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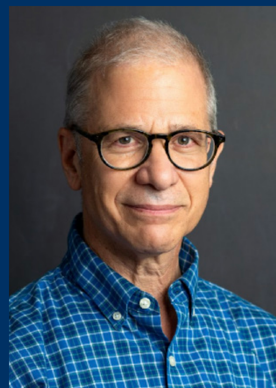
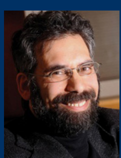
APAM NEWS

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







Dear APAM Community,

I am pleased to share with you the Spring 2025 edition of the APAM Newsletter, which highlights the many achievements of our students, faculty, and alumni over the past semester. This issue celebrates the academic and research excellence that continues to define our department. Among the many student accomplishments, Andrew Yang (BS '25), a double major in Applied Physics and Applied Mathematics, received the Illig Award as SEAS Valedictorian as well as the Applied Physics Faculty Award. We also recognize Mihnea Leonte (Applied Mathematics), Sarah Asher (Materials Science), and Dr. Tianwei Jin, winner of the 2025 Robert Simon Memorial Prize, along with the many graduates of our programs whose work and dedication inspire us all.

Our faculty have similarly distinguished themselves on the world stage. Simon Billinge received the Gregori Aminoff Prize and the MRS Innovation Award, Michal Lipson was elected to the National Academy of Engineering, and Michael Weinstein joined the American Academy of Arts & Sciences. Research in the department continues to break new ground—from AI tools that reveal atomic structures of nanocrystals, to advances in superconductors and quantum systems, to innovations in photonics and energy technologies. The launch of the Columbia Fusion Research Center, led by Prof. Carlos Paz-Soldan, marks a major milestone in our commitment to addressing global energy challenges through academic-industry partnerships and further strengthens the long history of Columbia's leadership in Plasma and Fusion physics.

As you read through this issue, I hope you share our sense of excitement about the future of APAM and the impact our community continues to make across disciplines and around the world.

Warm regards,

Marc Spiegelman
Chair, Department of Applied Physics
& Applied Mathematics

Cover images: (left-right)
Professors Elizabeth Paul, Carlos Paz-Soldan,
Michael Weinstein, Simon Billinge, and Michal Lipson

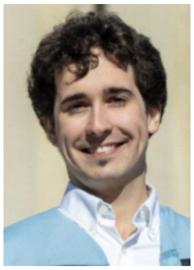
Andrew Yang (BS ‘25)

2025 SEAS Valedictorian, Illig Award Winner, and Applied Physics Faculty Award Winner

Columbia Engineering Valedictorian Andrew Yang (BS ‘25), a double major in applied physics and applied mathematics, is also the recipient of this year’s Applied Physics Faculty award. His interest lies in the intersection between physics, mathematics, and computation. His research direction has swung wildly from designing LSTMs to searching for periodic singular structures with Xuenan Li, Chu Assistant Professor of Applied Mathematics. The majority of his work has been with Simon Billinge, professor of materials science and professor of applied physics and applied mathematics, on designing fast techniques and programs to probe changes in material structure from high-throughput diffraction data. He and Billinge have taken these techniques to beamlines in three continents.

Andrew Yang, 2025 SEAS Valedictorian

Yang enjoys discussing his work and was the first undergraduate to speak at a Bruker-AXS / MIT Symposium. He also loves outreach and teaching, having been heavily inspired by Michael Mauel’s energetic style, Prashant Iyengar’s deep dives into lecture material, and Joseph Kraisler’s dedication to students. Throughout college, he has taught computer aided design to local high-schoolers with Sinisa Vukelic through the SHAPE program, as well as dynamical systems with Li and machine learning with both Nakul Verma and Billinge to local Columbia students as a TA. Yang will continue his exploration of material structures and behaviors through (neutron) diffraction and machine learning (of interatomic potentials) at Caltech. **(Originally published by Columbia Engineering)**



Mihnea Leonte (BS ‘25), Applied Mathematics Faculty Award Winner

Mihnea Leonte (B.S. ’25, Applied Mathematics) is the winner of the 2025 Applied Mathematics Faculty Award. Mihnea is passionate about applying mathematics to real-world problems to create tangible impact – whether in robotics, machine learning or in finance. This motivation has shaped his academic path at Columbia, where, alongside his Applied Mathematics coursework, he pursued advanced courses in Computer Science, Economics, and Industrial Engineering. He explored topics such as Machine Learning and Unsupervised Learning, Game Theory, and Algorithmic Trading, building a strong interdisciplinary foundation. In his junior summer, he conducted research in the Applied Mathematics Department under the supervision of Prof. Xuenan Li on the design of singular and flexible bar frameworks with applications to robotics. The project brought together constrained optimization, rigidity theory, and numerical methods to study the geometry of mechanical systems. By implementing a constrained saddle search algorithm, he discovered multiple families of bar frameworks that satisfied both singularity and flexibility, achieving the project’s core objective. Together with Prof. Li, he co-authored a paper based on these results, which they submitted to a conference for review. In the Fall semester, he presented these results as part of the senior seminar. Outside of research, he regularly attended talks hosted by the Undergraduate Math Society where he enjoyed diving into more abstract and theoretical mathematical topics. After graduation, he will continue at Columbia as a Master’s student in Financial Engineering, aiming to build on his interdisciplinary foundation and apply mathematical models to complex problems in quantitative finance.

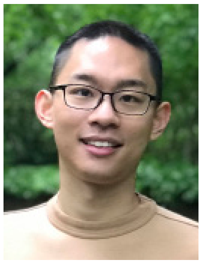
Sarah Asher (BS ‘25), Rhodes Prize for Materials Science Winner

Sarah Asher (B.S. ’25, Materials Science) is this year’s winner of the Frances B.F. Rhodes Prize. She began her research at Columbia in Professor Katayun Barmak’s lab, where she developed Python code for a UNet-based grain boundary segmentation project and co-authored a related publication. She later joined the Steingart Group in Earth and Environmental Engineering, where she used signal processing to analyze acoustic data from lithium metal batteries for health diagnostics. For her Senior Design Project, advised by Professor Dan Steingart, she built a low-cost 3D printing system for electrode slurry deposition. She also served as the SEAS student government sustainability representative in her junior year. After a gap year, Sarah plans to pursue graduate research in electrochemical energy storage.

Abdullah Hyder Awarded 2025 Tau Beta Pi Fellowship

Abdullah Hyder, a Ph.D. student in plasma physics, has been awarded a 2025 Tau Beta Pi fellowship. Since 1929, Tau Beta Pi – the engineering honor society – has awarded the fellowship to graduate students who exemplify scholarship, leadership, and service. The organization selected 31 outstanding members from 376 applicants pursuing full-time graduate studies in engineering or related fields. Fellows are additionally selected for their potential to contribute to the advancement of the engineering profession.

2025 Simon Prize Winner: Dr. Tianwei Jin



Dr. Tianwei Jin is the winner of the 2025 Simon Prize for the most outstanding dissertation in the APAM Department.

Dr. Jin received his PhD from Columbia in October 2024, advised by Prof. Yuan Yang. His thesis, "Materials Design for Lithium Batteries with High Energy Density," focuses on developing innovative material design principles for next-generation energy storage technologies. His key contributions include: (1) designing a scalable interfacial architecture that integrates all layer components of a commercial battery, enhancing its mechanical strength by a factor of 11 with minimal impact on electrochemical performance and enabling batteries to serve as structural components in electric vehicles to extend mileage; (2) proposing a phase-separation phenomenon in polymer electrolytes under applied current as a novel strategy to suppress lithium dendrite growth in lithium-metal batteries, thereby enhancing both safety and performance; and (3) identifying two critical limitations in a widely used cathode design for solid-state lithium-sulfur batteries and introducing a counterintuitive design principle that achieves long cycle life with minimal capacity fade. His work has been published in *Advanced Energy Materials* (2021), *Joule* (2022), *Materials Today* (2023), and *Nano Letters* (2024). After graduating from Columbia, Tianwei continued his work in the battery industry on the development of next-generation batteries.

History of the Robert Simon Memorial Prize: Robert Simon (1919–2001) received a B.A. degree *cum laude* in Classics from the City College of New York in 1941, where he was elected to Phi Beta Kappa, and an M.A. in Mathematics from Columbia University in 1949. From 1941 to 1944, he was a lieutenant in the U.S. Armed Forces, serving in England, France, and Italy. He participated in the D-Day operation as a navigator for a plane that dropped paratroopers in the vicinity of Omaha Beach, and General Eisenhower personally shook his hand and wished him well the night before the assault. Simon, who was born and lived in New York City, spent a lifetime making valuable contributions to the field of computer science. Starting in 1953, he worked for 15 years at Sperry's UNIVAC Division in various capacities, including marketing, planning, systems engineering, systems programming, and information services. He spent a year working at the Fairchild Engine Division as Director of the Engineering Computer Group and personally directed the establishment of several company computer centers at sites throughout the United States. From 1969 to 1973, he was a partner with American Science Associates, a venture capital firm. He was a founder and vice president of Intech Capital Corporation, serving on its board from 1972 to 1981, and a founder and member of the board of Leasing Technologies International, Inc., from 1983 until his retirement in 1995. The prize was established in 2001 by Dr. Jane Faggen, with additional support from friends and relatives of Mr. Simon.

2025 NSF GRFP Competition

Several Applied Physics majors and alumni have earned "Honorable Mention" distinctions in the highly competitive 2025 National Science Foundation Graduate Research Fellowship Program (NSF GRFP). Their recognition is especially impressive in a year when the number of awardees and honorable mentions dropped significantly nationwide. Despite the tougher competition, these students stood out for their academic excellence and research potential, earning national acclaim in one of the most prestigious graduate fellowship competitions in the country.

