

UNIVERSITY OF ROCHESTER
LABORATORY FOR LASER ENERGETICS

LLE IN FOCUS

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FOCUS ON COLLABORATION

WORKING TOGETHER FOR SCIENTIFIC PROGRESS



LLE IN FOCUS

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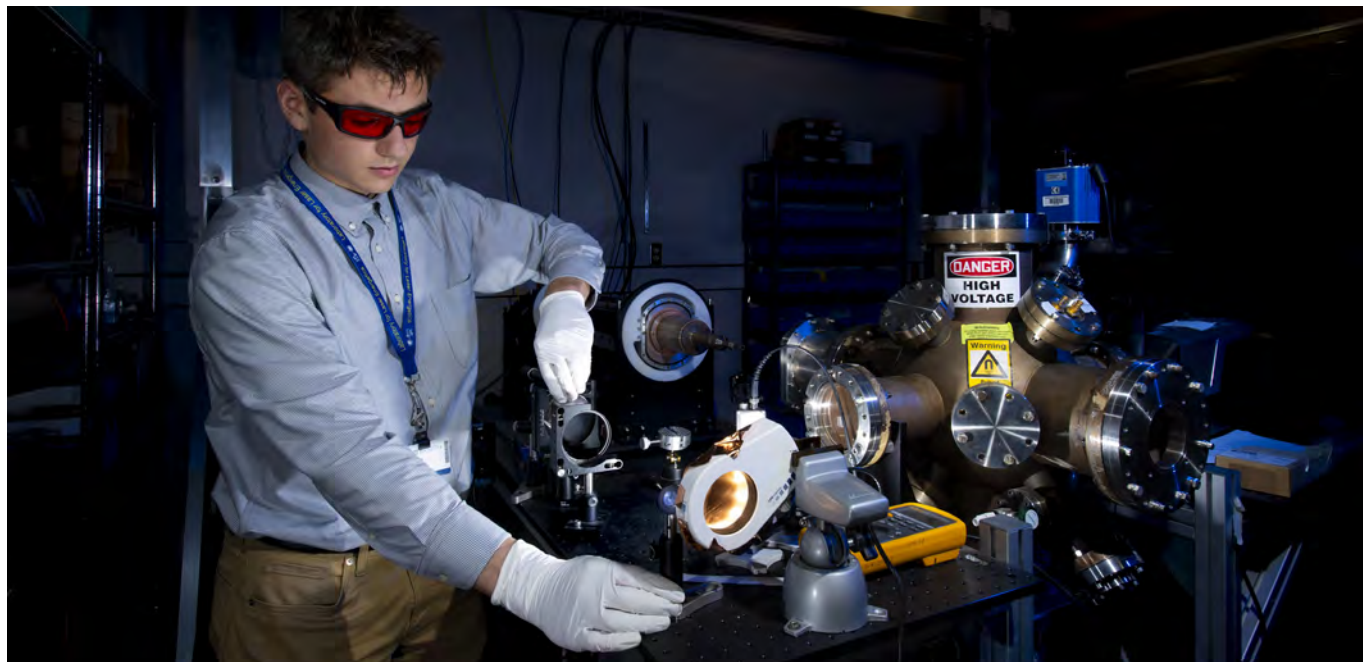


Installation of the phoswich detector on the OMEGA EP target chamber marks the culmination of a collaboration between Houghton University, SUNY Geneseo, and LLE. Undergraduate students played a central role in designing and building this diagnostic, which is now ready to deliver clean measurements of light-ion reactions at one of the world's leading laser facilities. To read more about this collaboration, see the Laser Facility Report on page 4.

LLE IN FOCUS

Focus on: Collaboration

Fall 2025 | Issue 7



By engaging students directly in advanced research, LLE's educational programs help train tomorrow's scientific workforce. Here, Summer High School Research Program student Caleb Krenzer (Churchville-Chili High School) conducts experiments in the magneto-inertial fusion electrical discharge system (MIFEDS) laboratory.

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About the cover

The cover shows a map of the United States featuring photos of students and partners, representing LLE's broad network of collaborations that extend research, education, and innovation nationwide.



From the Director

DR. CHRISTOPHER DEENEY | DIRECTOR, LABORATORY FOR LASER ENERGETICS

As I reflect on another year of impactful work, I realize that the spirit of collaboration has fueled our progress from the very beginning. This issue highlights stories of students and mentors, partnerships spanning the nation, and innovations driven by many hands.

Among these achievements, we proudly celebrate the fortieth anniversary of chirped-pulse amplification—a groundbreaking technique first demonstrated at LLE by graduate student Donna Strickland and mentor Gérard Mourou. Their pioneering work, honored with the 2018 Nobel Prize in Physics, revolutionized laser science and continues to enable advances in both fundamental and applied physics.

The path to fusion ignition—a transformative milestone recently achieved at the National Ignition Facility at Lawrence Livermore National Laboratory—epitomizes the collaborative essence of our field. Achieving ignition required the ingenuity and dedication of thousands of scientists and engineers working across multiple institutions, many of whom have a long history of conducting research at LLE.

Central to scientific progress is a network of academic partnerships. Besides being home to a large graduate student community from the University of Rochester, we collaborate closely with academic institutions across the United States. These relationships enrich research and training opportunities, providing critical hands-on experience for students and creating a pipeline of talent prepared to meet the evolving demands of the fusion and high-energy-density physics fields.

Helen Keller once said, “Alone we can do so little; together we can do so much.” Looking ahead, it’s clear that the best science happens when people come together. The challenges before us are big, but with curiosity and teamwork at our core, I’m confident we’ll continue to innovate and make discoveries that have impact. It’s my privilege to be on this journey with all of you.

A handwritten signature in black ink, appearing to read 'C. Deeney', with a stylized flourish at the end.

Christopher Deeney
Director, Laboratory for Laser Energetics

Awards and Honors

2024 Nuclear Fusion Journal Award Recognizes Paper Coauthored by LLE Scientists



Stephen Craxton



Emma Garcia



Patrick McKenty



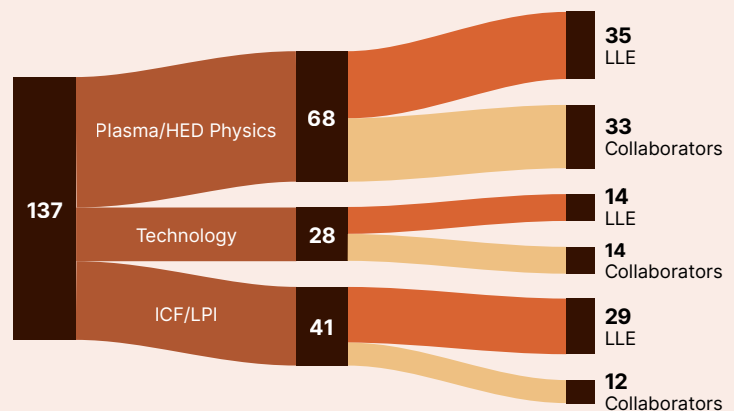
Yujia Yang

LLE scientists Patrick McKenty and Stephen Craxton and two former members of the LLE High School program, Emma Garcia and Yujia Yang, have been recognized as coauthors of a paper entitled, “[High-yield polar-direct-drive fusion neutron sources at the National Ignition Facility](#),” which has been selected as the winner of the 2024 Nuclear Fusion Journal Award as “the most outstanding article from the 2021 volume.” Each year, just one paper published two or three years earlier is selected based on citation record and scientific impact. The winning paper, led by first author Charles Yeaman of Lawrence Livermore National Laboratory (LLNL), describes [collaborative work between LLE and LLNL](#) that uses polar direct drive to produce very high neutron yields for radiation effects experiments and other high-energy-density physics investigations. Since the inaugural Nuclear Fusion Journal Award in 2006, all awards prior to the current award have been for articles on magnetic fusion. The 2024 award is the first to recognize work on inertial confinement fusion.

Publications

Research Highlights

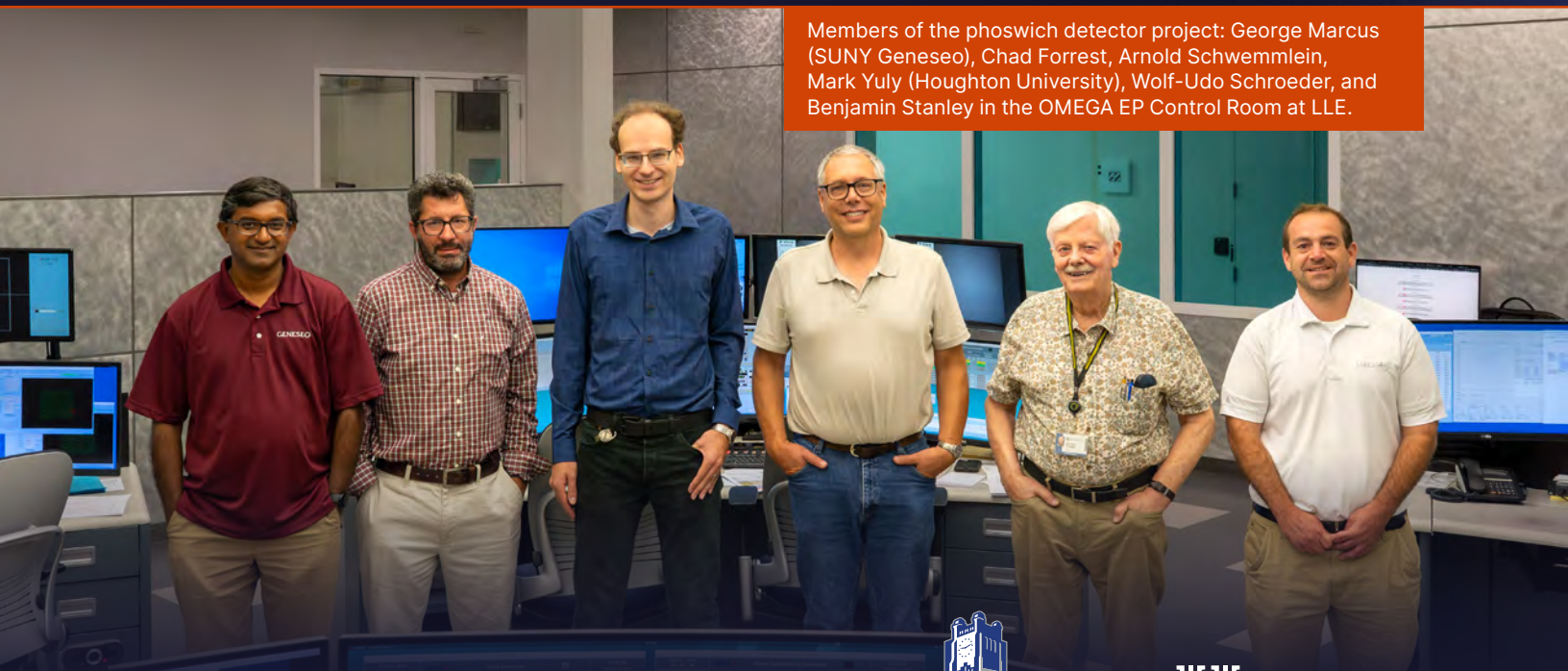
LLE’s science and engineering research is captured through peer-reviewed publications, which include LLE lead-authored and LLE co-authored papers. These publications reflect not only the laboratory’s technical leadership but also its strong commitment to collaboration with external laboratories and academic partners. LLE averages more than 100 published articles annually across three broad areas: Technology, Plasma and High-Energy-Density (HED) Physics, and Inertial Confinement Fusion/Laser-Plasma Interactions (ICF/LPI). The graphic to the right shows the distribution across topics.



