Plasma Configurations for the Columbia University Tokamak for Education using TokaMaker

Julia Kirby: Automation and Operation of Pellets at Columbia

Cassandra McGinley: Application of Diagnostic Systems in the Pellets at Columbia Test Stand

Shean Rahman: ELM State Classification Using Machine Learning and Hybrid Deep Neural Networks

Samuel Sebastian: Magnetic Field Curvature and its Role in Particle Acceleration by Relativistic Curvature

Vayu Singhal: Design and Manufacturing of TF Magnet and Support Structures for CUTE

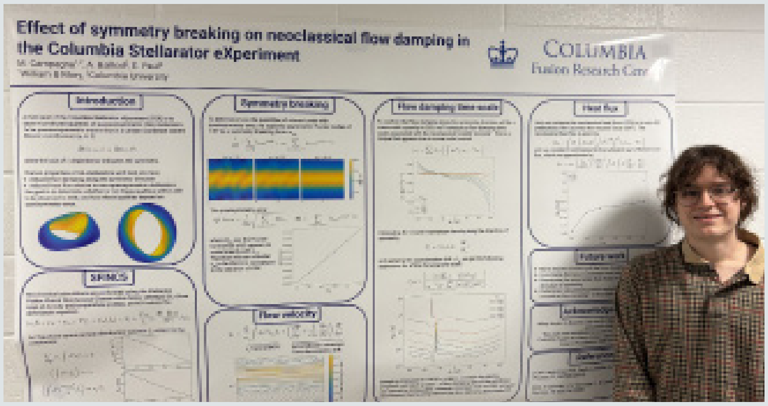
Alexander Skrypek: CalcSX: A lightweight toolkit optimized for analysing non-planar coils

Sonia Sobel: Energy-resolved Detection of Hard X-Rays on the HBT-EP Tokamak

Franco Sorza-Enriques: Disassembly and Relocation of CUTE

Brianna Yang: Operations and Hardware Developments of Pellets at Columbia

(Above) Fusion Research Center students participated in the 3rd annual Summer Student Poster Symposium



(above) Michael Campagna - winner of best poster prize : Effect of Symmetry Breaking on Neoclassical Flow Damping in the Columbia Stellertor eXperiment

(Above) Graduate student Alexa Lachmann (right) observes the research presentation delivered by undergraduate student Brianna Lan (left)

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