NSF-GRFP Honorable Mention:

Sridevi Rama Pulugurtha, SEAS'25, Applied Physics
Ceaser Stringfield, CC'24, Applied Physics
Ari Noah Willner, SEAS'24, Applied Physics
Andrew Yang, SEAS'25, Applied Physics

Congratulations 2024-2025 Graduates

October 2024 BS: Ken Kidangalil (AM), Vittorio Luzio (AM), Nathan Minyard (AM), Caidan Speth-McCrary (AM)

October 2024 MS: Mani Bayani (AM), Eugene Emono (AM), Ethan Li (AM) Niall Nethercote (AM)

October 2024 MPhil: Sidarth Raghunathan (AP)

October 2024 PhD: Sasaank Bandi (MSE), Andrew Bishop (AP), Sean Cohen (AM), Julia Hestenes (MSE), Xiaoyan Huang (AP), Tianwei Jin (MSE), Chenxing Luo (MSE), Mark Mathis (AP), Patrick Orenstein (AM), Bonan Shen (MSE), Yumou Wei (AP), Zirui Xu (AM), Qi Zhang (MSE)

February 2025 BS: Peiqi Ding (AM), Ashlyn Fulgham (AP), Caroline Sun (AM), Ari Willner (AP)

February 2025 MS: Yassine Bakkouch (AP), Shuangqi Bao (AM), Dylan Cawman (MP), Beiji Chen (AM), Wenting Cheng (AM), Javier Chiriboga (AP), Raul Cordies-Maso (MSE), Tianshu Dai (AM), Yishu Dong (AM), James Eckstein (AP), Karl Falb (AP), Samuel Freiberger (AP), Benjamin Gauthier (AM), Neil Hazra (AP), Runze He (MSE), Jingxuan Hu (MSE), Chuqiao Huang (AM), Yutong Huang (AM), Hongxi Jiang (AP), Ziyi Jiang (MSE), Peter Jin (AM), Ayman Khaleq (AM), Vanshika Kishore (AM), Alexandra Lachmann (AP), Zhizheng Lang (MSE), Eden Lee (AM), Katherine Lee (MSE), Chengze Li (AM), Dengyang Li (AM), Qiankun Li (AM), Tianyu Li (AP), Yanqi Liang (AP), Kaiheng Lin (AM), Zhaowen Lin (MSE), Chengyu Liu (AP), Rohan Lopez (AP), Cefu Lyu (AP), Julia Moncayo von Hase (AM), Caden Myers (MSE), Yernar Orda (MP), Marie Peduto (AM), Yudong Peng (MSE), Abhinav Radhakrishnan (AM), Yu Shan (AM), Frederick Sheehan (AP), Yanling Shen (AM), Jinkai Si (MSE), Arvind Singh (MSE), Yue Wang (AM), Ruicheng Wu (MSE), Yipeng Wu (AM), Jamie Xia (AP), Zhecheng Xiao (MSE), Yuhan Xu (AM), Yingsong Yang (AM), Zhihao Yang (AP), Jayanthi Yerchuru (AM), Xinran You (AM), Winston Yu (AM), Zhiqi Yu (AM), Ciming Zhang (AM), Liu Zhang (AM), Jianing Zhou (MSE), Zezheng Zhu (AP), Ketian Zou (MSE)

February 2025 MPhil: Yan Cheng (AM), Carl Elliston (AP), Benjamin Reilly (MSE), Hongjin Wang (MSE), Yin Zhou (AM),

February 2025 PhD: Rian Chandra (AP), Ling Lan (AM), Francesco Ruta (AP), Tianqi Wan (MSE)

May 2025 BS: Vikram Ailiani (AP), Samuel Andrello (AP), Kei Asano (AM), Sarah Asher (MSE), Lucas Bosteels (AM), Michael D'Agostino (AM), Karina Dovgodko (AM), Luke Filor (AP), Nicolaus Gagliano (AM), Chandra Gangavarapu (AM), Laya Gollamudi (AM), Jacobo Guzowski Lang (AM), Erik Heitsmith (AP), Tatsuya Hiki (AM), Aryaman Himatsingka (AM), Ethan Kim (AM), Connor Knezic (AM), Somin Lee (AM), Mihnea Leonte (AM), Ethan Lipson (AM), Dong Luo (AM), Marianna Mattin (AM), Jalaj Mehta (MSE), Raphael Mostov (AM), Geraldine Nina Montano (AM), Guillermo Peschard Rioboo (AP), Sridevi Pulugurtha (AP), Dylan Schmeling (AP), Neilesh Shrotri (AM), Farhan Tanvir (AP), Ze Wang (AM), Anna Weinacht (AM), Andrew Yang (AM), Andrew Yang (AM/AP), Shiqi Yang (AP), Tieqiong Zhang (AP), Yuqi Zhang (AM)

May 2025 MS: David Anderson (AM), Yao Cai (AM), Zhe Cao (AM), Alison Chen (AM), Han Chen (MSE), Yiwei Chen (AM), Yucong Chen (AM), Kyra Cho (AM), Malachi William Coleman (AM), Sophia Guizzo (AP), Aishwarya Gujarathi (MSE), Yusang He (MSE), Jeffrey Holmes (AM), Plamen Hristov (AM), Chunying Huangdai (AM), Ilia Karp (MSE), Sangjoon Lee (MSE), Yitian Liang (AM), Zaikang Lin (AM), Bingyi Liu (AM), Mier Liu (MSE), Xinyi Liu (AP), Wendi Lu (AM), Qi Luo (AM), Jingwen Lyu (AM), John Magargee (AM), Emily Moy (MSE), Praneeta Nalluri (AM), Balzhan Smailova (AM), Jiahua Song (AM), Matthew Wilson (MP)

May 2025 MPhil: Garrett Beals (AP), Megan Eisele (MSE), Dion Ho (AM), Kristina Nabayan (MSE), Swarnava Sanyal (AP), Han Yong Wunrow (AM), Yuan Xu (AP)

May 2025 PhD: Yinan Dong (MSE), Madison Ihrig (AM), Richard Oliver (AP), Joseph Wild (MSE), Edith Zhang (AM), Yin Zhou (AM)

AP: Applied Physics | AM: Applied Mathematics |
MSE: Materials Science & Engineering | MP: Medical Physics

Billinge Awarded 2025 Gregori Aminoff Prize & MRS Innovation in Materials Characterization Award

Simon J. L. Billinge, Professor of Applied Physics, Applied Mathematics, and Materials Science at Columbia Engineering, was awarded the 2025 Gregori Aminoff Prize in crystallography by the Royal Swedish Academy of Sciences. He was awarded the prize for his decisive contribution to the further development of the pair distribution function, a tool that is widely used in materials science.

Prof. Billinge, the Aminoff Prize Laureate, presented the lecture, "Watching real materials in action: everything, everywhere, all at once," at the 2025 Gregori Aminoff Prize Symposium on April 2, 2025. As part of the award ceremony, he was presented with a certificate, a medal, and a monetary prize of 120,000 Swedish kronor. The Gregori Aminoff Prize celebrates outstanding individual achievements in crystallography, particularly those related to the formation and transformation of crystal structures.

Billinge also received the Innovation in Materials Characterization Award at the 2025 Materials Research Society (MRS) Spring Meeting. This distinguished award recognizes ground-breaking advances in the way scientists understand and analyze materials—whether through structure, composition, or how they behave under various conditions. Billinge's work stood out for its exceptional impact on the field of materials research, pushing the boundaries of how materials are characterized, regardless of method or material type. The award, which includes a $5,000 cash prize, a presentation trophy, and a certificate of achievement, is endowed by Dr. Gwo-Ching Wang and Dr. Toh-Ming Lu, both renowned figures in the field.

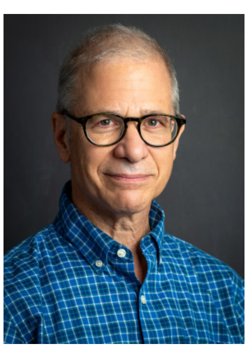
Billinge was featured in *The Independent* article, "AI solves 100-year-old mystery to supercharge scientific discovery." (https://tinyurl.com/4xxp72r7). He was also interviewed by MRS TV and discussed data analysis algorithms in materials science and how they've evolved with artificial intelligence and machine learning. Watch the video at https://tinyurl.com/m37sca5z

Michal Lipson

Lipson Elected to the National Academy of Engineering

Michal Lipson, the Eugene Higgins Professor of Electrical Engineering and professor of applied physics, was elected to the U.S. National Academy of Engineering, one of the highest professional honors recognizing exceptional contributions to the field.

Professor Lipson, who joined the Columbia Engineering faculty in 2015, graduated from Technion, Israel in 1992 with a B.S. in Physics, followed by a M.S. in Physics in 1994 and a Ph.D. in Physics in 1998 from the same university. She has pioneered critical building blocks in the field of Silicon Photonics, which today is recognized as one of the most promising directions for solving the major bottlenecks in microelectronics. She is the inventor of over 30 issued patents and has co-authored more than 200 scientific publications. She was awarded the NAS Comstock Prize in Physics, the MacArthur Fellowship, the Blavatnik Award, the Optical Society's R. W. Wood Prize, the IEEE Photonics Award, and has received an honorary degree from Trinity College, University of Dublin. Since 2014 every year she has been named by Thomson Reuters as a top 1% highly cited researcher in the field of Physics. She is also a member of The National Academy of Sciences. Learn more about Prof. Lipson on page 10.



Michael Weinstein

Weinstein Elected to the American Academy of Arts & Sciences

Michael I. Weinstein has been elected to the American Academy of Arts and Sciences.

Professor Weinstein joined the Columbia University faculty in 2004 and holds joint appointments as a Professor of Applied Mathematics in the Department of Applied Physics and Applied Mathematics, and as a Professor of Mathematics in the Department of Mathematics. He has made major contributions to the mathematical analysis of partial differential equations and other models governing waves in classical and quantum systems.

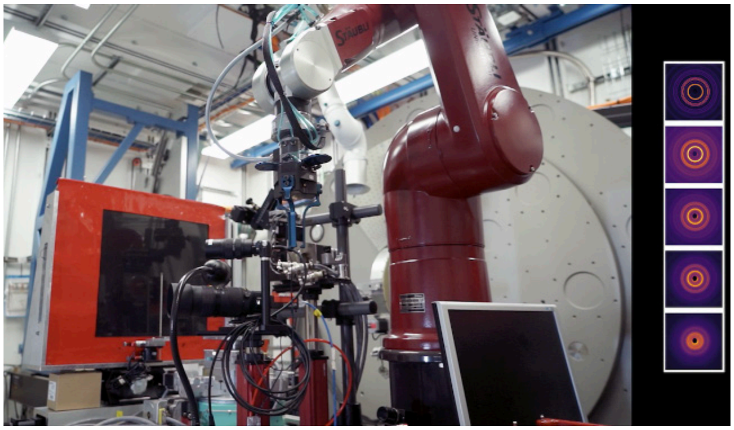
A recognized leader in his field, Professor Weinstein is a Fellow of the American Mathematical Society (AMS), a Fellow of the Society for Industrial and Applied Mathematics (SIAM), and a Senior Fellow in the Simons Society of Fellows. He has served as a Simons Foundation Math + X Investigator since 2015 and also received the Martin Kruskal Prize from SIAM in 2018 for his work on nonlinear waves and coherent structures.

Founded in 1780, the American Academy of Arts and Sciences elects members who have made exceptional contributions to the arts, sciences, academia, business, and public affairs. Professor Weinstein now joins a distinguished group that includes Nobel laureates, Pulitzer Prize winners, and leaders across disciplines.

With AI, Researchers Can Now Identify the Smallest Crystals

AI solves the century-old puzzle of uncovering the shape of atomic clusters by examining the patterns produced by an X-ray beam refracted through fine powder.

By Gabe Guo, Originally published by Columbia Engineering



The technique uses the low-information results of x-ray diffraction.

One longstanding problem has sidelined life-saving drugs, stalled next-generation batteries, and kept archaeologists from identifying the origins of ancient artifacts.

For more than 100 years, scientists have used a method called crystallography to determine the atomic structure of materials. The method works by shining an X-ray beam through a material sample and observing the pattern it produces. From this pattern – called a diffraction pattern – it is theoretically possible to calculate the exact arrangement of atoms in the sample. The challenge, however, is that this technique only works well when researchers have large, pure crystals. When they have to settle for a powder of minuscule pieces — called nanocrystals — the method only hints at the unseen structure.