Number of publications July 1, 2024 to June 30, 2025

Laser Facility Report

Members of the phoswich detector project: George Marcus (SUNY Geneseo), Chad Forrest, Arnold Schwemmlin, Mark Yuly (Houghton University), Wolf-Udo Schroeder, and Benjamin Stanley in the OMEGA EP Control Room at LLE.



Working Together to Build a New Window into the Universe



GENESEO
New York's Public
HONORS COLLEGE



HOUGHTON
UNIVERSITY

A new diagnostic system utilizing a “phoswich”-style detector (short for phosphor sandwich) has been developed through a collaboration between Houghton University, SUNY Geneseo, and LLE. This innovative device is designed to study the behavior of light ions, which are tiny particles that play a fundamental role in processes like star formation and the evolution of the early universe. Undergraduate physics students were integral to the project, contributing at every stage of the detector’s development. The device is now being prepared for deployment at the Omega Laser Facility, where it will soon support experiments on the OMEGA-60 and OMEGA EP lasers.

Understanding how light ions interact is essential for explaining the creation of elements during the Big Bang and within stars. However, studying these reactions in traditional laboratory settings is extremely challenging. At low energies, the reactions are rare and difficult to detect. At higher energies, existing data often conflict or carry significant uncertainties. Additionally, some reactions involve tritium—a rare and radioactive form of hydrogen—introduce contamination risks that further complicate experiments.

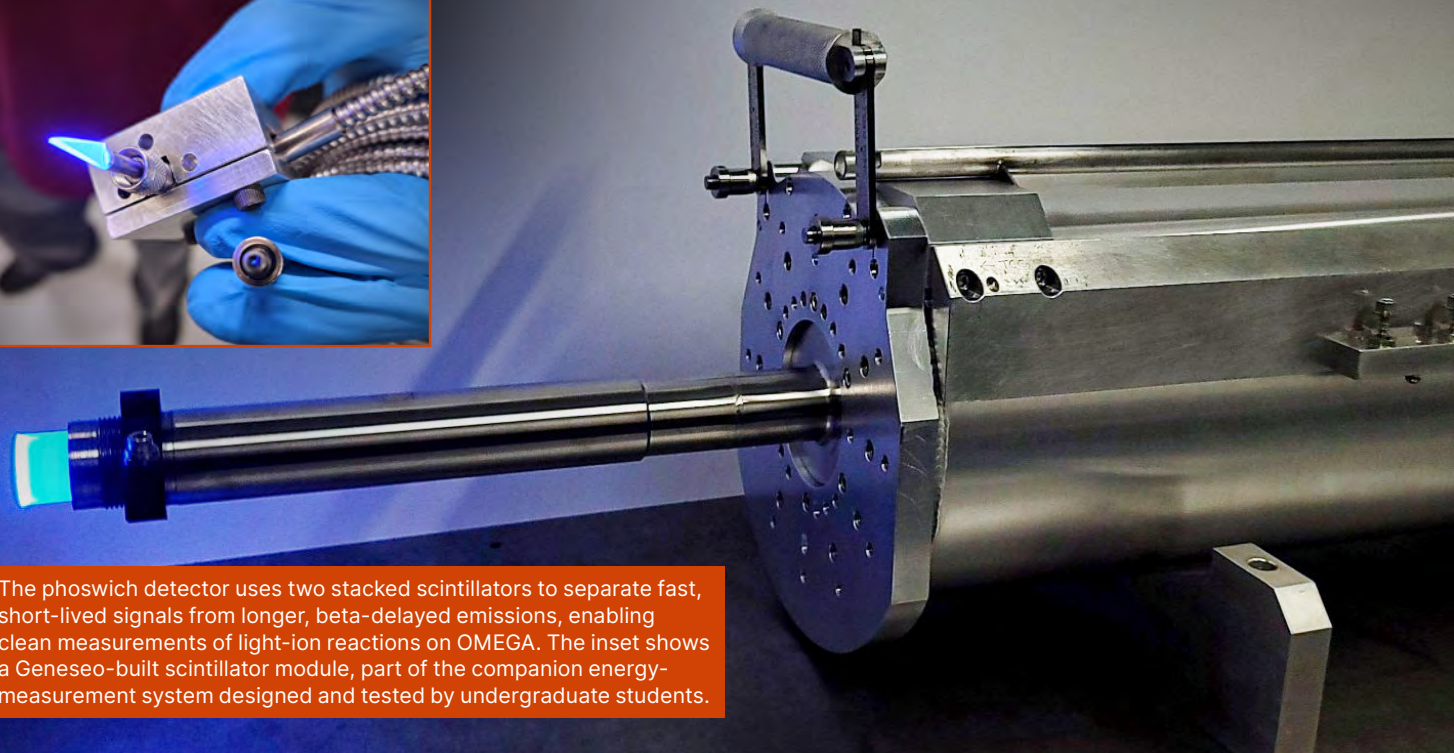
The Omega Laser Facility provides a unique solution to these challenges. Its advanced lasers create ideal conditions

for studying these reactions in a controlled, low-noise environment. This enables scientists to collect data that would be nearly impossible to obtain elsewhere.

The development of the phoswich detector was a collaborative effort involving researchers and students. Early prototypes were built and tested at Houghton University, with initial experiments conducted at SUNY Geneseo’s particle accelerator and LLE’s Multi-Terawatt (MTW) laser system. These early tests demonstrated the feasibility of the design and allowed the team to refine the detector further. Subsequent “ride-along” experiments on high-yield OMEGA-60 shots confirmed the detector’s ability to make low-background-noise measurements over the required timescales (ranging from a few milliseconds to approximately 20 seconds). The detector also successfully integrated with Omega’s standard controls, timing systems, and mechanical interfaces. The phoswich diagnostic fills an important gap in LLE’s ability to measure short-lived nuclear reaction products. Its sensitivity to beta-delayed emissions and light-ion reactions makes it well suited for future studies, inertial confinement fusion, and astrophysical processes. Qualification for routine use on OMEGA-60 and OMEGA EP is currently underway.



The phoswich detector uses two stacked scintillators to separate fast, short-lived signals from longer, beta-delayed emissions, enabling clean measurements of light-ion reactions on OMEGA. The inset shows a Geneseo-built scintillator module, part of the companion energy-measurement system designed and tested by undergraduate students.



How the Phoswich Detector Works

The phoswich detector uses two layers of specialized materials to capture and analyze particles from nuclear reactions. The steps below describe how it operates:

- 1. Capturing Reactions:** The detector can be set up in two ways. In one mode, it collects particles from reactions happening during a laser-driven implosion. In another mode, it uses a small target to create reactions when hit by high-energy particles from the laser.
- 2. Detecting Signals:** As the reaction products decay, they release tiny bursts of energy. The detector captures these signals and distinguishes them from background noise, ensuring accurate measurements.
- 3. Measuring Energy:** A companion tool, developed at SUNY Geneseo, measures the energy of the particles hitting the target, providing additional insights into the reactions.

Educational Impact

One of LLE's core missions is to train the next generation of scientists, and the phoswich project shows how undergraduate students can play an essential role in major research efforts. Since 2016, nearly 40 physics majors from Houghton University and SUNY Geneseo have contributed to the project. Their work has spanned the entire process, from the original concept and prototype construction, to accelerator tests at SUNY Geneseo, experiments on LLE's MTW laser, ride-along shots on Omega, and now deployment on the OMEGA-60 and OMEGA EP target chambers.

This long-term involvement has generated significant academic results. Nineteen Houghton students alone have participated, producing five undergraduate physics theses and more than thirty poster presentations at regional, national, and

international conferences. Faculty mentors include Mark Yuly (Houghton University), and Stephen Padalino, George Marcus, Charlie Freeman, and James McLean (all SUNY Geneseo). Their guidance has ensured students were fully involved in data analysis, system design, and hands-on experimental work.

The project has also led to national recognition. One of the first Houghton participants, Katelyn Keparutis (née Cook), received the 2019 LeRoy Apker Award from the American Physical Society for her contribution to this research. Most recently, three Houghton students took part in an OMEGA EP shot day, underscoring that student involvement continues to be central to the collaborative research at LLE.

The phoswich project demonstrates how collaboration between universities and LLE creates meaningful opportunities for undergraduates to participate directly in advanced research while building the skills needed for future scientific careers.

Quarterly Shot Report

The Omega Laser Facility conducts experiments for research and development in support of the NNSA High-Energy-Density (HED) Program, National Laser Users' Facility (NLUF), and Laboratory Basic Science (LBS), in addition to other research and educational efforts.

During the third quarter of FY25, the Omega Laser Facility conducted 294 target shots on OMEGA and 168 on OMEGA EP, totaling 462 target shots for 61 campaigns. OMEGA averaged 91% availability and 95% experimental effectiveness, while OMEGA EP averaged 91% availability and 96% experimental effectiveness.

The Future of Science



Some of LLE's graduating students following the doctoral graduation ceremony at Eastman School of Music's Kodak Hall on Friday, May 16, 2025. Pictured here (left to right) are Kassie Moczulski, Yu (Victor) Zhang, Irem Nesli Erez, Zaire Sprowal, Mary Kate Ginnane, and Zachariah Barfield.



Graduating students and their advisor (center) are Debamitra Chakraborty, Roman Sobolewski (advisor), and Jing Cheng.

Dr. Zach Barfield

Department: **Physics and Astronomy**

Advisor: **D. H. Froula**

Zach Barfield joined the University of Rochester's Department of Physics and Astronomy in 2018 with a strong physics foundation, which he gained as an undergraduate at SUNY Geneseo. Soon after starting graduate school, he began plasma physics research as a Horton Fellow at the Laboratory for Laser Energetics.

Initially interested in measuring the local magnetic fields in a plasma, Zach developed a novel concept using Thomson scattering to compare ion-acoustic wave frequency to the magnetosonic wave frequency by measuring the low-frequency waves propagating parallel and perpendicular to an externally imposed magnetic field. In his early shot days, Zach measured a difference in frequency between these low-frequency waves, but when he turned off the external magnetic field the difference remained!

Using ten shot days over five years on the OMEGA Laser System, Zach's research focused on studying the evolution of laser-produced plasmas in order to understand the origin of the differences in frequency between parallel and perpendicular low-frequency waves and the hydrodynamics within this laser-produced plasma. The research identified discrepancies between the predictions of advanced magnetohydrodynamic models and the evolving plasma conditions, but ultimately, Zach and the team were unable to determine the cause of the difference between parallel and perpendicular low-frequency waves.

