UNIVERSITY OF ROCHESTER
LABORATORY FOR LASER ENERGETICS

A Unique National Resource

UNIVERSITY of ROCHESTER

www.lle.rochester.edu

FROM THE DIRECTOR

DR. CHRISTOPHER DEENEY
DIRECTOR
LABORATORY FOR
LASER ENERGETICS

The Laboratory for Laser Energetics (LLE) is truly a unique national resource. At the heart of this uniqueness is our amazing team of over 150 scientists and research engineers who on a daily basis advance the frontiers of fusion, high-energy-density science, laser technologies, and fundamental plasma physics. Of course, these advances would not be possible without the dedication of 300 additional staff members who operate our facilities, engineer components in our laboratories, maintain our infrastructure, and administer our business operations.

As a major institution within the University of Rochester, LLE is guided by an overarching educational mandate. Our 20 staff scientists who hold appointments within departments on campus supervise 60 to 70 graduate students, with 10 on average graduating with doctoral degrees each year. In addition, a similar number of visiting PhD students graduate annually from our broader user community. LLE also hosts researchers from MIT, UCLA, UCSD, University of Michigan, Princeton University, and other institutions to execute shots at the Omega Laser Facility. We also collaborate with local institutions like SUNY Geneseo, Rochester Institute of Technology, and Monroe Community College on collaborative programs which create a talent pipeline for ourselves and the region. Finally, the laboratory's thriving educational opportunities for younger students are led by our energetic scientific and engineering staff, who provide projects that engage over 50 undergraduates from various universities and over 30 high school students from the city of Rochester and its suburbs each year.

Hopefully, it is immediately apparent from this brochure that we realize our vision of being "the leading academic institution for fusion, high-energy-density science, and laser technologies of scale." We are proud of our team and our accomplishments, and our university motto Meliora challenges us every day to be "ever better"—whether it is in our operations, our research in science and technology, or on our journey to be a more diverse and inclusive workplace. Of course, none of this would be possible without the incredible support we receive from federal and state governments. We are incredibly grateful for the strong support we receive from the U.S. Congress and our federal sponsors: the National Nuclear Security Administration, the Department of Energy Office of Science, the U.S. National Science Foundation, the U.S. Department of Defense, and the State of New York.

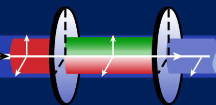
Christopher Deeney
Director, Laboratory for Laser Energetics

HISTORY OF LLE

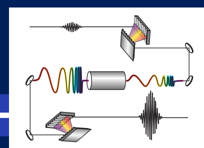
1978 LHG-8 Nd:phosphate laser glass

1979 National Laser Users' Facility established

1980 High-efficiency frequency tripling



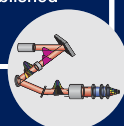
1981 24-beam OMEGA established



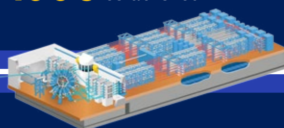
1985 Chirped-pulse amplification (CPA)

1989 High School Program established

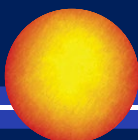
Smoothing by spectral dispersion (SSD)



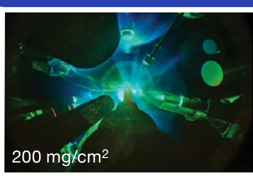
1995 60-beam OMEGA established



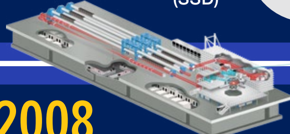
1999 THz 2D SSD



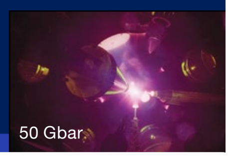
2000 High-fluence optic coatings for the National Ignition Facility