Scientists at Columbia Engineering have created a machine learning algorithm that can observe the pattern produced by nanocrystals to infer the material's atomic structure, as described in a new study published in *Nature Materials*. In many cases, their algorithm achieves near-perfect reconstruction of the atomic-scale structure from the highly degraded diffraction information — a feat unimaginable just a couple of years ago.

"The AI solved this problem by learning everything it could from a database of many thousands of known, but unrelated, structures," says **Simon Billinge**, Professor of Materials Science and of Applied Physics and Applied Mathematics at Columbia Engineering. "Just as ChatGPT learns the patterns of language, the AI model learned the patterns of atomic arrangements that nature allows.

Crystallography Transformed Science: Crystallography is vital to science because it's the most effective method for understanding the properties of virtually any material. The method typically relies on a technique called X-ray diffraction, in which scientists shoot energetic beams at a crystal and record the pattern of light and dark spots it produces, sort of like a shadow. When crystallographers use this technique to analyze a large and pure sample, the resulting X-ray patterns contain all the information needed to determine its atomic-level structure. Best known for enabling the discovery of DNA's double-helix structure, the method has opened important avenues of research in medicine, semiconductors, energy storage, forensic science, archaeology, and dozens of other fields.

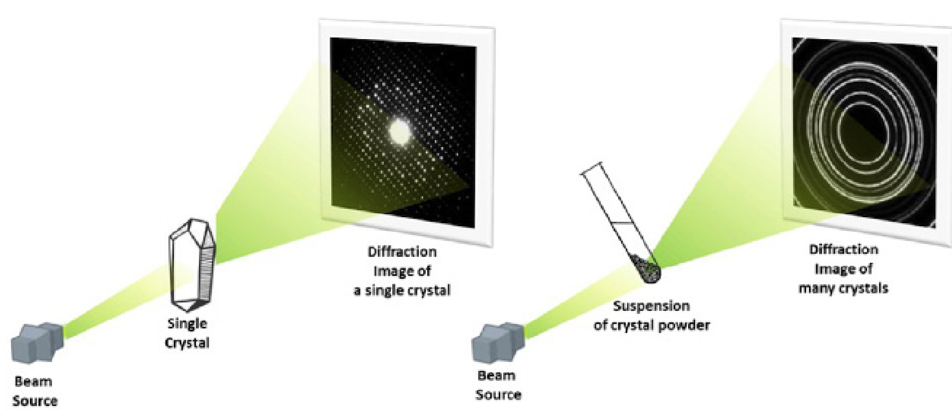
Unfortunately, researchers often only have access to samples of very small crystallites, or atomic clusters, in the form of powder or suspended in solution. In these cases, the X-ray patterns contain much less information, far too little for researchers to determine the sample's atomic structure using existing methods.

AI Extends the Method to Nanoparticles: The team trained a generative AI model on 40,000 known atomic structures to develop a system that is able to make sense of these inferior X-ray patterns. The machine learning technique, called diffusion generative modeling, emerged from statistical physics and recently gained notoriety for enabling AI-generated art programs like Midjourney and Sora.

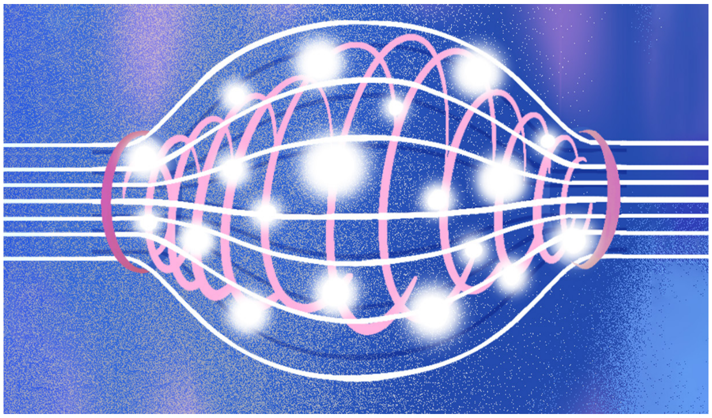
"From previous work, we knew that diffraction data from nanocrystals doesn't contain enough information to yield the result," Billinge said. "The algorithm used its knowledge of thousands of unrelated structures to augment the diffraction data."

To apply the technique to crystallography, the scientists began with a dataset of 40,000 crystal structures and jumbled the atomic positions until they were indistinguishable from random placement. Then, they trained a deep neural network to connect these almost randomly placed atoms with their associated X-ray diffraction patterns. The net used these observations to reconstruct the crystal. Finally, they put the AI-generated crystals through a procedure called Rietveld refinement, which essentially "jiggles" crystals into the closest optimal state, based on the diffraction pattern.

Although early versions of this algorithm struggled, it eventually learned to reconstruct crystals far more effectively than the researchers had expected. The algorithm was able to determine the atomic structure from nanometer-sized crystals of various shapes, including samples that had proven too difficult for previous experiments to characterize. **(Continued on page 12)**



Crystallography is the science of analyzing the pattern produced by shining an X-ray beam through a material sample. A powder sample produces a different pattern than solid crystal.



In fusion, powerful magnets contain high-energy plasma that is far hotter than the center of the Sun.

Columbia Engineering Launches the Columbia Fusion Research Center

The new center will help address global energy challenges, contribute to sustainable climate solutions, and create a new industry and associated employment.

By Grant Currin, Originally published by Columbia Engineering

Columbia Engineering is proud to announce the launch of the Columbia Fusion Research Center, which aims to accelerate the development of fusion energy science and technology to provide a sustainable and scalable energy source for the benefit of society. **Carlos Paz-Soldan**, Associate Professor of Applied Physics and Applied Mathematics at Columbia Engineering, will serve as founding director.

The Center aims to accelerate the development and deployment of this technology through deep engagement with the fusion private sector. It will nurture existing partnerships with industry and provide a strategic framework for collaboration with new partners. The Center will approach the complex research challenges facing fusion energy by facilitating interdisciplinary collaboration across fields including mechanical engineering, applied mathematics, materials science, data science, plasma astrophysics, and energy policy.

Carlos Paz-Soldan

The private sector is racing to develop an approach to economically generate electricity using this safe and sustainable source. The Center aims to support this effort through an innovative partnership mechanism that enables timely access to expertise from academia. This will strengthen Columbia's partnerships with the constellation of fusion startups that currently sponsor research at the University and set the stage for additional partnerships.

"The establishment of a center for fusion energy represents a great milestone for Columbia," said Shih-Fu Chang, Dean of Columbia Engineering. "We have one of the most well-established plasma physics research laboratories in the nation and have been expanding our efforts ever since. This new Center is a significant step forward for fusion energy science and the search for more sustainable energy solutions."

The Center will further support research by funding projects and fellowships that offer early career researchers the opportunity to work without the burden of meeting specific external grant requirements. The Center will also support undergraduate-focused computational programs and contests for Columbia students, a summer internship program for undergraduate and graduate students, and a weekly seminar series. It will also support a K-12 student-run outreach program operated by Plasma Physics Laboratory.

"We see an opportunity to align our research and teaching to the needs of our industry members during this period of rapid growth for the fusion sector," Paz-Soldan said. "To expand quickly, they need a workforce that's able to execute their plans and access to expertise that can respond quickly to problems and opportunities. We're positioning ourselves to grow alongside the fusion industry."

Faculty and Students in the **Plasma Physics Lab** was profiled in the article, "Harnessing the Sun at the Columbia Plasma Physics Lab," published by the *Columbia Spectator*. "Columbia's plasma physics lab is part of a global effort to solve the challenges around fusion with critical contributions to pellet injection, plasma confinement, and plasma modeling research. While larger-scale global projects capture most of the world's attention, Columbia's plasma physics research focuses on both experimental and theoretical obstacles, working to make fusion energy a reality." **https://tinyurl.com/4z4c46y4**

Paul Hosts Sherwood Fusion Theory Conference

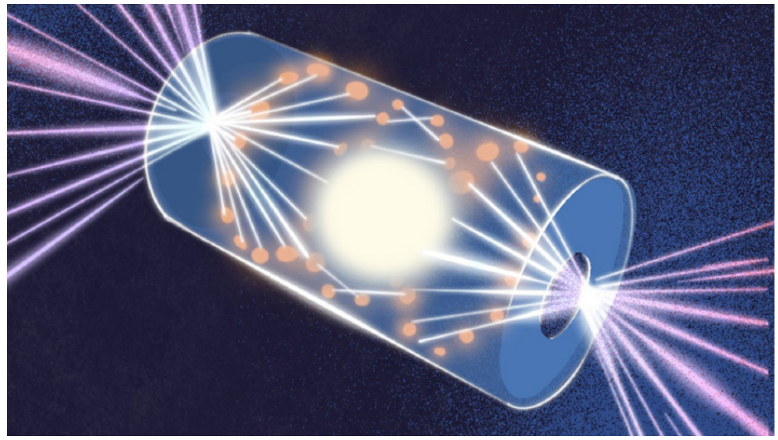
Elizabeth Paul, Assistant Professor of Applied Physics, hosted the 2025 Sherwood Fusion Theory Conference as chair of the Local Organizing Committee and member of the Executive Committee. The meeting took place April 7-9, 2025 at the New Yorker Hotel in midtown. The conference has a long history, the first meeting being held in 1952 when the classified U.S. fusion research effort went under the codename "Project Sherwood." It continues to be the primary annual meeting for theoretical and computational fusion research. The 2025 meeting drew 152 registered participants, including 16 international participants. The program included 12 invited talks, two plenary lectures, three poster sessions, and a panel discussion on "The role of theory and computation in advancing the FPP". On the first day of the conference, the participants enjoyed a reception and plasma lab tour in the Mudd building in celebration of the launch of the Columbia Fusion Research Center.

Every year, outstanding student poster presentations are recognized at the conference banquet. In 2025, Applied Physics Ph.D. student Amelia Chambliss was awarded the Bill Dorland award for her presentation "Quadratic flux-minimizing maps for characterization of energetic particle transport mechanisms in quasihelical and quasiaxisymmetric stellarators". **(Continued on page 13)**

Will Fusion Solve Our Energy Problems?

The new Columbia Fusion Research Center is supporting academic-industry collaborations to accelerate a new paradigm for generating electricity.

By Grant Currin, Originally published by Columbia Engineering



(Above) Fusion artwork courtesy of Kailey Whitman (Below) Prof. Paz-Soldan addresses the crowd at the Columbia Fusion Research Center launch

Fusion energy would transform the energy landscape. Without the carbon emissions of fossil fuels, the potential risks of nuclear fission, or the intermittent supply from wind and solar, the technology would define a new era of clean and reliable electricity.

Over the last several years, investors have underwritten billions of dollars in private-sector R&D and early-stage commercialization efforts. Researchers at Columbia University have supported this effort through basic research, technical consulting, and workforce development. The new Columbia Fusion Research Center aims to deepen those efforts by strengthening existing partnerships with industry and providing a strategic framework for collaboration with new partners.