Zach and his collaborators have submitted the manuscript, "Anomalous Anisotropic Electron Temperatures in Laser-Produced Plasmas," to *Physical Review Letters*. This article presents his unexplained measurements that suggest anisotropic electron temperatures, even in unmagnetized laser-produced plasmas. The relative temperature anisotropy increased with laser intensity and reached a maximum value $\Delta T/T_e \approx 0.57$ at an intensity of $1 \times 10^{15} \text{ W/cm}^2$.

Throughout his graduate school journey, Zach has had several mentors who have made each stage of his research both productive and successful. Initially, Jonathan Peebles worked tirelessly to field the magneto-inertial fusion electrical discharge system (MIFEDS) used to create the externally imposed magnetic fields, while Joe Katz ensured the highest quality Thomson-scattering measurements. In later stages, plasma theorists John Palastro and Nathaniel Shaffer helped Zach explore all reasonable explanations for the anomalous anisotropic electron temperatures. These individuals are just a few of the many who make LLE such a uniquely supportive environment for graduate research.

Looking ahead, Zach has accepted an Assistant Professor position at Hobart and William Smith Colleges, which will allow him to continue to stay connected with the team at the lab and also help attract and encourage outstanding students to pursue research opportunities at LLE.



“My time as a graduate student at LLE has been extremely formative. **Access to this state-of-the-art facility has enabled me to perform extremely complicated experiments** that challenge our understanding of laser plasmas.”



Dr. Debamitra Chakraborty

Department: **Materials Science Graduate Program**

Advisor: **R. Sobolewski**

Debamitra Chakraborty did her doctoral research on the implementation of a THz time-domain spectroscopy (THz-TDS) imaging system for studies of biological materials, focusing on high-resolution parametric imaging of normal and tumor pancreatic tissues. This project was unique from the start since it was in direct collaboration with the University of Rochester Medical Center's Department of Surgery. The basis of the collaboration was to use optically generated transient THz bursts of electromagnetic radiation (using femtosecond laser pulses) not only to image medical pancreatic ductal adenocarcinoma (PDAC) tissues *ex vivo*, but also to detect their microenvironment and to analyze tumor responses to different medical treatments—radiation or immunotherapy, for example. PDAC is a rapidly progressing cancer that ranks third in cancer mortality in the United States with only a 9% five-year survival rate.

The materials science research approach is completely novel and based on the raster scanning of a tissue sample in transmission geometry with a 100- μm resolution and, subsequently, extracting from each transmitted THz transient both the index of refraction n and the attenuation coefficient α —this way describing the tissue material properties independent of the experiment specifics. Extracting n and α information from raw THz-TDS data required, in turn, development of advanced numerical analysis of megapixel size images. At LLE, Debamitra not only built a dedicated, fully automated THz-TDS imaging system and performed all experiments but also developed a special, MATLAB-based program to query those images efficiently. This unique program is at the core of her PhD dissertation as well as the subject matter of a seminal paper entitled, “Development of Terahertz Imaging Biomarkers for Pancreatic Ductal Adenocarcinoma using Maximum A Posteriori Probability (MAP) Estimation,” which was published in 2023 in the *ACS Omega* journal and, additionally, the subject of a US patent.

Debamitra's dissertation also includes a machine learning approach to directly correlate the THz-based n and α maps with histopathology images—the gold standard in cancer medicine—that in the future should lead to automated AI models for processing and cataloging tumor samples, such as those held at the URMW Wilmot Cancer Institute Biobank. Debamitra's research represents a breakthrough in the science of biomaterials since such a complex THz-TDS imaging and data analysis system has never been developed before. In addition, her research is likely to lead a new medical imaging modality—namely, 2D THz tomography. This is the first truly medical application (pending acceptance by the medical community) and is expected to be a novel diagnostic technique to measure and map tumor tissue responses to neoadjuvants during clinical pathology diagnoses.

“LLE has been a remarkable home where my ideas took shape and curiosity was encouraged every step of the way. I am deeply grateful for my advisor Prof. Sobolewski's mentorship throughout this journey, and especially to LLE Scientist Bob Boni, whose guidance has been a lasting inspiration.”

Dr. Zaire Sprowal

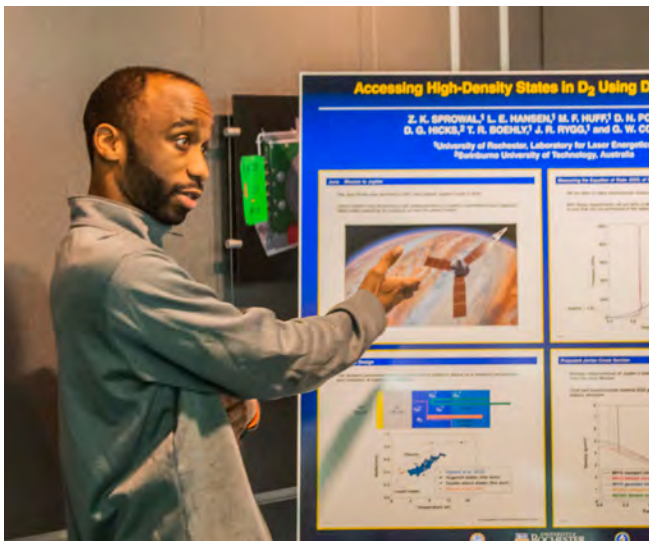
Department: **Physics and Astronomy**

Advisors: **R. Rygg and G. W. Collins**

Zaire Sprowal's PhD research has focused on the thermodynamic and transport properties of hydrogen and hydrocarbons at high temperatures and pressures (above one million atmospheres). The competition between thermal, electrostatic, and degeneracy effects at these conditions are challenging for theoretical models: it is too hot for traditional condensed matter physics, and too dense for traditional plasma physics.

Zaire used the OMEGA laser facility to drive multishock sequences into hydrogen and polystyrene (plastic) using high-precision velocimetry and pyrometry to simultaneously measure the pressure, density, temperature, and optical properties of the high-pressure conditions. These experiments are distinguished from typical single-shock experiments by allowing a tunable density by adjusting the relative strengths of the two shocks, and from previous double-shock experiments by allowing direct measurements of the temperature and optical reflectivity.

Zaire's hydrogen experiments revealed a different conductivity behavior in the low-temperature "metal-like" regime of condensed matter and "plasma-like" behavior at higher temperatures. Combined with earlier studies, Zaire constrained this "handoff" to occur when the temperature is about 40% of the Fermi temperature, which is the characteristic scale for electron degeneracy. Zaire's plastic experiments showed anomalous behavior in the optical properties at higher density. Combining his plastic results with other works, including his hydrogen data, he showed that this surprising anomalous behavior can be explained by detailed accounting of the dissociation and ionization processes. Zaire's work leads to a better understanding of the high-pressure behavior of hydrogen and hydrocarbons and will enable design improvements to the performance and reliability of inertial confinement fusion implosions.



“LLE is the smallest big lab and the biggest small lab of its kind anywhere. **Within it resides an ecosystem of innovation and a community of learners;** it's a place where scientific inquiries are probed in tandem with others in diverse collaborations.”



“Like many others, LLE was a major **reason I chose to attend the University of Rochester**—it sparked my passion for lasers and plasma. I’m incredibly grateful for the chance to contribute to its cutting-edge research alongside such a prolific team of scientists and students.”

Dr. James Young

Department: **Physics and Astronomy**

Advisor: **P. Gourdain**

James Young conducted his PhD research on laser-plasma interactions (LPIs), a fundamental process in high-power laser experiments. These interactions play a central role in applications such as inertial confinement fusion and laser-driven particle acceleration, where intense laser energy interacts with matter to form rapidly evolving plasmas.

Traditionally, LPIs are studied using particle-in-cell (PIC) simulations, which model plasma behavior at the kinetic level by tracking individual particles. While highly accurate, PIC codes are computationally expensive and become impractical for simulating macroscopic systems. As an alternative, researchers often use magnetohydrodynamics (MHD) simulations, which treat plasma as a conducting fluid and are better suited to modeling large-scale behavior. However, conventional MHD simulations make simplifying assumptions: they model energy transport using ray-tracing approximations and energy deposition through inverse bremsstrahlung absorption. These assumptions hold during early stages of laser interaction with solid targets but become invalid as the target heats up, expands, and develops hot, unstable plasma conditions.

To address these limitations, James investigated the use of extended magnetohydrodynamics (XMHD) as a more robust alternative. XMHD incorporates additional physical effects that are absent in traditional MHD models, including displacement currents, electron pressure, Hall effects, and electron inertia. These enhancements allow XMHD to capture a broader range of plasma behavior.

James’s work included theoretical analysis showing how XMHD can represent LPI phenomena that lie beyond the scope of conventional MHD. He also performed simulations comparing XMHD to standard PIC results to assess the model’s accuracy. These comparisons demonstrated that XMHD can effectively reproduce several key features of LPIs while offering significant computational efficiency.

James’s research contributes to the ongoing effort to improve simulation tools for high-energy-density physics, with the goal of better understanding how laser energy couples to plasma in complex experimental environments.



Dr. Yu (Victor) Zhang

Department: **Mechanical Engineering**

Advisors: **C. Ren and J. R. Davies**

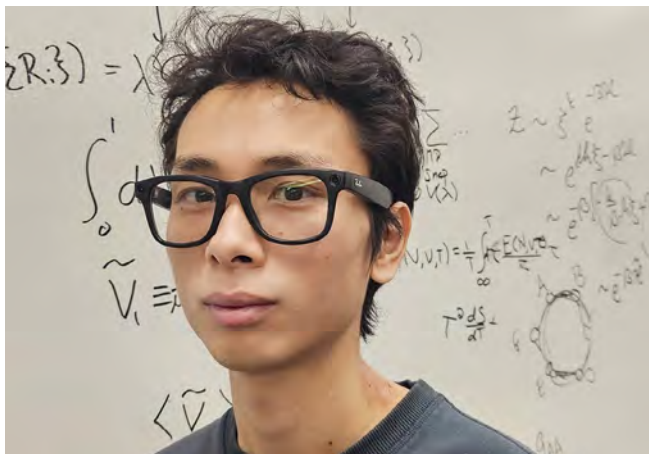
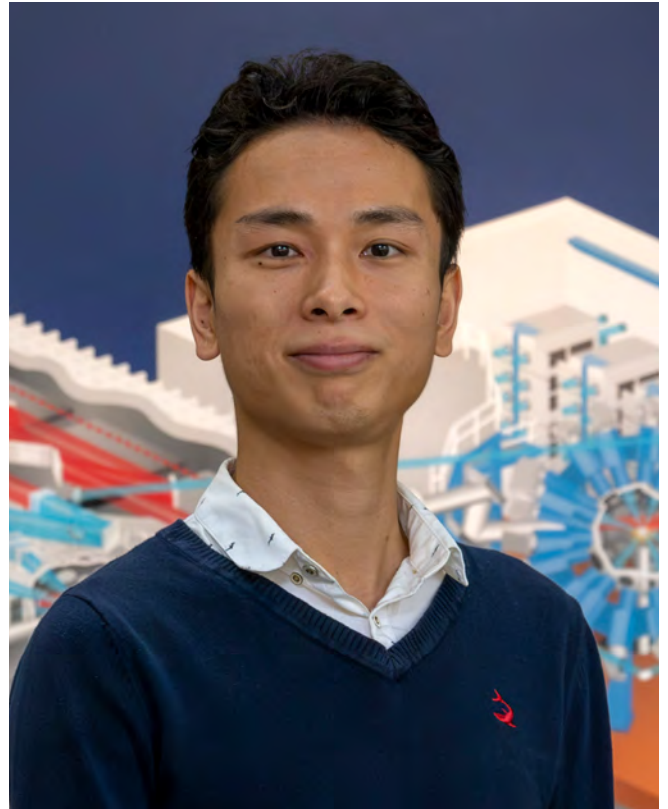
Yu (Victor) Zhang studied magnetized collisionless shocks with fully kinetic particle-in-cell (PIC) simulations and a multifluid model. Space is a low-density (and collisionless) plasma permeated with magnetic fields from a variety of sources; therefore, magnetized collisionless shocks are found in many astrophysical settings, such as supernovae and the Earth's bow shock. Magnetized shocks are believed to be the acceleration mechanism responsible for cosmic rays, the highest energy particles found in nature.

Victor's studies were motivated by his desire to study magnetized shocks in the laboratory using high-power lasers such as LLE's OMEGA laser, requiring a search for the physics of interest in a limited parameter space. Victor's first study showed that collisionless shocks traveling perpendicular to the magnetic field could be formed on OMEGA EP and were used to design an experiment and have been published.

The next study considered parallel shocks, which are of particular interest because they are believed to be the most effective at accelerating charged particles, but take a long time to form. Victor was able to show that a quasi-parallel shock could be formed on the National Ignition Facility (NIF), and this work formed part of a successful NIF Discovery Science proposal led by UCLA, and has been published.

During the study of parallel shocks, rapid ion-electron energy exchange was observed. Using simplified PIC simulations and a multifluid model, Victor was able to identify the mechanism as a resonance between electron whistler waves and ion waves, and these results have been submitted for publication. Victor's collisionless ion-electron coupling model could explain observations of higher than expected electron to ion temperature ratios in satellite data, and work with NASA researchers to compare the predictions to observations is underway.

Victor will be continuing his work in astrophysical studies as a postdoc at the University of Maryland in a collaborative group with NASA.



“ At LLE, I feel genuinely fortunate to have engaged in cutting-edge research and to have received unwavering support and encouragement from so many wonderful people **who are among the brightest in the field**, perhaps the finest of our kind.”

Fusion Student Delegation

Dear Reader,

This summer, I joined the Fusion Student Delegation (FuSD) to better understand fusion energy policy and the systems that shape its development. My background is technical—my research focuses on plasma confinement—but as I learned quickly, effective science policy requires translating complex ideas into practical decisions.

FuSD brought together 14 graduate and undergraduate students from across the country. Our preparation began in January, with biweekly meetings devoted to research on workforce development, innovation, supply chain logistics, and regulation. We analyzed legislation, reviewed recent agency reports, and spoke with professionals from different corners of the fusion ecosystem.

After five months of remote work, our group traveled to Washington, DC, from May 31 to June 6. During that week, we finalized a policy statement that outlines why fusion energy matters, what obstacles remain, and how policy-makers can help address them.

The most direct conversations took place in offices on Capitol Hill. Between the 14 of us, we met staffers from 71 congressional offices—49 in the House and 22 in the Senate. We presented our findings and policy recommendations, focusing on issues such as research funding, regulatory reform, and the importance of a robust supply chain. Each office received our policy statement, which we had updated with input from every delegate.

While most time was spent on policy, I valued hearing about my peers' research and perspectives—from novel fusion reactor designs to questions about public outreach. The variety of backgrounds made each discussion more rigorous and grounded.

If you are a student in fusion science or adjacent fields, and have an interest in how national policy works, consider applying to join FuSD in the future. The delegation provides access to decision makers, and a chance to see firsthand how technical and policy considerations interact.

Best regards,

Katarina Nichols

Katarina Nichols
Graduate student
High-Energy-Density Physics Theory Group
Laboratory for Laser Energetics, University of Rochester

Our schedule was rigorous:

- We met with legal and advocacy experts at Hogan Lovells, Third Way, ClearPath, Commissioner of the Nuclear Regulatory Commission Matthew J. Marzano, and representatives of the American Physical Society.
- We spoke to both Democratic and Republican staff on the House Committee for Science, Space, and Technology, and discussed priorities with the Department of Energy's Office of Fusion Energy Sciences.
- We visited ARPA-E and the Fusion Industry Association to understand current industry challenges.

Fusion Student Delegation at the US Capitol, including Katarina Nichols (front row, second from right).



Powering Discovery Through Academic Partnerships

Scientific discovery thrives when expertise and resources come together. At the University of Rochester's Laboratory for Laser Energetics, collaboration is not just a practice—it is the foundation for advancing plasma physics, fusion research, laser science, and technology innovations. As a unique national resource operating the Omega Laser Facility, LLE partners with over 70 user institutions across the United States and around the world, including over 25 members of the American Association of Universities. This network creates a rich ecosystem of shared knowledge and innovation.

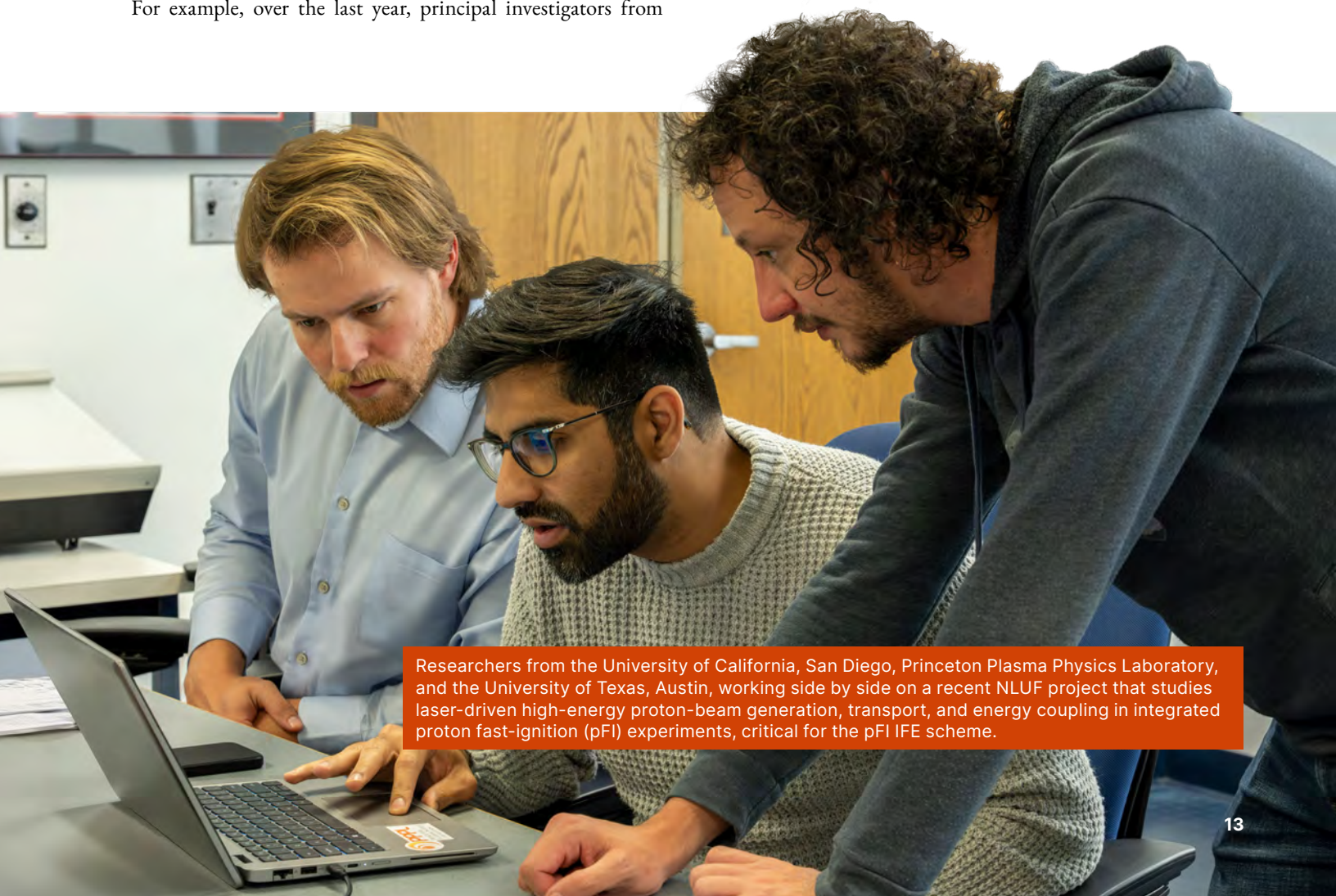
A National Network for Fusion and Plasma Innovation

Through the National Laser Users' Facility (NLUF), which was established in 1979, LLE extends access to its unique Omega Laser Facility, welcoming dozens of institutions each year. For example, over the last year, principal investigators from

Princeton University, Massachusetts Institute of Technology, the University of Michigan, the University of California, and other top programs have led major experiments at Omega, leveraging capabilities unavailable anywhere else.

LLE's expansive network fuels a dynamic exchange of ideas that accelerates progress in high-energy-density physics (HEDP), inertial confinement fusion (ICF), and laser technology research. Through the NLUF, these institutions gain access to LLE's world-leading experimental platforms, enabling novel experiments that reshape our understanding of plasma behavior, fusion ignition, and laser-matter interactions.

These partnerships are not just convenient—they are essential. More than half of the facility's experiments each year are led by early career researchers, including graduate students and postdocs, fostering a culture of mentorship and innovation that sets a national standard.



Researchers from the University of California, San Diego, Princeton Plasma Physics Laboratory, and the University of Texas, Austin, working side by side on a recent NLUF project that studies laser-driven high-energy proton-beam generation, transport, and energy coupling in integrated proton fast-ignition (pFI) experiments, critical for the pFI IFE scheme.

Diagnostics and Discovery

LLE's collaborative projects span the frontiers of science and are often focused on building and using sophisticated diagnostics to probe the mysteries of fusion and plasma behavior. With the Massachusetts Institute of Technology (MIT), one of the laboratory's most productive partnerships, numerous pioneering advances have been made in fusion diagnostics.

Together, LLE and MIT have developed advanced diagnostic systems that serve the entire high-energy-density physics community conducting experiments at both the Omega Laser Facility and the National Ignition Facility. These diagnostics, including sophisticated particle and neutron measurement tools, provide vital data used to understand and optimize fusion implosions and plasma conditions across multiple experimental platforms. By building and refining these shared diagnostic capabilities, LLE and MIT enable researchers from various institutions to advance their experiments with precise and reliable measurements, strengthening the broader scientific efforts in inertial confinement fusion and laser-driven research beyond individual facilities alone.