Carlos Paz-Soldan, Associate Professor of Applied physics and Applied Mathematics, is the center's founding director.

What is the promise of fusion energy? For one, it's a dispatchable energy source, which means it can be built where it's needed. The inputs are seawater and lithium, so it's an opportunity for true energy sovereignty. The waste streams are manageable, which puts it in a different ballpark from traditional nuclear energy or fossil fuel sources. It's also what we call baseload energy, meaning it's able to run when the wind isn't blowing and the sun isn't shining.

How does fusion work? When we heat certain kinds of hydrogen atoms to very high temperatures, they release high-energy neutrons that contain energy that we can capture and use. The hydrogen atoms transform into a state of matter called plasma, which is far hotter than the Sun. It's so hot that no material can contain it, so we have to use magnetic fields to prevent it from touching (and destroying) the walls of the reactor.

What are some of the biggest engineering challenges? Researchers in academia and industry have spent decades developing technologies that can contain plasma and heat it to more than 100 million degrees Celsius. The challenges include designing magnetic fields to keep the plasma stable and away from reactor walls, building materials and components that can endure intense heat and neutron bombardment, developing blanket systems to capture energy from high-energy neutrons and convert it into usable heat, and developing precise control systems to manage plasma behavior in real-time.

When could we see the first fusion power plants plugging into the grid? Certain things have to happen before electrons generated by fusion start flowing onto the grid, and those things cost money. So, it depends on how much our society — both the government and private capital — is willing to invest. If that funding is sufficient to enable continued growth in the sector, then we're looking at a timeframe in the 2030s. Optimistic people will tell you mid-2030s, but I personally envision a late-2030s scenario if the required investments are made.

What hurdles stand in the way? Most people still don't think this technology is even possible, so it's essential that we see demonstration facilities to prove the viability of this technology. Furthermore, public awareness remains low – what fraction of our society understands the potential benefits fusion offers? One of our partners, Commonwealth Fusion Systems, has a project in Massachusetts that's well on its way to demonstrating long-duration energy production from fusion plasma. Other companies are gathering momentum for their own demonstration devices. Efforts like that will unlock new funding that's essential for the next stage of fusion power generation.

How is the Fusion Research Center helping to achieve this goal? The new Center will promote basic research, knowledge transfer and technical support, workforce development, and public outreach. We're actively expanding collaboration with industry partners. One of our most exciting new initiatives is the branded fellowship program, which pairs students with companies on complementary projects. The objective is to enable rigorous and useful research while building a skilled fusion workforce. The Center also plans to launch seed funding calls to support early-stage research, encouraging broader participation across the university and diversifying the research portfolio.

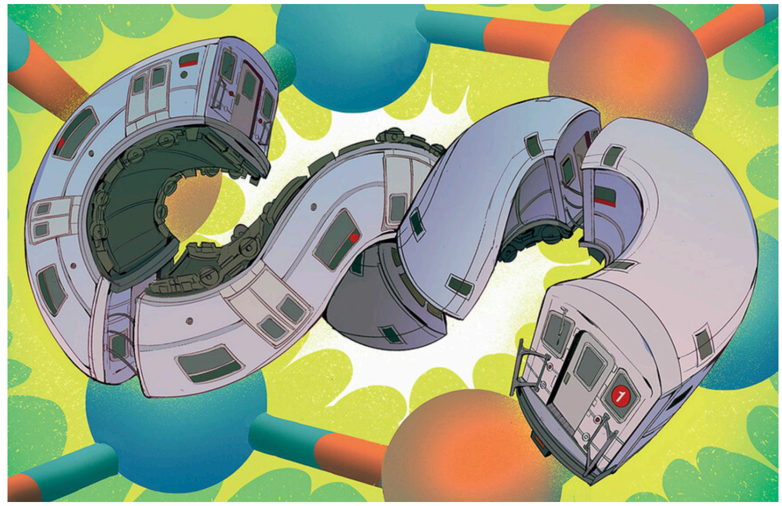
How else does the Center support its industry partners? We can provide on-call technical expertise to our industry partners, offering rapid support for specialized calculations and design assessments that companies may not have the capacity to handle in-house. Once a master research agreement is in place, new collaborations can be launched very quickly. Our goal is to complement our partners' core competencies.

Why is Columbia uniquely positioned to lead in this moment? This is one of the first university centers focused on supporting the fusion industry's growth. We're not just pursuing academic milestones, we're working closely with companies to accelerate their progress and guide our academic work. That alignment is rare, and it reflects something distinctive about Columbia Engineering: a willingness to engage directly with industry to solve urgent global challenges.

Scientists Edge Closer to Affordable Superconductors

Novel materials could eventually power electric vehicles and more, say Columbia researchers

By David J. Craig, Originally published by *Columbia Magazine*



Animated image of a subway train by Andy Kim, *Columbia Magazine*

Imagine a world in which free-floating electric vehicles charge wirelessly as they glide down highways, laptops are hundreds of times more powerful, and clean energy flows in limitless supply.

Such a future, experts say, hinges on the development of new superconductors, or materials capable of transmitting electricity with near-perfect efficiency. The problem? All known superconductors—from pure elements like lead, tin, and aluminum to exotic compounds like niobium-titanium—must be subjected to extreme cold or pressure to function, making them impractical for widespread use. More problematic still, scientists don't fully understand how these materials work, making it difficult to engineer better versions.

Superconductors have already made their way into MRI machines, particle accelerators, and electromagnetic levitating trains, but they are extraordinarily expensive and finicky. The real game changer, experts say, will be figuring out how to custom-design superconductors that are cheaper and more versatile.

Now a multidisciplinary team of Columbia researchers led by physicist Cory R. Dean is bringing the scientific community closer to that goal. In a recent study in *Nature*, the scientists demonstrated that a compound called tungsten diselenide, which has a crystalline structure, can be made to exhibit superconductivity when sliced into sheets just one or two atoms thick and then manipulated in precise ways. The discovery marks one of the first times that scientists have induced superconductivity in a material by modifying its structure at the nanoscale, thus offering new clues about how to create the next generation of superconductors.

Dean and his colleagues, who include fellow Columbia physicists Andrew Millis and Abhay Pasupathy, along with mechanical engineer Jim Hone and **materials scientist Katayun Barmak**, have been experimenting with tungsten diselenide since 2020. Their interest was sparked by a previous discovery by MIT physicist and former Columbia research fellow Pablo Jarillo-Herrera, who found that graphene—a novel material that consists of a single layer of carbon atoms—becomes superconductive when stacked and twisted at particular angles. Inspired by Jarillo-Herrera's finding, Dean and his colleagues set out to see if a similar approach could work for other ultra-thin, so-called "two-dimensional" materials.

"An important question was whether superconductivity arises from unique properties of graphene or rather could be induced by twisting any combination of two-dimensional materials," says Dean.

The Columbia researchers, after wrestling with tungsten diselenide for years, recently found a winning formula: place two sheets next to each other, rotate one of them five degrees, and cool them to -272.7°C, or about half a degree above absolute zero. When the researchers finally applied a charge, electrons surged through the material at lightning speed—orders of magnitude faster than they'd move through ordinary metals.

The discovery of superconductivity in tungsten diselenide, like that in graphene before it, is just one step toward the larger goal of designing more versatile superconductors. Both of these exotic materials must still be cooled to extraordinarily low temperatures before electricity will flow unimpeded through them, meaning that they are not yet viable alternatives to superconductors currently found in medical-imaging equipment and a handful of other advanced technologies. But Dean's breakthrough is regarded as one of the most significant advances in materials science in years, providing crucial new insights into the mechanism of superconductivity and fueling optimism that scientists might one day engineer superconductors that can operate under more practical conditions.

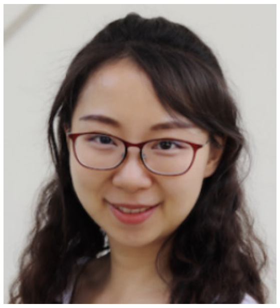
"To develop a superconductor that works at room temperature is really the dream," says Dean, adding that such a material would revolutionize nearly all industries that rely on electronics, from computing and medicine to power generation and transportation. "Our discovery could very well be the key that makes this dream a reality."

Barmak Research Published in Advances in Engineering

Prof. Katy Barmak and colleagues were featured in the article, "Advancing the Study of Grain Growth Dynamics in Thin Films: Real-Time Imaging, Crystallography and Deep Learning at the Frontier," published in *Advances in Engineering*.

The article describes how Columbia researchers have pioneered a method to observe grain growth dynamics in nanocrystalline thin films in real time by combining transmission electron microscopy with MEMS heating systems and deep learning algorithms. Linking the dynamics to the experimental crystal orientations and grain boundary crystallography will guide the development of grain growth theory. Read more at **https://tinyurl.com/27azu978**

Searching for Unorthodox Improvements to Quantum Systems



Sherry Zhang

Sherry Zhang is working on new approaches to enhance quantum computing performance

By Grant Currin, Originally published by Columbia Engineering

Computers that leverage the principles of quantum mechanics stand to far exceed the capabilities of classical computers—but there are still many hurdles for the technology to overcome.

For example, researchers still have to reduce error rates and figure out how to fix the mistakes they can't prevent. They have to improve connectivity within these systems while scaling them orders of magnitude larger. And they have to refine and develop hardware that can work at incredibly high levels of precision on extremely small scales.

At Columbia Engineering, **Xueyue (Sherry) Zhang,** an Assistant Professor of Applied Physics and Applied Mathematics, is leading a new research group that's investigating overlooked and underappreciated ideas for addressing some of the most important outstanding problems in quantum computing.

We sat down with Zhang to learn more about the research happening in her Photonic Quantum Integrated Systems Lab.

What's the overarching goal of your research program?

We're focused on building quantum devices and hardware that can potentially outperform classical computers by harnessing quantum mechanics. Our goal is to find practical pathways towards realizing quantum computing—something that many researchers consider a holy grail. However, there are substantial challenges to overcome, especially concerning the interactions among qubits, the quantum bits fundamental to these systems.

What makes your approach unique?

We are addressing core quantum computing challenges from a fresh perspective. Rather than incrementally advancing existing technologies, we're exploring unconventional methods and architectures that have previously been overlooked or dismissed. Specifically, we're rethinking how quantum bits communicate with each other, moving beyond traditional short-range interactions.

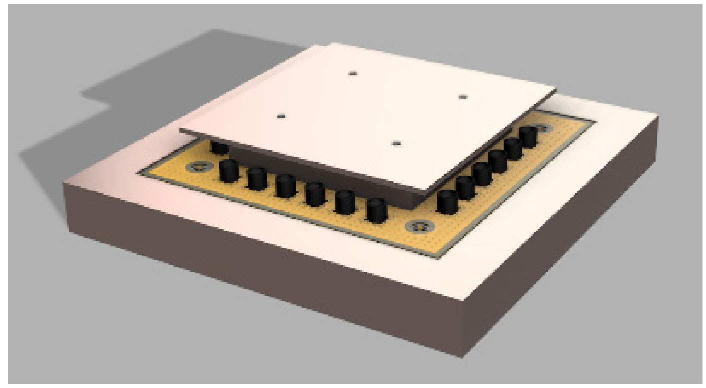
Can you give an example?

Our current project, funded by Amazon, focuses on superconducting qubits. These are among the most advanced qubit technologies today and are already widely adopted by major companies like Google, IBM, and Amazon. Superconducting qubits are solid-state devices made on silicon or sapphire substrates using semiconductor manufacturing techniques, offering exceptional controllability and reliability.

However, traditional superconducting quantum processors arrange qubits in two-dimensional grids. While effective for simpler quantum circuits, this setup becomes inefficient when scaling up to hundreds or thousands of qubits, especially when performing complex quantum error corrections required for practical quantum computing. The limitation arises because each qubit is connected only to its immediate neighbors, forcing information to take inefficient, roundabout paths.

How is your research addressing this issue?

Our solution involves enabling long-range interactions between qubits through waveguides, which are communication channels for quantum signals. They're similar to a fiber-optic cable for quantum signals, guiding microwave photons across the processor. These photons act as carriers of quantum information, linking qubits that are physically distant from each other. This significantly enhances connectivity without needing extensive physical wiring or complicated layering.



A CAD rendering of a quantum chip from the Zang lab

Could you explain more about the waveguides you're using?

In our experiments, waveguides are fabricated alongside the superconducting qubits on the same silicon chip. They form a pathway that photons can use to travel freely, allowing multiple qubits to interact efficiently across greater distances. This architecture reduces the complexity and increases the effectiveness of the quantum processor, potentially making error correction and quantum computing operations more efficient.

What's the status of this project today?

We're working on building prototypes to demonstrate the viability of these concepts. Initially, our lab will create smaller-scale setups of around ten qubits to show proof of concept. Demonstrations at this level are the first step toward larger quantum processors comprising hundreds of qubits.

How will this project impact the future of quantum computing?

Our waveguide-based architecture would significantly accelerate quantum computing's progress by simplifying the pathway to more scalable, practical quantum processors. This approach addresses fundamental bottlenecks in quantum information processing and could become a key technology enabling more efficient quantum error correction and larger quantum systems.

Why is Columbia Engineering an ideal place for this research?

Columbia Engineering is uniquely positioned due to its strong emphasis on innovative and interdisciplinary approaches. The culture here supports taking risks on new ideas that might initially seem unconventional but have the potential to address significant scientific and technological challenges. The strong partnership with industry leaders like Amazon also provides essential resources and a direct link to real-world quantum computing applications.

What's next for your research?

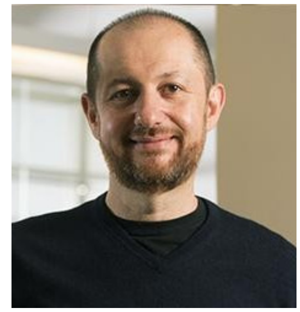
Beyond the current project, we continue exploring novel architectures and coupling strategies for quantum processors. We're actively pursuing additional avenues that can further enhance quantum performance and scalability, including entirely different types of qubits and advanced control techniques.

Ultimately, our goal is to bring quantum computing closer to reality, transforming this powerful theoretical technology into practical, usable devices that can tackle computational challenges far beyond the capabilities of today's classical computers.

DNA Helps Electronics to Leave Flatland

These miniature scaffolds for 3D circuits are designed to assemble themselves.

By Charles Q. Choi, Originally published by Columbia Engineering



Oleg Gang

Researchers at Columbia Engineering have for the first time used DNA to help create 3D electronically operational devices with nanometer-size features.

"Going from 2D to 3D can dramatically increase the density and computing power of electronics," said corresponding author **Oleg 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 new manufacturing technique could also contribute to the ongoing effort to develop AI systems that are directly inspired by natural intelligence.

"3D electronic architectures that imitate the natural 3D structure of the brain may prove enormously more effective at running brain-mimicking artificial intelligence systems than existing 2D architectures," Gang said. The researchers detailed their findings March 28 in the journal *Science Advances*.

From etching to folding: Conventional electronics rely on flat circuitry. To help microchips grow more powerful, researchers worldwide are experimenting with approaches to building them in three dimensions.

However, current electronics manufacturing techniques are top-down in nature—a piece of material is gradually eroded, for example, by an electron beam, until the desired structure is achieved, like sculpting a block of stone. These methods have encountered problems fabricating 3D devices when it comes to creating complex structures and doing so in a cost-effective manner. For instance, they face challenges in assembling multiple layers of circuitry that stack up properly. "Over the course of hundreds of steps during production, errors accumulate that are prohibitive from the point of view of performance and cost," Gang said.

A conceptually different way to build a 3D system is from the bottom up, where many components self-assemble into complex structures. Now Columbia Engineering researchers have developed a new biologically inspired bottom-up way for 3D electronics to build themselves. The key behind the new technique is the way in which strands of DNA can fold themselves into shapes—so-called origami. These building blocks, called frames, are then used to assemble large-scale 3D structures, called frameworks, with nanoscale precision.

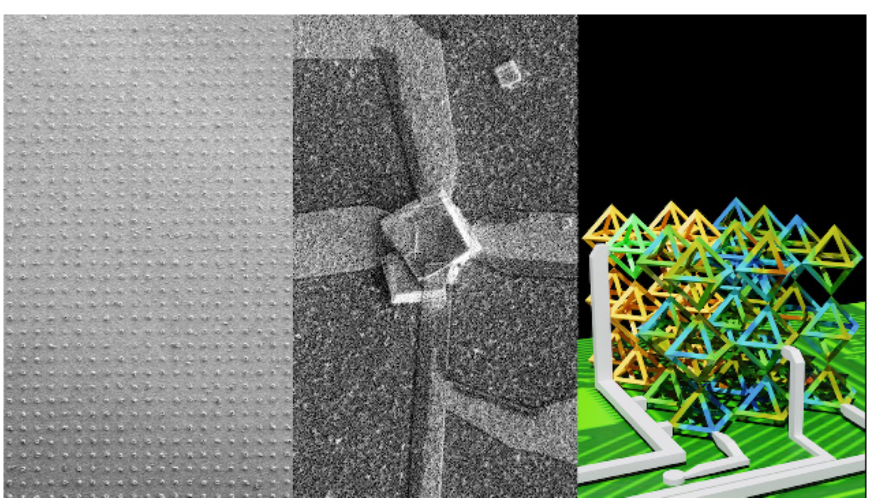
DNA is made of strings of four different kinds of molecules, known by the letters A, T, C and G. These stick to each other in highly specific ways—A to T, and C to G. By designing multiple molecules with the right sequences, researchers can get long DNA strands to fold themselves into 2D or 3D shapes. Snippets of DNA stapled onto these strands then hold the folded designs in place.

Building the prototype: In the new study, the study's first author **Aaron Michelson** (PhD '22, Materials Science & Eng.), a staff scientist at Brookhaven National Laboratory's Center for Functional Nanomaterials, who was previously a PhD student in Gang's group, along with Gang and their colleagues, deposited arrays of gold squares on a surface, onto which they could attach short pieces of DNA. These molecules served as anchors to which they could fasten eight-sided diamond-like octahedral DNA frames that self-assemble into 3D frameworks at these specific surface locations.

"These gold arrays with anchored DNA strands promote the growth of 3D DNA scaffolds on designated areas in desired patterns and orientations, which allows us to establish and integrate this DNA onto an electronic wafer," Gang said.

The researchers, in collaboration with Professor Vald Pribiag's group at the University of Minnesota, next coated these DNA scaffolds with silicon oxide, laced them with the semiconductor tin oxide, and connected electrodes to each structure. The result—light sensors that respond electrically when illuminated.

"We've demonstrated that not only can we create 3D structures from DNA, but integrate them into microchips as part of the workflow of how electronic devices are fabricated," Gang said. "We can place thousands of these structures at specific sites on silicon wafers in a scalable way. This demonstrates that we can drastically change how we fabricate complex 3D electronic devices."



"For a long time, we have worked on what phenomena might help build a self-assembling electronic device," Gang said. "It's exciting to now actually demonstrate these futuristic ideas, to actually make an operational device using these bottom-up fabrication processes."

In the future, Gang and his colleagues would like to use their new method to create more complex electronic devices using more than one material. "The next dream is creating 3D circuitry," he said.

Image: Chip-integrated 3D nanostructured device fabricated using DNA self-assembly (Left panel). A DNA crystal is grown at a designated substrate location (about 1000 crystals on 5μm pads are shown on a Right panel), then mineralized to silica and volumetrically templated with a semiconductor material before electrodes are attached (Center panel). The resulting device exhibits an electrical response when exposed to light. Thousands of such 3D devices can be grown in parallel using this bottom-up fabrication approach.

Michal Lipson

Lighting the Way for Women in Science

From being the only woman in her physics class as an undergraduate to revolutionizing silicon photonics in the industry, Michal Lipson's journey proves that belief in one's work can change the future.

By Xintian Tina Wang, Originally published by Columbia Engineering

In 1987, **Michal Lipson** and her twin sister walked into their first physics class at the Instituto de Física of the University of São Paulo in Brazil, eager to embark on their academic journeys. As they looked around, an unsettling realization set in—they were the only two women in the classroom. That evening, when she returned home, Lipson asked her father, Reuven Opher, himself a physicist, why he had never warned them that they would be such an anomaly in their field.

"My father honestly didn't even think about it as an issue," Lipson recalls. "He was so used to it, so he didn't see women pursuing STEM majors as a problem. He didn't see gender—for good and for bad."

The moment stayed with Lipson. It became a source of quiet strength. "By not putting us into this 'minority' title, my father inspired me to pursue what we loved without hesitation," she says.

That unshaken belief carried her through a groundbreaking career in silicon photonics, a field she helped pioneer and which has now revolutionized data transmission, artificial intelligence, and microelectronics. Today, Lipson is the Eugene Higgins Professor of Electrical Engineering and Professor of Applied Physics at Columbia Engineering, member of the National Academy of Sciences and newly elected member of the National Academy of Engineering.

Changing the narrative: Throughout her career, Lipson has had to navigate the same gendered dynamics she first encountered in that first-year physics class. Decades later, she still finds herself scanning the room at scientific conferences, counting the number of other women present—often just a handful or none at all.

"Despite our enormous efforts, I don't think the numbers have improved," she says. "The awareness has changed, but the numbers? Not so much."

One of the biggest hurdles for women in STEM, she notes, isn't outright discrimination but rather subtle biases—the ways women are described, evaluated, and often diminished in professional settings.

Lipson has been vocal about these disparities, particularly in academia, where women's recommendation letters tend to focus on qualities like being "hardworking" and "enthusiastic" rather than their intellectual brilliance. "Men are rarely praised for 'working hard'—it's just assumed," she says.