Researchers at the University of Michigan and LLE develop novel approaches in high-intensity laser-plasma physics, their work centered on flagship facilities like the Omega Laser Facility and ZEUS. Collaborations between these institutions include probing magnetic reconnection, laser-plasma interactions, laboratory astrophysics, and more.

Princeton researchers regularly conduct experiments at LLE through national user programs, tackling critical topics such as planetary interiors, magnetic fields, plasma flows, and laboratory astrophysics, often with a strong emphasis on innovative diagnostic techniques. These joint projects have advanced capabilities in plasma imaging, tomographic proton radiography, and the study of magnetic reconnection, benefiting the broader scientific community and enabling deeper insights into both fundamental and applied physics.

Education and Workforce Development

LLE's collaborative ethos extends to education and training. Beyond partnering with the top research universities, LLE supports regional institutions such as SUNY Geneseo, Rochester Institute of Technology, and Monroe Community College, providing undergraduate and high school students with hands-on research experiences to ignite curiosity and build technical skills. LLE's Summer Research and Undergraduate Education Programs welcome the next generation into active fusion science with a wide variety of mentorship and career development opportunities.

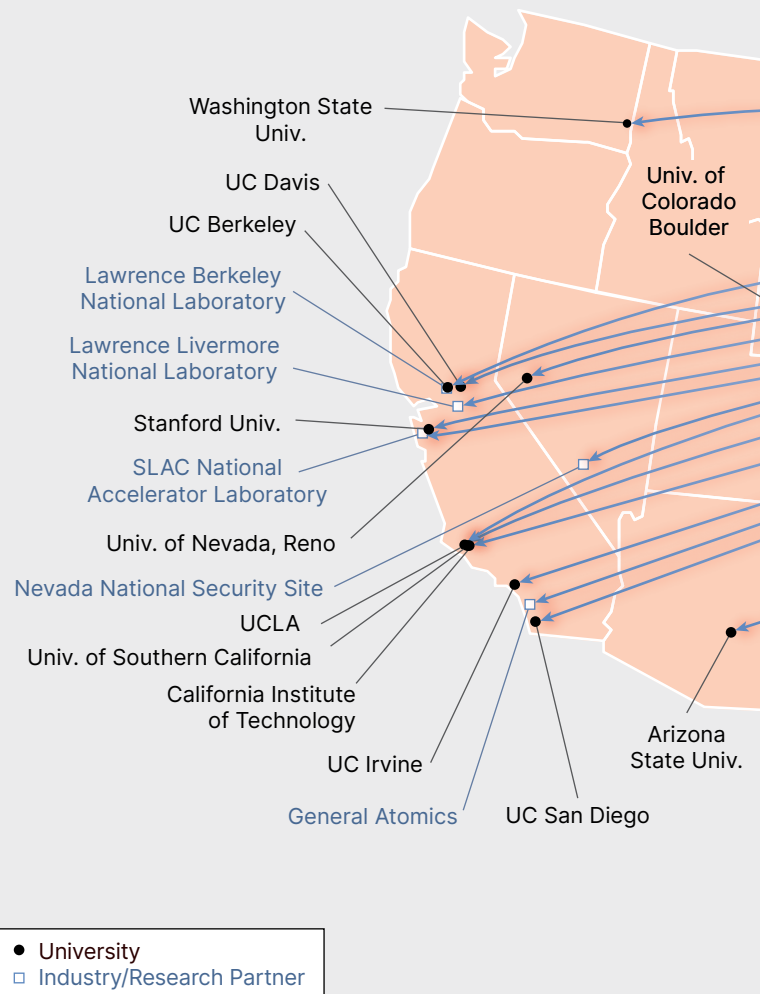
Consortia like the IFE-COLoR Hub and the IFE-SURE program ([see article on page 24](#)) further integrate advanced fusion research with undergraduate education, enabling shared experiments and collaborative curriculum development. Students

work alongside faculty and researchers from the University of Rochester and other leading universities, learning on the same diagnostic platforms that drive national research.

IFE-COLoR, or the Inertial Fusion Energy-Consortium on LPI (laser-plasma instability) Research, is located at LLE and is one of three national hubs selected by the Department of Energy to accelerate research and development in inertial fusion energy (IFE), building on recent achievements like fusion ignition. IFE-COLoR includes experts from the University of Rochester, the University of California, Los Angeles, the University of Nebraska-Lincoln, and private companies such as Ergodic, LLC, and Xcimer Energy, Inc.

Our National Network

From coast to coast, LLE partners with leading institutions to power discovery and train the next generation.



Focus on Collaboration: Powering Discovery Through Academic Partnerships

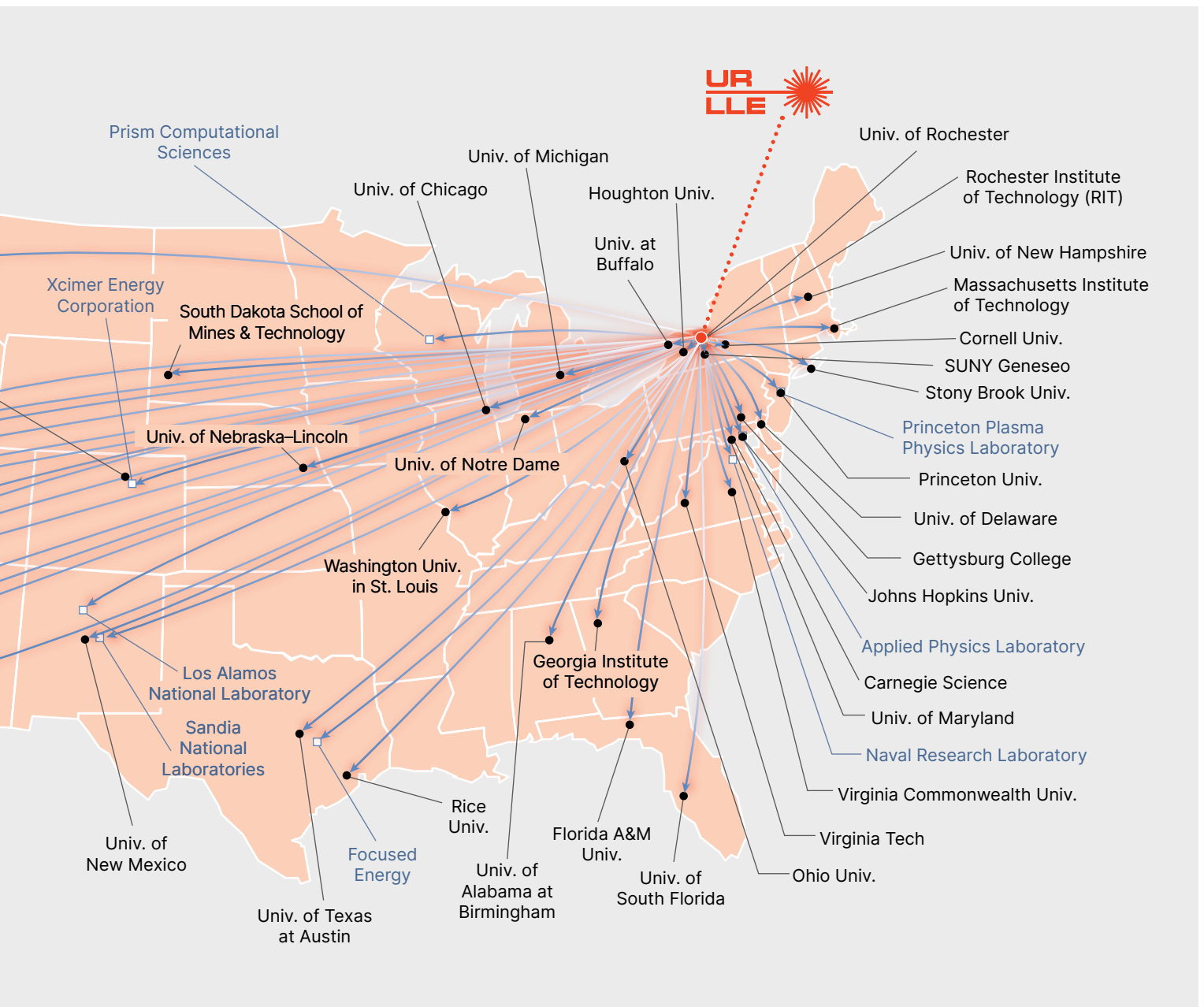
In addition to its research, IFE-COLoR is dedicated to developing the next generation of IFE scientists and engineers. By supporting LLE's Undergraduate Education Program, IFE-COLoR addresses future workforce needs of the fusion energy sector and helps ensure a supply of skilled individuals to drive innovation in this field.

Energizing America's Leadership In Science

LLE and its network of university partnerships form a research ecosystem where new ideas are born, tested, and

realized for the benefit of all. The research, science, technology, and engineering conducted here illustrate the enduring power of collaboration: every milestone in fusion science and HEDP reflects synergistic innovation along with a collective spirit of the nation's best minds working together.

As science confronts the questions and opportunities of the twenty-first century, the lessons—and successes—of LLE's collaborative model continue to light the way. The discoveries made today will help to secure our nation and our energy independence while inspiring tomorrow's generations to pursue knowledge, guided always by the principle that together, we go further.



FOCUS ON

NSF OPAL

Where Frontier Science Meets the Future Workforce

Currently under design, the US National Science Foundation Optical Parametric Amplifier Line (NSF OPAL) laser facility will be the world's most powerful laser system to explore the frontiers of science—unlocking mysteries about the universe under extreme conditions. Based at the University of Rochester, this multi-institutional collaboration brings together leading universities, private industry, and government agencies, uniting expertise and resources to build a facility unlike any other.

NSF OPAL's lasers will create electromagnetic fields, temperatures, and pressures so intense that they mimic conditions found only in the cosmos. This capability will enable breakthrough research in particle acceleration, quantum

physics, astrophysics, and nuclear science, driving innovations that could transform technology and deepen our understanding of fundamental forces, advance technology in key sectors, and strengthen national security.

The project extends beyond laser science and innovation and will serve as a hub for building the future workforce—training students and early-career researchers in world-class science and engineering who will lead tomorrow's discoveries. By advancing frontier science and nurturing talent through collaboration, NSF OPAL is more than a facility—it is a pathway for innovation and opportunity that will ensure America remains at the forefront of scientific leadership.



See what's happening at NSF OPAL

Find out how scientists are pushing the boundaries of optics and lasers:
nsf-opal.rochester.edu



Three-dimensional architectural rendering of the proposed NSF OPAL Facility, courtesy of SWBR.