Her advocacy extends beyond words. At Columbia Engineering, she works to ensure that young female faculty and students receive the mentorship and support they need to thrive. "We have to make sure they are supported and respected like everybody else," she says. "And this part of the puzzle is improving."

Though men still dominate the architecture and engineering fields, women have made strides over the decades. According to the U.S. Bureau of Labor Statistics, women accounted for just 9 percent of professionals in these industries in the 1990s. By 2024, that number had risen to 17.2 percent.

Betting on silicon photonics: In the early 2000s, silicon photonics was far from the established field it is today. At the time, many believed that silicon was not an ideal optical material, particularly when compared to well-known photonic materials like compound semiconductors. There were no commercial foundries dedicated to fabricating silicon photonics, and some dismissed the entire concept as a fleeting academic trend.

Lipson, then a faculty member at Cornell University, was repeatedly advised to diversify her research and not to "put all her eggs in one basket." It was a risky bet—there were no guarantees that silicon photonics would gain traction, and pursuing a niche, unproven field could jeopardize her academic career.

But Lipson saw the potential. By the time she faced her three-year tenure review, the pressure to shift research directions intensified. Some urged her to explore safer, more conventional areas of optics. But instead of stepping away, she made a bold decision: "I believed in it. I was going to continue. And if I couldn't stay at Cornell, that's okay."

The decision proved to be pivotal. Lipson's foundational work—particularly her breakthroughs in ring modulators, fiber-to-chip coupling and slot waveguides—laid the groundwork for what would become a booming field. Her research paper on slot waveguides (*Optics Letters*, 2004) has since been cited over more than 1600 times, helping trigger a wave of research and industry adoption.

This paper was originally viewed as a theoretical exercise, Lipson says. Years later, she was visiting a semiconductor foundry when they presented a standardized industry fabrication process, a detailed method for coupling fibers to silicon waveguides—one that was, to her astonishment, nearly identical to what she had published years before. "I was stunned to see that they used it exactly as we had described," she says. "I didn't believe it would be so heavily used at the time."

Silicon photonics is now integral to high-speed data transfer, cloud computing, and AI infrastructure. Large-scale foundries now manufacture silicon photonic chips, something that seemed nearly impossible when Lipson first started.

Quantum, AI and novel materials: Now, her work is focused on the next frontier: scaling silicon photonics for AI and quantum computing.

"The bandwidth is never enough. There are never enough channels, never enough speed," she explains. "So one direction we're working on is enabling silicon photonics to keep scaling in efficiency."

Another avenue of her research involves integrating novel materials into silicon photonics systems, an area that was once considered impractical.

"Foundries today are much more willing than we initially thought to integrate new materials," she says. "We're now exploring lithium niobate, silicon nitride, and even emerging materials like barium tantalite."

Her research has also led her to Xscape Photonics, the company she cofounded in 2022 along with Columbia Engineering faculty and frequent collaborators Keren Bergman and Alexander Gaeta to tackle AI's growing data transfer bottleneck. The startup recently secured $44 million in Series A funding to develop multi-color photonic connectivity solutions that could dramatically reduce energy consumption and increase computing efficiency in AI data centers.

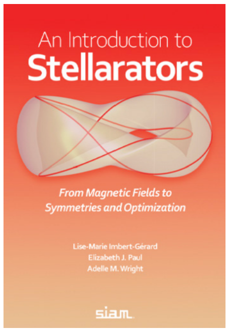
"It's extremely gratifying," she says. "For the first time, we're taking the technology we developed in our labs and applying it directly to solve one of the biggest problems in the industry."

Words of wisdom for the next generation: When asked what advice she would give to young women entering STEM, Lipson's answer is clear: pursue what you truly believe in, even if it means going against the grain.

"Make sure that what you pursue is something you understand deeply and believe in—not because it's fashionable, not because others think it's important, but because you do," she says. "If you do that, it's going to fly."

Her own story is proof of that conviction. From a lone female student in a physics lecture hall in Brazil to a leader in the booming field of silicon photonics, Lipson has been instrumental in reshaping the future of technology—all by trusting in the power of her own light.

Paul Co-authors *An Introduction to Stellarators*



Elizabeth Paul, Assistant Professor of Applied Physics, has published the monograph, *An Introduction to Stellarators: From Magnetic Fields to Symmetries and Optimization,* along with her co-authors, Lise-Marie Imbert-Gerard (University of Arizona, Tucson) and Adelle Wright (University of Wisconsin, Madison).

The book project grew out of the Hidden Symmetries and Fusion Energy collaboration, funded by the Simons Foundation. Since this group brought together mathematicians, computer scientists and plasma physicists to advance stellarator optimization, it became clear that a common language was needed in order to communicate effectively. The project initially started in 2018 as a "plasma dictionary", defining key terms in stellarator plasma theory, but then grew into a more substantial book as the collaboration progressed. Along the way, the text has been used as a reference for several summer schools. Prof. Paul has also developed a course around the text, which was taught in Spring 2024 under APPH9143: Special Topics in Applied Physics.

The book aims to present the basic theoretical building blocks to understand modeling of stellarator magnetic fields. Given its multidisciplinary nature, it is accessible to a broad technical audience who may not have a background in plasma physics. The book is available to Columbia affiliates through the University library system and can be purchased from SIAM.

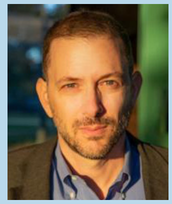
With AI, Researchers Can Now Identify the Smallest Crystals (continued from page 5)

"The powder crystallography challenge is a sister problem to the famous protein folding problem where the shape of a molecule is derived indirectly from a linear data signature," said Hod Lipson, James and Sally Scapa Professor of Innovation and chair of the Department of Mechanical Engineering at Columbia Engineering, who, with Billinge, co-proposed the study. "What particularly excites me is that with relatively little background knowledge in physics or geometry, AI was able to learn to solve a puzzle that has baffled human researchers for a century. This is a sign of things to come for many other fields facing long-standing challenges."

The century-old powder crystallography puzzle is particularly meaningful to Lipson, who is the grandson of Henry Lipson CBE FRS (1910–1991) who pioneered computational crystallography methods. In the 1930s, Henry Lipson worked with Bragg and other contemporaries to develop early mathematical techniques that were broadly used to solve the first complex molecules, such as penicillin, leading to the 1964 Nobel prize in Chemistry.

Gabe Guo BS'24, currently a PhD student at Stanford University, who led the project while he was a senior at Columbia, said, "When I was in middle school, the field was struggling to build algorithms that could tell cats from dogs. Now, studies like ours underscore the massive power of AI to augment the power of human scientists and accelerate innovation to new levels."

APAM in the News



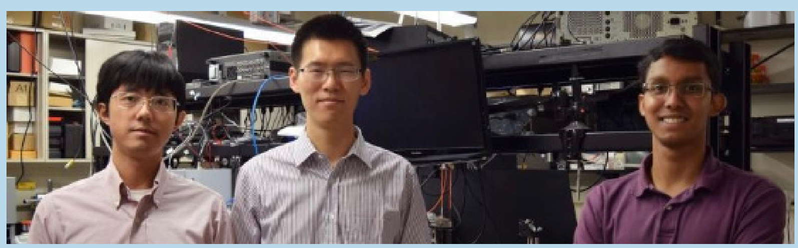
Prof. Adam Sobel's opinion piece, "With NOAA Cuts, a Proud Legacy and Vital Science Are at Risk" was published in *Yale360*. Sobel writes, "For more than 50 years, NOAA has pioneered climate research and been instrumental in advancing modern weather forecasting. Now labeled by Project 2025 as part of the "climate alarm industry" and facing DOGE-driven cuts, the future of this valuable public asset is in jeopardy. **https://tinyurl.com/2tv3xeu6**

Sobel's other piece, "How the Trump administration could end a century of American scientific dominance," was published in the *Bulletin of the Atomic Scientists*. Sobel writes, "The chaos and unpredictability, and the shocking new reality that a hostile administration can undermine or even disable entire agencies on a moment's notice, are already causing the gifted, hardworking young researchers who power American scientific institutions to rethink their career choices." **https://tinyurl.com/3eb3haaz**

Sobel was also featured in the article, "Highlights: 'From Chaos to Code: How AI Can Tame the Climate Crisis,'" published by *The State of the Planet*. Sobel participated in a panel of experts at the Columbia AI Summit, where they discussed the growing role of AI in advancing climate science, improving disaster preparedness, and strengthening resilience in complex, interconnected systems. **https://tinyurl.com/4k4mzb4d**

What does data governance mean? The vague meaning has consequences for ethics and AI. **Prof. Chris Wiggins** and Alison Powell argue it's time to articulate a vision of governance that centres social participation, shared decision-making and equitable distribution of benefits and risks. Learn more in their article, "How data governance happens (and why it matters)" was published by *LSE Business Review*. **https://tinyurl.com/yc5bjr97**

Wiggins was also featured in the article "Introducing 'Persuasion at Scale,'" published by *Columbia College News*, which highlights a new interdisciplinary course he launched with Prof. Eunji Kim (Columbia College). The course, developed with support from the 2024 Cross-Disciplinary Frontiers Courses award—an initiative established by the Office of the Provost in 2023—explores the multifaceted nature of persuasion in the modern world, bridging political science, communication, journalism, marketing, and public health. Designed to foster innovative, collaborative teaching, the program encourages faculty from different schools to co-develop new courses or re-envision existing ones through an interdisciplinary lens. **https://tinyurl.com/26dz4tsc**



(Above) Nanfang Yu, Yuan Yang, and Jyotirmoy Mandal)

ChillSkyn, a startup commercializing Passive Daytime Radiative Cooling Technology (developed by Columbia Engineering faculty, **Prof. Yuan Yang** and **Prof. Nanfang Yu**, and APAM alumn, **Dr. Jyotirmoy Mandal '19**) raised $1.94M in seed funding led by TandemLaunch Ventures III and IV, Cycle Momentum, and a group of angel investors. Learn more at: **https://tinyurl.com/2zcttjfv**

For additional information about the research behind this technology, see the patent: Y. Yang, J. Mandal and N. F. Yu, "Scalable Method of Fabricating Structured Polymer for Passive Daytime Radiative Cooling and Other Applications", WO-2019113596 (2017), licensed to ChillSkyn. **https://pubchem.ncbi.nlm.nih.gov/patent/US-12210146-B2**

Figure 1: (left-right) APAM students Freddie Sheehan, Matt Tobin, Prof. Steven A. Sabbagh, Dr. Guillermo Bustos-Ramirez, & Dr. Hankyu Lee, part of the APAM Team producing the first disruption avoidance with real-time Disruption Event Characterization & Forecasting (DECAF) on the KSTAR fusion device.

Figure 2: (left-right) APAM students Matt Tobin & Juan Riquezes (1st & 3rd from left) with Prof. Steven A. Sabbagh, Dr. Guillermo Bustos-Ramirez, Dr. Hankyu Lee, & colleagues Dr. Shira Morosohk (General Atomics) & Dr. Jun-Gyo Bak (KFE) touring the $1B USD-class international superconducting KSTAR device.