Partners



Chirped-Pulse Amplification at 40

From Student Research to Global Impact

40th

Anniversary

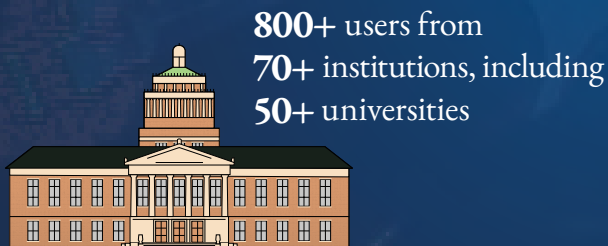
This year marks the fortieth anniversary of chirped-pulse amplification (CPA), a groundbreaking laser technology first developed at LLE in the 1980s. Invented by then-graduate student Donna Strickland and physicist Gérard Mourou, both pictured above, CPA transformed the field of high-intensity laser physics and earned them the 2018 Nobel Prize in Physics.

The innovation began as part of Strickland's doctoral research at the University of Rochester's Institute of Optics, with Mourou serving as her advisor. They developed CPA by stretching a laser pulse before amplification, amplifying it, and then recompressing it. This process made it possible to achieve extremely powerful outputs without damaging the laser system.

Since its debut in 1985, CPA has revolutionized medicine, industry, and science, enabling delicate procedures like laser eye surgery, precision machining of strengthened glass for smartphones, and advances in particle acceleration and imaging. At LLE, CPA remains central to high-energy-density physics and fusion research, including experiments conducted on the OMEGA EP Laser System. Around the world, CPA underpins ultrahigh-power laser facilities, such as the National Ignition Facility's Advanced Radiographic Capability and the Extreme Light Infrastructure in Europe.

From a student's thesis project to a globally adopted technology, the story of CPA is one of collaboration, curiosity, and lasting impact. It is an innovation born at LLE that continues to shape the frontiers of science 40 years later.

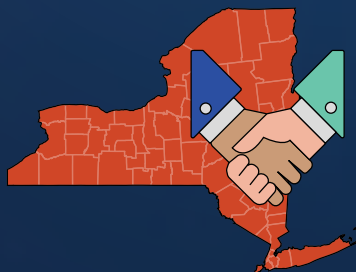
LLE Collaboration by the Numbers



64 external user PhDs in the last 10 years,
>50% joined DOE national laboratories
post-graduation

\$57.6M
in purchases
from over

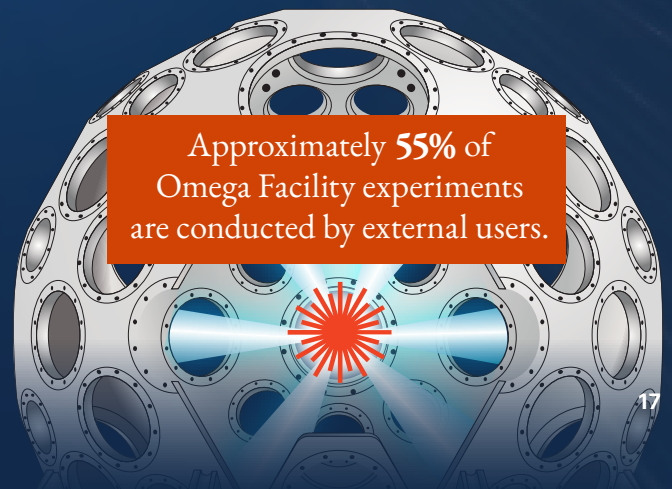
1000 New York State
vendors since 2015



13 industrial partnerships
working on development
projects



Multiple collaborations
with 4 government labs



Approximately 55% of
Omega Facility experiments
are conducted by external users.

Shaping Futures

The LLE–LLNL Collaboration’s Lasting Impact

When Dayne Fratanduono was a graduate student at the Laboratory for Laser Energetics, he spent long hours at the Omega Laser Facility gaining invaluable hands-on experience in the challenging work of compressing matter to its limits and studying its fundamental properties. Today, as Deputy Director for Capabilities at the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL), Fratanduono helps lead the world’s most advanced experiments in inertial confinement fusion (ICF) and high-energy-density (HED) science in support of the nation’s stockpile stewardship program. His story is one of many to emerge from the longstanding LLE–LLNL partnership—a collaboration that for decades has launched countless scientific careers.

While its partnership with LLNL is one of the most visible, LLE’s collaborative reach extends much further. LLE regularly joins forces with universities, national labs, and private industry, building networks that advance science while also cultivating the next generation of scientists, engineers, and technicians.

An Incubator for Talent

In the early days of laser-driven fusion research, the field was both specialized and competitive. By the late 1990s, as the community prepared for the construction of the NIF, and LLNL decommissioned its earlier lasers, the OMEGA-60 facility at LLE had evolved into a uniquely flexible and powerful platform. This transition sparked a 25-year collaboration between LLE and LLNL, focused on high-energy-density physics (HEDP) and, crucially, on training future scientific leaders.

Concurrent with the HEDP studies was an effort by LLE to develop techniques and diagnostics that contributed to the 2022 achievement of fusion ignition. LLE scientists were stationed at Livermore for extended periods, and LLNL scientists worked on experimental campaigns at LLE. During this period, novel diagnostics were developed that provided the foundation for solving complex science issues on the NIF. Each effort provided a method, proven on Omega, to achieve



Left to right: Alex Zylstra, Annie Kritcher, Jean-Michel Di Nicola, Michael Stadermann, Arthur Pak, and Tammy Ma at a Department of Energy Press Conference after ignition was achieved on the National Ignition Facility. Many of the fusion experiment’s architects can trace their careers back to their early years using the Omega Laser Facility. Photo courtesy Lawrence Livermore National Laboratory.

measurements critical to understanding and improving the performance of NIF implosions. The groups responsible for these developments were comprised of senior scientists plus young researchers and graduate students. This intense experience was formative and a path to significant career advancement. Early-career researchers from LLNL have also led many laboratory basic science (LBS) experiments and collaborated with university researchers on their National Laser Users’ Facility (NLUF) projects for fundamental HED science on the Omega Laser Facility.

Building Foundations for Ignition

Long before NIF’s first full-power shots in 2010, LLE and LLNL scientists were laying the foundations for ignition, both in terms of technical capabilities and scientific expertise. From the late 1990s through the 2000s, Omega served not only as a testbed for experimental techniques but also as a training ground for the people who would one day lead NIF’s most critical campaigns. Over this decade, tightly knit teams of experimentalists, diagnosticians, theorists, and modelers—many of them early in their careers—worked side by side on a relentless schedule of experiments. They refined diagnostics, perfected target designs, and pushed modeling capabilities, all while learning to operate in the uniquely demanding environment of large-scale HED experiments, where precision, speed, and teamwork were paramount. These experiences prepared a community of scientists to tackle the challenges that NIF would bring on the journey to ignition.

When NIF’s lasers first came online, these researchers were more than technically ready—they had years of shared problem solving behind them, having served as principal investigators and coprincipal investigators on Omega campaigns. The result was a cadre of scientists—including Tammy Ma, Art Pak, Annie Kritcher, Alex Zylstra, along with other future ignition leaders—all poised to tackle NIF’s grand challenge. The years of preparation proved decisive. When the NIF team achieved fusion ignition in December 2022, many of the experiment’s architects (pictured at the press conference on page 18) could trace their careers back to their early years on Omega, thus bringing the achievement full circle. In total, the panelists participated in 1342 shots at LLE.

The 2022 ignition shot was not just the culmination of decades of pioneering advanced laser physics; it was a testament to a workforce pipeline that had been deliberately cultivated through sustained collaboration between LLE and the broader community. With further LLE–LLNL collaboration and the continued pipeline of scientists trained at LLE, NIF is now repeating fusion ignition at higher yields and greater target gain. The ignition experiment at the NIF in April 2025 set a record fusion yield of 8.6 MJ with a target gain >4 .

What originally began as a partnership between a handful of LLE scientists and LLNL soon blossomed into a broad and enduring collaboration, with LLNL scientists taking on roles at LLE and the University of Rochester, over time expanding

the mentoring network and supporting a growing cohort of early career scientists and student researchers. Today, LLE supports over 80 graduate student researchers throughout the community, offering them unparalleled access to world-class facilities and expertise—a veritable national laboratory experience at a university.

From Grad Student to Principal Investigator

A defining feature of the LLE–LLNL partnership is the degree of responsibility that is entrusted to students. Within a year of starting graduate school, students are participating in experiments on one of the world’s largest laser facilities. By their second year, many are leading experiments as principal investigators, coordinating teams, and making key decisions in real time.

At the Omega Laser Facility, students use high-power lasers to compress matter to millions of times atmospheric pressure, recreating conditions found deep within planets or even in distant exoplanets. Each experiment is a chance to discover new states of matter or to uncover clues about how planets evolve and whether they might support life. Students are also exposed to the complex instrumentation needed for these experiments, working in a world of picosecond timescales (approximately the time it takes light to transit the width of a single strand of hair) and micron spatial scales (approximately 1/100th the diameter of a strand of hair).

As a University of Rochester graduate student, Dayne Fratanduono was drawn to these opportunities. He focused

“LLE provided me with the opportunity to do research at the boundaries of high-energy density science—something I would never have had the opportunity to do at other institutions.”

Dayne Fratanduono
Deputy Director for Capabilities,
National Ignition Facility

Focus on Collaboration: The LLE–LLNL Collaboration’s Lasting Impact

on understanding materials under extreme conditions—research that demanded rigorous experimentation and creative problem-solving. At Omega, he developed expertise in dynamic compression experiments, probing the behavior of matter at the pressures and temperatures found in planetary interiors and nuclear detonations.

After earning his PhD, Fratanduono joined LLNL, where his research expanded across multiple high-energy-density facilities both within the laboratory and through national collaborations. He became known for his work on warm dense matter and material science at extreme conditions, ultimately contributing to experiments that bridged fundamental science and national security applications that had lasting impact on program priorities. His technical achievements led to broader responsibilities: he served as a scientific advisor to the National Nuclear Security Administration’s Office of Experimental Sciences, providing guidance to policymakers on the implications of high-energy-density physics for the nuclear stockpile.



Photo courtesy of LLNL

Dayne Fratanduono

DEPUTY DIRECTOR FOR
CAPABILITIES, NATIONAL
IGNITION FACILITY

Dayne Fratanduono’s career illustrates the profound impact of LLE’s longstanding partnership with LLNL. As a graduate student at the University of Rochester, Fratanduono conducted experiments at LLE, exploring how matter behaves under extreme pressures and temperatures. This foundational work prepared him for increasingly complex challenges. Currently, as Deputy Director for Capabilities at the National Ignition Facility, Fratanduono is leading the effort to upgrade the National Ignition Facility to boost fusion yields in support of stockpile stewardship and fundamental science.

From Student Researchers to Leaders in Fusion Science

The transition from student researcher to leader in fusion science is shaped by early immersion in meaningful research, sustained mentorship, and opportunities to make tangible contributions to national projects, while being exposed to the broader community that uses the LLE facilities on a daily basis. At LLE, students are given responsibility from the outset—designing and executing experiments, analyzing data, and presenting results to both peers and senior scientists. This environment instills confidence, cultivates independence, and develops the ability to navigate complex, multidisciplinary challenges.

Mentorship is central to this process. Guidance from experienced scientists doing research at LLE exposes students to a range of research cultures and problem-solving strategies. The collaborative model encourages students to build professional networks and to see themselves as contributors to a larger scientific mission.



Michelle Marshall

HEDP EXPERIMENTS
GROUP LEADER AT LLE

Michelle Marshall’s journey through the LLE–LLNL partnership shows how technical innovation and mentorship work together to shape leaders. As a graduate student at LLE, she characterized the high-density carbon used in NIF capsules. This work fostered a collaboration with LLNL scientists, which motivated Marshall to become a postdoctoral researcher at LLNL, where she used her Omega expertise to lead NIF experiments. She then returned to LLE, where she now leads the High-Energy-Density Physics Experiments Group and is known for championing student researchers and fostering their growth as future leaders.

High-Impact Science and Skill Building

LLE collaborations with the community are more than a training program, they are an incubator for leadership, creativity, and scientific innovation. Students gain hands-on experience with high-impact research, from supporting NIF’s ignition experiments to advancing planetary science in meaningful ways. For example, Maggie Huff led experiments to characterize iron under extreme conditions while she was a graduate student at LLE. Huff’s measurements have informed models of planetary interiors and the search for exoplanets capable of supporting life.

Beyond technical skills, students learn to lead teams, solve complex problems, communicate with stakeholders and the public, and thrive in high-pressure environments. Many alumni credit their experiences at LLE with shaping their careers and instilling a lifelong commitment to scientific discovery and collaboration.



Danae Polsin

STAFF SCIENTIST AT LLE

Danae Polsin’s path shows how early access to world-class facilities accelerates scientific growth. A SUNY Geneseo graduate, Polsin came to LLE to study materials under extreme conditions using x-ray diffraction. That expertise led to rare opportunities at the NIF, where she led experiments on ramp-compressed sodium. As part of a joint LLE–LLNL team, she advanced multiframe x-ray diffraction on Omega. Now a Staff Scientist at LLE and Assistant Professor of Mechanical Engineering at the University of Rochester, Polsin views collaboration with LLNL as an essential part of her research—an example of teamwork she passes on to her students.

Shaping National and Energy Security

The ripple effects of the LLE–national laboratory partnerships extend far beyond individual careers. Student contributions have advanced national security, fusion energy, and planetary science while also strengthening the leadership pipeline for critical national security and scientific discovery programs. The collaboration stands as a widely recognized national model for workforce development in high-energy-density science and demonstrate how hands-on research and cross-institutional mentorship can produce leaders who are exceptionally well equipped to tackle some of society’s most complex and pressing scientific challenges.

As the LLE–national laboratory collaboration enters its second quarter century, its impact is evidenced not just in scientific breakthroughs, but in the people it has trained and the relationships they have forged. Today’s students are tomorrow’s leaders—scientists, mentors, and innovators who will shape the future of national laboratories and the frontiers of science for decades to come.



JJ Ruby

SENIOR DIRECTOR OF R&D,
HOUSTON ASTROS

JJ Ruby’s journey spans extremes—from studying matter at millions of degrees on the NIF as a Lawrence Fellow at LLNL to applying analytical innovation with Major League Baseball team the Houston Astros. A Horton Fellow at LLE, Ruby built a foundation in high-energy physics before making the leap into sports science. Now Senior Director of Research and Development for the Astros, Ruby blends physics and data analysis to advance player performance and mentor teams, bringing science directly onto the field.



OLUG at 16

Annual Workshop Strengthens Collaboration

This past May, LLE hosted the 16th Omega Laser Facility Users Group (OLUG) Workshop, which brought together over 140 participants from 38 institutions worldwide, with 110 attendees joining in person and 31 virtually. Highly anticipated each year, this event provides invaluable opportunities for users to collaborate and engage with the facility and for students and early-career researchers to present their work and develop connections within the community.

A Platform for Innovation and Connection

This annual workshop is more than just a meeting for Omega users—it is a hub for innovation and community building. Designed to spark dialogue between users and facility management, OLUG also creates a welcoming space for students and young researchers to exchange ideas and build lasting professional networks.

Over two and a half days, participants attended sessions that explored a wide range of topics, including:

- **Federal Funding Agency Talks:** Program managers from the National Nuclear Security Administration (NNSA) and the National Science Foundation (NSF) presented an overview, perspectives, and program updates
- **Findings and Recommendations (F&Rs) Sessions:** Omega users provided valuable feedback on desired improvements, new capabilities, and future directions with 34 F&R items
- **Omega Laser Facility Talks:** Facility updates and progress on prior OLUG F&Rs, and Omega user program updates
- **Expert Science Talks:** Discussions on ignition in the laboratory and efforts toward higher target gain on the National Ignition Facility (NIF), imaging of inertial fusion energy foams at the Linac Coherent Light Source, and the scaling of high-energy-density (HED) vortex rings formed at shocked interfaces on OMEGA EP
- **PhD Thesis Presentations:** Graduate students shared their research and insights



Group photo of in-person attendees at the 2025 OLUG Workshop.

“The key to success is collaborating with people here at LLE and other people in the user community. No one person can be an expert in everything.”

Landon Tafoya, University of Michigan

- New Diagnostic Capabilities: The latest advancements in diagnostics at the Omega Laser Facility
- FLUX and NSF OPAL Updates: The new FLUX laser, experiments on Omega, and exciting updates on the NSF OPAL design project
- Young Researcher Forum and Career Opportunities: Students and postdoctoral researchers discussed F&Rs unique to them, and met with scientists from national laboratories, industry, and academia for career and training opportunities in HED science
- Two Poster Sessions: 62 posters, 51 of which were presented by students and postdocs, showcasing innovative research

Maria Gatú Johnson, Principal Research Scientist at the MIT Plasma Science and Fusion Center, closely collaborates with LLE and has been focusing on studying inertial confinement fusion (ICF) and plasma nuclear physics using particle and nuclear diagnostic techniques. These techniques have been essential for guiding the ICF Program on OMEGA to record yields and on the NIF for ignition and energy gain. “OLUG is the opportunity to build connections,” she says, “both with other teams doing experiments, and with the facility and the team at LLE to do the best possible science.”

Landon Tafoya, a doctoral student at the University of Michigan conducting his thesis research with a Los Alamos National Laboratory team, has been conducting experiments on the Omega Laser Facility for his thesis research. He says, “The key to success is collaborating with people here at LLE and other people in the user community. No one person can be an expert in everything.”

Celebrating Excellence

The workshop culminated in the recognition of outstanding contributions by young researchers through the Best Poster Awards. Congratulations to the five winners:

- Graduate Students: Matthew Cufari (MIT), Huws Landberger (Princeton University), Jaya Sicard (Lawrence Livermore National Laboratory, soon joining UC Berkeley)
- Undergraduate Student: Selma Zuhrić (University of Michigan)
- Postdoctoral Researcher: Edoardo Rovere (University of California, San Diego)

A Special Thanks to the Workshop Organizers and Sponsors

This workshop was organized by the OLUG Executive Committee in collaboration with LLE. It was made possible through the generous support of the NNSA’s Academic Programs, which provided travel grants to 40 students and postdocs, and Prism Computational Sciences, Inc., which sponsored the Best Poster Awards.



Corresponding author

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Want to see the highlights for yourself?

Check out our video recap on our YouTube page: www.youtube.com/@LaboratoryforLaserEnergetics



Building Fusion Leaders

IFE-SURE Undergraduates Connect In Nation's Capitol

The Inertial Fusion Energy Summer Undergraduate Research Experience (IFE-SURE) is a new Department of Energy (DOE)-funded workforce development initiative launched by the IFE Science and Technology Accelerated Research (IFE-STAR) program. This summer marked the program's inaugural year, with 46 undergraduate students engaged in hands-on research experiences across 11 universities, national laboratories, and private-sector organizations.

Designed to attract and develop the next generation of scientists and engineers in inertial fusion energy, the IFE-SURE program provides students with research opportunities to contribute to the scientific and engineering challenges of fusion energy. By immersing participants in real-world challenges, the program aims to inspire and prepare them for careers in fusion energy and related fields while addressing the critical need for a skilled and diverse workforce in the energy sector.

The program brings together public and private institutions and national labs to advance IFE science and accelerate the development of energy technologies. By working across different sectors, IFE-STAR fosters mentorship, collaboration, and innovation—all of which benefit students participating in IFE-SURE.



Inaugural IFE-SURE students at the 2025 Symposium in Washington, DC.

A National Effort to Build the Talent Pipeline

Undergraduates interested in IFE-SURE are selected through a national application process that connects students with host sites aligned with their interests. Applicants are able to review detailed information about participating institutions before choosing their preferred locations, which include LLE, Ergodic, SLAC, Texas A&M University, the University of California, San Diego, the University Nebraska–Lincoln, Focused Energy, Leonardo Electronics, Brigham Young University, Colorado State University, and Lawrence Livermore National Laboratory. Each organization then selects students from the applicant pool to join their research teams.

“Through the IFE-SURE program, I’ve been able to explore the intersection of engineering and fusion science. This experience has motivated me to learn more about the wide range of challenges and innovations involved in inertial fusion energy.”

Ruth Reynolds
IFE-SURE student

IFE-SURE student Ruth Reynolds conducting research in LLE’s Microfabrication Lab.

As the US strengthens its energy security, the demand for a well-trained workforce has never been stronger. IFE-SURE addresses this urgent need by providing students with hands-on exposure to fusion science and engineering in practice. Whether working on diagnostics, simulations, target design, or experimental systems, students contribute meaningfully to active research efforts while gaining technical skills, mentorship, and exposure to career pathways within fusion energy and related fields.

Beyond the Lab: Broadening Participation and Perspective

In addition to their research, students participate in a series of webinars, workshops, and other virtual events throughout the summer. These sessions deepen students' understanding of fusion science and engineering, connect them with experts, foster cross-disciplinary engagement, and provide professional development. Topics range from the physics of fusion to career exploration and the societal impacts of fusion energy development. This layered experience ensures that IFE-SURE students walk away not only with new technical knowledge but also with a broader understanding of how their contributions fit into IFE.

This year's program culminated in the IFE-SURE Symposium in Washington, DC, where students presented their research, connected with peers from across the country, engaged with leading experts in the IFE community, and met members of the Senate Committee on Energy and National Resources. The event celebrated student achievement, solidified connections, and strengthened the talent pipeline for years to come.



Participants in the IFE-SURE program at the US Capitol during the 2025 Symposium in Washington, DC.



IFE-SURE students present summer research at the 2025 Symposium in Washington, DC.

"LLE has a strong tradition of mentoring undergraduate students, and the IFE-SURE program builds on that foundation by expanding opportunities in fusion research by connecting students to the broader ecosystem of fusion scientists. This is an exciting time for the field, and IFE students—both at LLE and nationwide—are contributing at the forefront of fusion-related research."