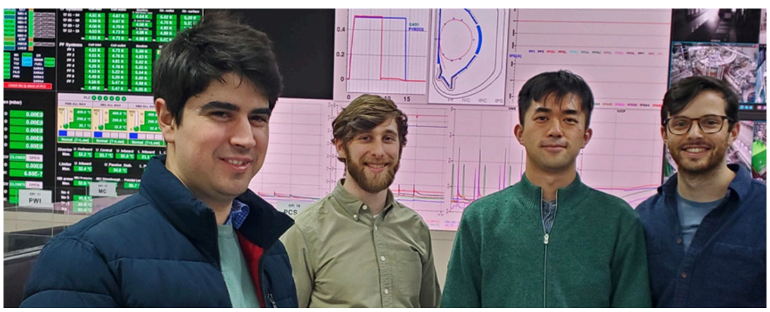


Figure 3: (left-right) Dr. Guillermo Bustos-Ramirez, Mr. Matt Tobin, Dr. Hankyu Lee, and Mr. Freddie Sheehan in front of the floor-to-ceiling display wall in the KSTAR control room.

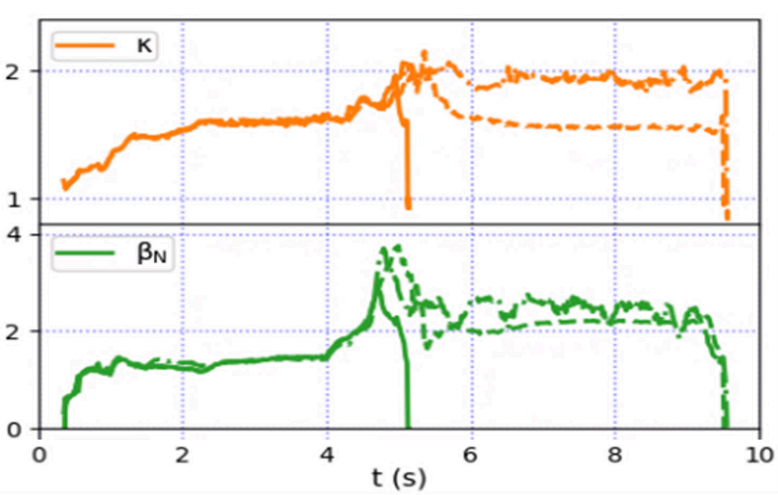


Figure 4: Time-evolving elongation and normalized beta stability values for three KSTAR plasmas: the shortest is terminated by a disruption (solid line). The second (dashed line) shows disruption avoidance by real-time DECAF, & the third shows an initial optimization of the disruption avoidance.

First Demonstration of Tokamak Disruption Avoidance by Disruption Event Characterization and Forecasting in the KSTAR Superconducting Fusion Device by Sabbagh Research Group

by Steven A. Sabbagh

Limitless energy produced by magnetic fusion has been a long sought goal. This process, which is the energy source of stars, including our Sun, has no carbon emissions and is now being pursued by a worldwide nascent industry. The leading type of magnetic fusion device, the tokamak, has a long-known critical shortcoming - the plasma that creates fusion can "disrupt", which stops energy production. To make the device viable for energy production, this issue needs to be overcome with high reliability.

Recently, a scientific and technological breakthrough has shown the first demonstration of a multi-element system for prediction, avoidance, and mitigation of plasma disruptions in the $1B USD-class South Korean KSTAR superconducting fusion device (https://www.kfe.re.kr/eng). An international team of scientists and engineers from the Columbia University APAM Department (Figs. 1-3), the Korea Institute of Fusion Energy, the Princeton Plasma Physics Laboratory, and General Atomics, led by APAM senior research scientist and adjunct professor **Steven A. Sabbagh**, produced the first experimental demonstration of a multi-element, high accuracy plasma disruption prediction approach (Disruption Event Characterization and Forecasting, or DECAF [S.A. Sabbagh, et al., *Physics of Plasmas* 30 (2023) 032506]; https://doi.org/10.1063/5.0133825) with the ability to avoid plasma disruptions in the device thereby allowing an otherwise disrupting plasma to continue operation until it was intentionally shut down after a long pulse duration.

Prof. Sabbagh's present Columbia research group includes APAM associate research scientist **Dr. Veronika Zamkovska**, post-doctoral researchers Dr. Guillermo Bustos-Ramirez, Dr. Joseph Jepson, Dr. Hankyu Lee, and students **Juan Riquezes, Matt Tobin, Frederick Sheehan,** and **Grant Tillinghast**. The majority of the group visited KSTAR in December 2024 and January 2025, tirelessly working until early morning hours to produce the first result on January 15th, and reproducing it under different plasma conditions and producing initial optimizations on January 17th (Figure 4).

The experiments showed the versatility of the DECAF system with "DECAF Event feedback", which includes device hardware actuation by a variety of internal feedback controllers and also couples to and commands external controllers seamlessly, such as a plasma shaping controller produced by Dr. Jayson Barr of General Atomics. All such controllers were used in these initial experiments.

Recently, plasma control management of the $22 billion dollar ITER Project (https://www.iter.org), led by Dr. Peter de Vries, has endorsed the implementation and use of DECAF for real-time disruption prediction and avoidance in ITER, along with associated physics analysis. (https://www.apam.columbia.edu/worlds-largest-fusion-energy-tokamak-device-endorses-sabbagh-research-group-solution-enabling).

This initial demonstration of tokamak disruption avoidance by DECAF on the KSTAR device paves the way for a comprehensive disruption avoidance solution by expanding the present system, providing a critical device control component that can help enable tokamak devices to produce abundant fusion energy for the planet.

Plasma Physics Program Welcomes Two New NSF Fellowship Recipients

Eleanor Winkler & Margaret "Meg" Fairborn

Margaret Fairborn and Eleanor Winkler, both recipients of the National Science Foundation Graduate Research Fellowship (NSF GRFP) have decided to pursue their doctoral education at Columbia University's Plasma Physics Program within the APAM Department.

Columbia continues to attract the largest number of national fellows interested in plasmas via these programs. Since 2023, including the Department of Energy Computational Sciences Graduate Fellowship (DOE CSGF) program, 50% of these national fellows studying plasma have matriculated at Columbia (5 of 11 NSF GRFP awardees and 3 of 4 DOE CSGF awardees). These competitive national fellowships enable awardees to engage in research free from the constraints of traditional grants, and enables the research program to move in new directions that may not yet have traditional funding programs established.

"I am continually impressed by the calibre of students interested in studying plasma physics and fusion energy, and honored that they choose to study at Columbia." said Prof. Carlos Paz-Soldan, the Director of the Columbia Fusion Research Center. "A key measure of a program's impact is its ability to recruit top talent."

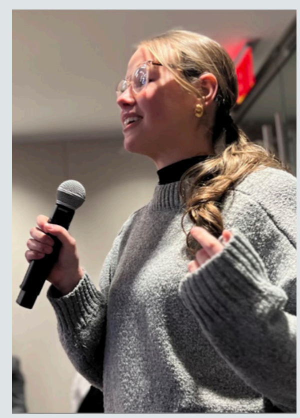
Eleanor Winkler is an incoming Ph.D. student. She completed her bachelor's degree in physics at MIT and spent her undergraduate years experimenting with various fields to determine what she is most passionate about. Her introduction to fusion research was a summer internship in neutronics for blanket design for a fusion start-up, exploring breeders, moderators, and how to layer them for a D-D stellarator. After this experience, she continued to learn about fusion and plasma physics through her coursework. More recently, she sought to understand how the strength of magnetic fields change the ion fraction of an ion source in order to produce an H2+ beam for IsoDAR, a novel experiment that will probe particle physics beyond the standard model.

Margaret "Meg" Fairborn decided to pursue her doctoral degree in plasma physics at Columbia University on the NSF GRFP fellowship after graduating from Whitworth University with a double major in Physics and Mathematics. She participated in two SULI summer internships at the Princeton Plasma Physics Laboratory. During her first summer, she worked with Dr. Adelle Wright to write a GPU-parallelized code that employs a grid-free Monte Carlo method called "walk on spheres" to compute heat transport in stellarators. Her second internship was with Dr. David Smith, exploring the use of quantum computers to obtain improved atomic data for fusion reactions. She is interested in using advanced computational techniques to create tools that will help advance fusion research. Outside of research, Meg likes making homemade ice cream and has made more than 200 flavors.

Fusion Pioneers: Celebrating Women in Fusion Energy

Five Columbia University Plasma Lab Students attended the inaugural annual Fusion Pioneers: Celebrating Women in Fusion Energy conference on January 13, 2025. The event highlighted woman-led research in Plasma Physics and supported the advancement of marginalized genders in the workforce. In addition to outstanding fusion researchers, notable members of the Department of Energy attended, including the Under Secretary for Science and Innovation Dr. Geraldine Richmond.

Graduate students **Sophia Guizzo, Jamie Xia,** and **Alexa Lachmann**, along with undergraduates **Pricilla Dua** and **Hope Hersom**, actively contributed to the program. Hope Hersom and Pricilla Dua presented their entirely undergraduate-run research project with Professor Carlos Paz-Soldan on the interaction of cryogenic ice pellets with energetic particle beams, highlighting the woman-majority team. Alexa Lachmann presented on efforts at Columbia University to build a strong community of fusion researchers strengthened by innovation through collaboration.



Below: Attendees at the 2025 Fusion Pioneers: Celebrating Women in Fusion Energy conference, Right: Hope Hersom

Zimmermann Receives EPS PhD Research Award

Dr. Benedikt Zimmermann, a postdoctoral researcher in the APAM Department at Columbia Engineering, has been awarded the Ph.D. Research Award of the Plasma Physics Division of the European Physical Society (EPS) for his doctoral work performed at the Max Planck Institute for Plasma Physics. This is the highest recognition for Ph.D. research in plasma physics in Europe. The award is given annually to young scientists whose research is recognized for its exceptional academic quality, international impact and contribution to the field.

Dr. Zimmermann completed his Ph.D. at the Max Planck Institute for Plasma Physics in Garching, Germany, and joined Columbia Engineering in October 2024. His ongoing work in this field has resolved a long-standing discrepancy between theory and experiment regarding the transport of momentum in tokamak machines, which are good candidates for future fusion power plants. Based on this, he then developed the first predictive models for plasma rotation in toroidal tokamaks. Plasma rotation is a key quantity that interacts with a number of different effects in the plasma and can prevent certain magnetic instabilities that can lead to harmful disruptions of the plasma. His research not only deepens fundamental knowledge in plasma physics, but also enhances predictive capabilities for future fusion reactors, positioning his work as highly influential in the field.

Dr. Zimmermann will receive the award at the opening ceremony of the EPS Annual Plasma Physics Conference in July in Vilnius, Lithuania, where he has also been invited to give an awardee talk on his research, which has been published in *Physics of Plasmas* (31, 042306, 2024) under the title "Experimental validation of momentum transport theory in the core of H-mode plasmas in the ASDEX Upgrade tokamak" (**doi.org/10.1063/5.0203092**).