Dustin Froula, Director of the IFE-STAR Program

2026 IFE-STAR Conference

Join us in Washington, DC, March 22–27, 2026 to connect, collaborate, and share knowledge that will help define the future of fusion energy.



IFE STAR

To learn more about IFE-STAR or the IFE-SURE program, visit ifestar.org.



LLE's Industry Partners Drive Progress Through Collaboration

Since its founding in 1970, LLE has been at the forefront of cutting-edge research, education, and technological innovation in the field of laser science. Over the years, LLE scientists, engineers, and students have made countless breakthroughs that have advanced the frontiers of science and led to important practical applications, significantly impacting society at large. At the heart of this success is the emphasis LLE places on fostering collaboration, not only among various teams at the laboratory itself but also through its important partnerships with companies in the private sector. As LLE looks ahead to the future, such strategic partnerships will be essential in driving progress to address pressing global challenges.

In addition to capitalizing on the unique skills, resources, and expertise of various groups in academia and industry, collaboration drives private investment, fosters job growth, and, on a local level, helps maintain the Rochester region's position as a leader in advancing manufacturing, communications, defense, and other high-tech sectors reliant on laser technology. On a national level, collaboration also supports the inertial fusion energy and inertial confinement fusion communities. In this article, we highlight five of LLE's many important partnerships that are leading the way in shaping our collective future. By achieving our goal of finding solutions today, we will be better equipped to meet tomorrow's challenges. Several of LLE's partnerships with industry are highlighted below as examples of how collaboration fuels discovery and progress.



QED Technologies

QED Technologies, based in Rochester, NY, was founded in 1996 and has a longstanding international reputation for providing optics manufacturers with world-class precision polishing and metrology solutions. Its pioneering magnetorheological finishing (MRF) technology, in particular, enables the manufacture and performance demands of the complex optics used in mission-critical research activities at LLE and the National Ignition Facility at Lawrence Livermore National Laboratory, which support NNSA's Inertial Confinement Fusion program—an integral part of its National Stockpile Stewardship and Management Plan.

MRF was invented in the late 1980s by William Kordonski and his colleagues at the Luikov Institute of Heat and Mass Transfer in Minsk, Belarus, and later refined and brought to commercial readiness by LLE scientist Stephen Jacobs and his

team at the University of Rochester's former Center for Optics Manufacturing. The technique uses a slurry of microscopic abrasive particles in a magnetorheological fluid—one whose viscosity can be altered with the application of a magnetic field—to shape and polish the surfaces of optical components to nanolevel smoothness. In addition to achieving mirror-like finishes, MRF is also known for its ability to polish complex shapes, including aspheres, with high accuracy and efficiency.

Earlier this summer, QED announced the news of an \$18.7 million expansion project that will add 20,000 square feet to the company's current campus on University Ave. to establish a new research and development center and expand its precision optics fabrication capabilities. "We [...] recognize the importance of collaboration within our local optics and academic ecosystem to ensure that Rochester remains a leader on the world stage in optics and photonics," says QED President and CEO Michael Mohammadi.



General Atomics

Another of LLE's important partnerships is with San Diego-based defense and diversified technologies company General Atomics (GA), which, since 1991 has manufactured nearly all of the LLE target capsules scientists use for experimental campaigns on the Omega Laser System.

Four team members from GA are permanently stationed at LLE, and they work closely with the laboratory's Target Fabrication Group and principal investigators on target design, fabrication, metrology, target delivery, and in providing target-specific shot support for national labs (Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratory), as well as the National Laser Users' Facility Program. Regular meetings and visits by the LLE team to the San Diego campus ensure close collaboration and sharing of knowledge between both teams, deadline adherence, and also help drive improvements to target fabrication processes.

To learn more about the LLE–General Atomics partnership, be sure to read the full-length feature article published in *LLE in Focus* Issue 5.



Attendees of the inaugural IFE-STAR conference in Breckenridge, CO, in April 2025.



IFE-STAR

This past January, with the support of a \$2.25 million grant extending over three years from the DOE's Office of Fusion Energy Sciences, LLE launched the Inertial Fusion Energy Science and Technology Accelerated Research (IFE-STAR) network, a collaborative platform focused on realizing a clean, safe, and virtually limitless energy source through inertial fusion energy.

IFE-STAR brings together academia, national laboratories, and the private sector, with three leading US research institutions each spearheading a unique hub to advance inertial fusion energy science and technology while upholding the program's five core pillars: Educate, Innovate, Accelerate, Integrate, and Collaborate. The institutions are:

- LLE's Consortium on Laser-Plasma Interaction Research (IFE-COLoR) hub
- Lawrence Livermore National Laboratory's Science and Technology Accelerated Research (STARFIRE) hub
- Colorado State University's Research in Inertial and Sustainable Energy (RISE) hub

In addition, a central focus of the ecosystem is to address critical challenges in inertial fusion energy development, which include achieving the sustainment of a burning plasma, engineering for extreme conditions, and harnessing fusion power.

This past April, IFE-STAR held its first annual meeting in Breckenridge, CO, where nearly 200 students, scientists, engineers, and industry leaders participated in an exciting week of talks, presentations, poster sessions, and networking events highlighting the latest advances and innovations in inertial fusion energy-related research and technologies. "The first IFE-STAR conference was a big success," says LLE scientist Mingsheng Wei. "I was impressed not only by the breadth and depth of the technical discussions, but also by how collaborative teams are working together including through public and private partnerships to accelerate IFE science and technology."



Sydor Technologies

Sydor Technologies, a global leader in complex measurement technology solutions, headquartered in Fairport, NY, is a key manufacturing partner for inertial fusion facilities and researchers alike. Its longstanding relationship with scientists at LLE and other research facilities has led to a wide variety of commercial applications.

Last fall, LLE and Sydor Technologies were awarded a \$1.15 million Phase-II Small Business Innovation Research grant from the DOE to advance the development of optical devices for high-powered laser systems. Their project, "Plasma-Electrode Pockels Cells for Inertial Fusion Facilities," is currently underway and focuses on commercializing midscale plasma-electrode Pockels cell (mPEPC) technology, an electro-optic component essential for enabling and reducing the cost of future fusion facilities. This technology offers several key benefits for inertial fusion applications:

- Facilitating multipass laser amplification, maximizing performance while reducing costs and facility size
- Enabling high-power, high-energy modular lasers necessary for scalable inertial fusion systems
- Integrating optical isolation and retroreflection protection within high-energy laser systems without additional optical components
- Pioneering future commercial facility designs by enabling various modular and economically reproducible configurations

"This grant provides the opportunity to work hand-in-hand with the experts at LLE while leveraging facility resources to construct a first-article mPEPC electro-optic cell and to further refine plasma-electrode Pockels cell technology," says Dr. David Garand, Advanced Instrumentation Business Unit Manager at Sydor Technologies. "The Sydor team is excited to continue working toward commercializing this technology and to make it accessible for broad adoption."



Plymouth Grating
LABORATORY

Plymouth Grating Laboratory

Founded in 2004 by Douglas Smith and based in Carver, MA, Plymouth Grating Laboratory (PGL) is a leading manufacturer of large, high-performance diffraction gratings for lasers and laser systems. Before starting PGL, Smith worked for nearly two decades in LLE's Optical Manufacturing (OMAN) department, overseeing the production of thin-film coatings and optics manufacturing, gaining expertise in the development of large optics for high-intensity laser applications.

These diffraction gratings, which consist of a series of adjacent grooves or slits etched onto the surface of a substrate, are used to separate a beam of light into its different wavelengths. This unique technology enables scientists to effectively manipulate and control the laser beam wavelengths as needed for a range of applications, including the inertial confinement fusion experiments that are conducted on the Omega Laser System at LLE.

In 2023, the University of Rochester received a three-year, \$18 million award from the National Science Foundation to design NSF OPAL, a proposed new facility at LLE dedicated to the study and exploration of ultrahigh intensity laser-matter interactions. PGL received a portion of this funding to design and develop extra-large gratings—potentially as large as two meters wide—for the two 25-petawatt all-optical parametric chirped-pulse amplification lasers that will be built and housed at the facility. The precise requirements and complexities involved in the fabrication of these large gratings make this process extremely challenging and therefore, this project is a testament to the skill and dedication of PGL's technicians and engineers who work together with LLE scientists to realize these highly advanced innovations. In parallel, LLE will be working with the community to increase the damage threshold of gratings and shrink the size of the gratings necessary to handle 25 petawatts.

"PGL is honored to play a crucial role in enabling the world's highest peak power laser," says PGL's President Turan Erdogan, who received his PhD in optics from the University of Rochester in 1992. "Not only are ultrahigh-intensity lasers like this one making possible pioneering science such as laser particle acceleration, laboratory astrophysics, and laser-driven nuclear science, but they will one day also have tremendous practical impact in areas that touch every individual's life, including energy, security, and medicine."

Workforce Development

LLE's commitment to workforce development is reflected in several initiatives that prepare students for careers in science, engineering, and industry. One is the Inertial Fusion Energy-Science and Technology Accelerated Research (IFE-STAR) network and its Summer Undergraduate Research Experience, IFE-SURE (see page 24)—an immersive program that places students at more than 20 institutions to work alongside leading scientists and engineers. Through IFE-STAR, industry is a key partner that helps students see future opportunities. Companies participate through Department of Energy programs such as INFUSE (Innovative Network for Fusion Energy) and FIRE (Fusion Innovation Research Engine). A consortium of universities, government laboratories, and private partners meets quarterly to coordinate efforts and strengthen the pathway toward a fusion-ready workforce.

Complementing these national collaborations, LLE's Undergraduate Education Program engages students each year in mission-critical science and engineering. More than 40 mentors across the Laboratory guide undergraduates majoring in physics, engineering, optics, computer science, data science, chemistry, and mathematics. Over 50 undergraduates are engaged in research at LLE. Their projects contribute directly to LLE's mission and give students hands-on experience with advanced technologies rarely accessible at the undergraduate level. Many students continue into graduate school, national laboratory internships, and careers in industry or at LLE itself. The program also provides opportunities to connect with alumni and workforce leaders at national laboratories, giving students valuable perspective on future career paths.

LLE's decades-long partnership with SUNY Geneseo further reinforces this pipeline. Hundreds of Geneseo undergraduates have gained experience at LLE with many continuing to doctoral programs or positions at national laboratories, in academia, industry, and at LLE. Roughly 10% of LLE's workforce today are Geneseo alumni, a testament to the enduring strength of this collaboration.

On a more local level, these initiatives dovetail with demands fueled by the Rochester region's burgeoning industry of optics, imaging, and laser technology. With over 150 businesses and an annual economic output of more than \$3.5 billion, the region is an unparalleled hub of innovation.¹ As a major research center and the world's largest laser facility in an academic setting, "LLE's impact locally, nationally, and across the globe is truly immeasurable," says New York State Assembly member Sarah Clark.

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References

1. "Home to 150+ Businesses Focused on Optics, Photonics, Imaging, and Lasers," Greater Rochester Enterprise, accessed August 28, 2025, <https://rochesterbiz.com/optics-photonics-imaging/>.



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