We'd love to hear from you, APAM Alumni!

Please send your news to apam@columbia.edu

Read more alumni updates online at: www.apam.columbia.edu/alumni-reports

APAM Alumni Updates

David Gates (Ph.D. '94, Plasma Physics) is part of a team from Princeton Plasma Physics Laboratory (PPPL) who received the 2024 Edison Patent Award from the Research & Development Council of New Jersey "for the invention of the planar coil stellarator, a device that eliminates the twisty coils of previous stellarator designs." PPPL News reports, "The planar coil stellarator was developed by David Gates, a principal research physicist at PPPL. Gates is currently the chief technical officer at Thea Energy, a commercial fusion energy company based in Kearny, New Jersey." "Gates said he is grateful for PPPL's support and encouragement. He especially appreciates the help of **Kenneth Hammond** (Ph.D. '17, Applied Physics), a PPPL research physicist, and Caoxiang Zhu, a former PPPL physicist and current professor in the Department of Plasma Physics and Fusion Engineering at the University of Science and Technology of China, who were named on the original portfolio patent application." (by Jeanne Jackson DeVoe, originally published by *PPPL News*)

Ralph Izzo (Ph.D. '81, Plasma Physics) discussed the future of sustainable energy at a recent Columbia Engineering seminar as a Silberstein Family Executive in Residence. The former CEO and chair of energy giant PSEG began his residency at the School on Feb. 17 with a student breakfast, followed by a series of one-on-one "office hour" sessions with graduate and undergraduate students. He also led a seminar on Feb. 28 to discuss the future of sustainable energy, the role of policy in creating a greener future, and steps the next generation of engineers can take to mitigate the growing climate crisis. Lear more at: **https://tinyurl.com/mc3mt6nd**

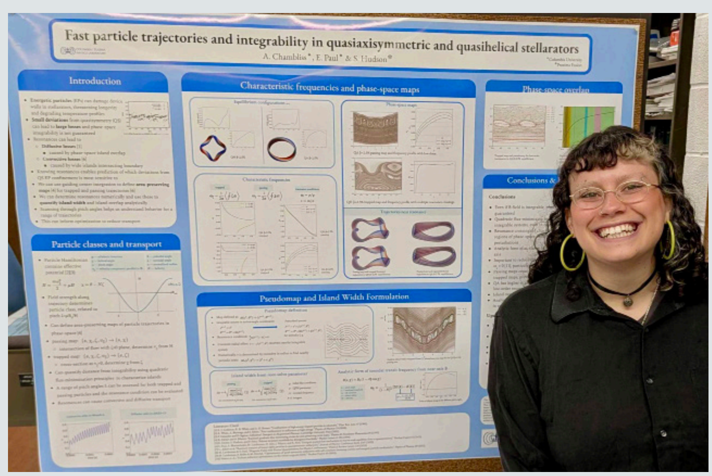
Changmin Shi, (M.S. '19, Materials Science & Engineering) will be joining the Department of Mechanical and Aerospace Engineering at Syracuse University in Fall 2025 as a tenure-track Assistant Professor (TTAP). Dr. Shi's group research is at the interface of materials, advanced manufacturing, and AI-driven methodology to push the frontiers of extreme batteries for energy storage and passive thermal-management technologies for temperature regulation and water harvesting. The group designs novel electrolyte chemistries and manufacturing approaches to achieve extremely safe, extremely fast-charging, and extremely energy–dense batteries. In parallel, the group designs novel passive materials and materials architectures that enable temperature regulation and water harvesting. By combining fundamental science and applied engineering, the group eventually advances sustainable solutions to address grand challenges in energy and environment for a circular economy.

Xiaochuan Tian (Ph.D. '17, Applied Mathematics) and Qiang Du, the Fu Foundation Professor of Applied Mathematics, are two of six authors who received the 2024 Frontiers of Science Award for their paper "Numerical Methods for Nonlocal and Fractional Models" (*Acta Numerica*, 2020). Established by the International Congress for Basic Science (ICBS), the awarded papers were chosen across 42 fields within the three basic sciences—mathematics, theoretical physics, and theoretical computer science and information science—represented at ICBS.

Sherwood Fusion Theory Conference

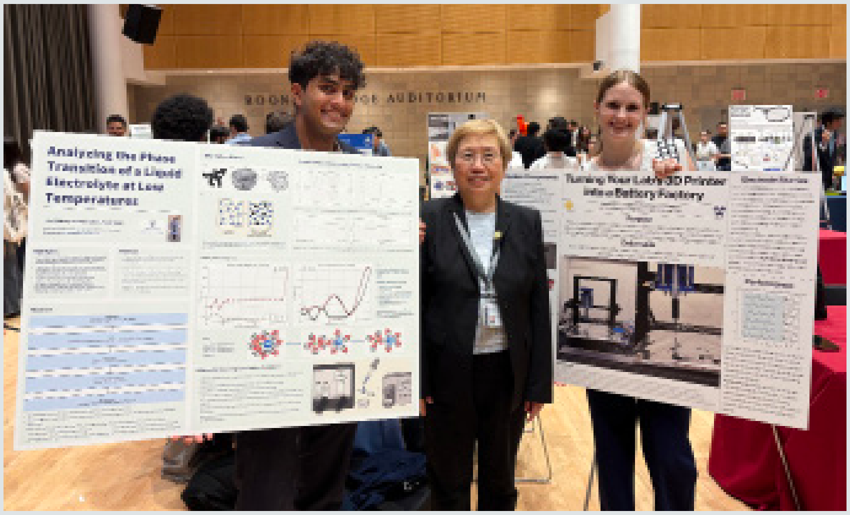
(continued from page 6)

Amelia Chambliss, a third year PhD student under the advisement of Professor Elizabeth Paul, was awarded the Sherwood Student Poster Award at the Sherwood Fusion Theory Conference, held in New York City from April 7th-9th. The poster, entitled "Fast particle trajectories and integrability in quasiaxisymmetric and quasihelical stellarators," discusses methods for evaluating important instabilities in stellarators, a fusion reactor concept. Confining the highest energy particles in the reactor will be essential for maintaining temperatures necessary to maintain the fusion reaction, and confinement can be degraded by these instabilities. This work hopes to inform understanding of these loss mechanisms for high energy particles, with the hopes of improving confinement in future devices.



(right): Amelia Chambliss at the Sherwood Fusion Theory Conference

(Student News, continued)



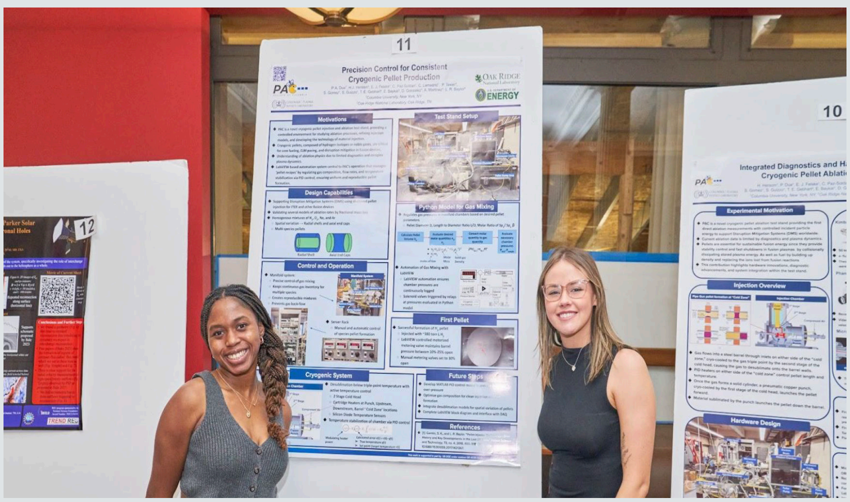
Jalaj Mehta (BS '25), Prof. Siu-Wai Chan, and Sarah Asher (BS '25)

2025 Senior Design Projects

Two Materials Science undergrads, **Sarah Asher (BS'25)** and **Jalaj Mehta (BS '25)**, presented research at the annual Columbia Engineering Senior Design Expo on May 8th, 2025 in Lerner's Roone Arledge Auditorium. The annual event offers students the chance to demonstrate their knowledge from foundational math and science courses alongside their engineering studies through innovative, creative, and meaningful designs and prototypes.

Sarah (who was advised by Dan Steingart) presented a poster on "Turning Your Lab's 3D Printer into a Battery Factory". She outlined how researchers modified a low-cost 3D printer to create thick battery electrodes more affordably and precisely, offering a new way to improve energy storage using sodium-ion materials.

Jalaj (advised by Yuan Yang) presented a poster on "Development of Phase Diagrams for Liquid Electrolyte Solutions." He described how lithium-ion battery performance suffers in cold environments due to electrolyte freezing, and how his team mapped phase transitions and used carbon black to improve battery efficiency in such conditions.



Pricilla Dua and Hope Hersom

2025 CU*iP

By Pricilla Dua

Two Columbia University Plasma Laboratory students attended the 2025 Conference for Undergraduate Women and Gender Minorities in Physics (CU*iP) at New York University from January 24–26, 2025. The conference provided an incredible platform for women and marginalized genders to connect with leading physicists, explore career opportunities, and showcase their research. Attendees participated in plenary talks led by renowned physicists Dr. Lina Necib, Dr. Chandralekha Singh, and Dr. Nikta Fakhri, alongside career fairs and poster sessions that fostered a strong sense of collaboration and mentorship within the physics community.

Undergraduates **Pricilla Dua** and **Hope Hersom** presented their entirely undergraduate, women-led, groundbreaking research under the mentorship of Professor Carlos Paz-Soldan. Their work focuses on the interactions of cryogenic pellets with energetic particle beams– a critical step towards understanding ablation processes for fusion applications. Columbia students thank the APS, NSF, DOE, and Cara Giovanetti at NYU for hosting and supporting this incredible event!

Contributing Authors

Columbia Engineering, Columbia Engineering Magazine, Columbia News, Grant Currin, Pricilla Dua, Gabe Guo, Holly Evarts, Margaret Fairborn, Michael Mauel, Ellen Neff, Carlos Paz-Soldan, Elizabeth Paul, Steven A. Sabbagh, Xintian Tina Wang, Eleanor Winkler, Benedikt Zimmermann

Photos/Images

Sarah Asher, Eileen Barosso, Simon Billinge, Siu-Wai Chan, Columbia Engineering, Columbia Engineering Magazine, Columbia Magazine, Pricilla Dua, Margaret Fairborn, Hope Hersom, Abdullah Hyder, Andy Kim, Mihnea Leonte, Elizabeth Paul, Steven A. Sabbagh, Kailey Whitman, Eleanor Winkler, Benedikt Zimmermann, Sherry Zhang

Contact Us

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The Department of Applied Physics and Applied Mathematics
Fu Foundation School of Engineering & Applied Science
Columbia University in the City of New York
500 W. 120th Street, Room 200 Mudd
MC 4701, New York, NY 10027
Phone: 212-854-4457 | Fax: 212-854-8257