2007 Record OMEGA areal density



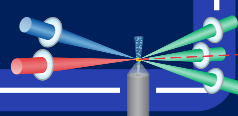
2008 OMEGA EP established



2015 Record hot-spot pressure on OMEGA

2018 Nobel Prize in Physics awarded to Donna Strickland and Gérard Mourou for pioneering CPA

2019 Tripled yield in direct-drive through statistical modeling



2020 Tunable OMEGA Port 9 for laser–plasma instability understanding

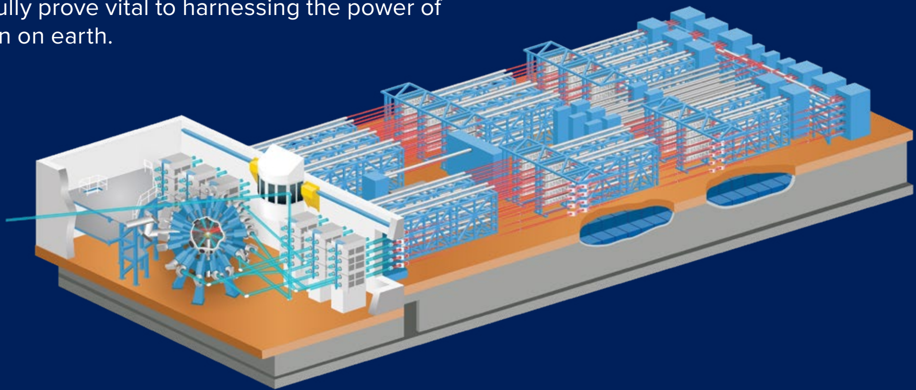
2021 BEST High School initiative established

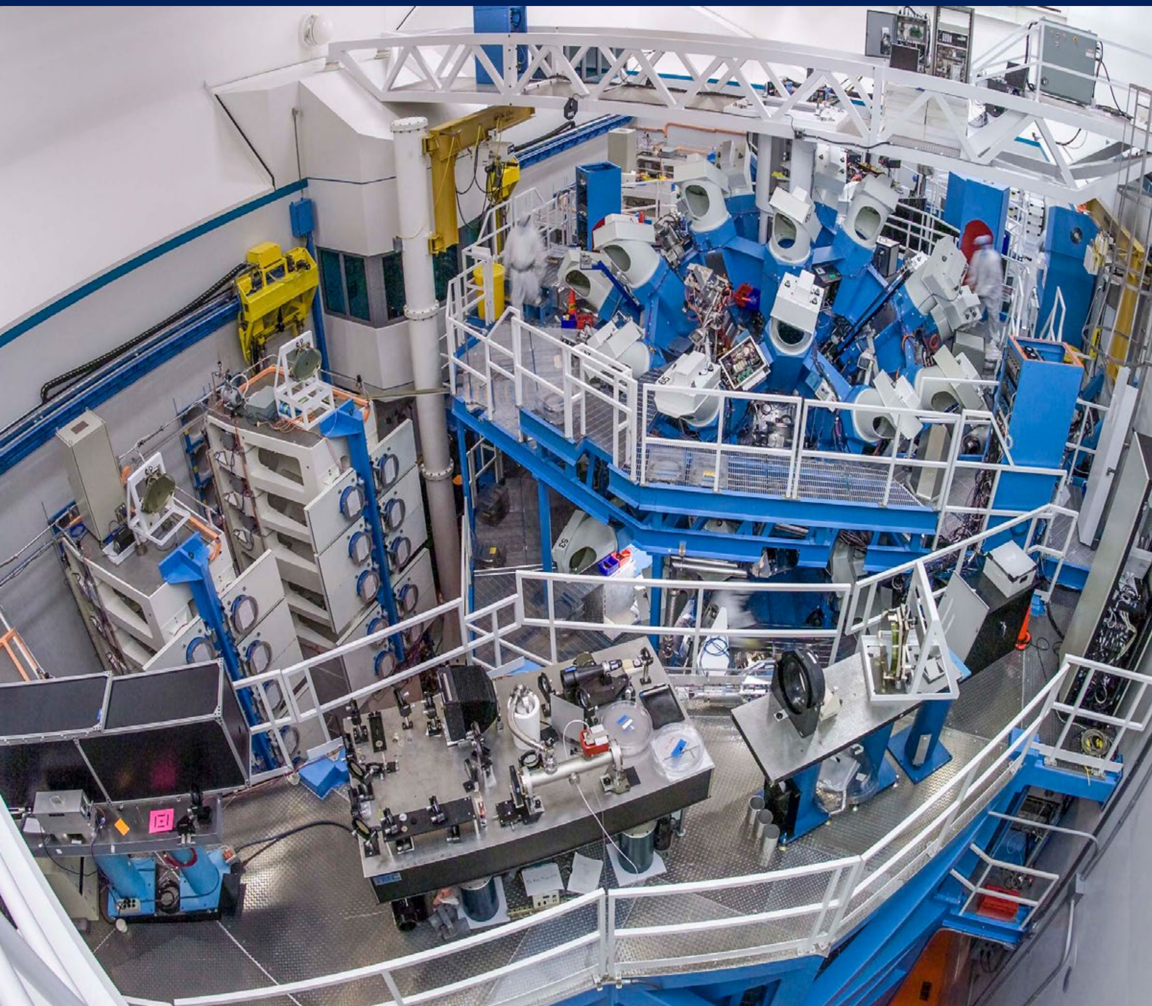
MTW-OPAL laser established

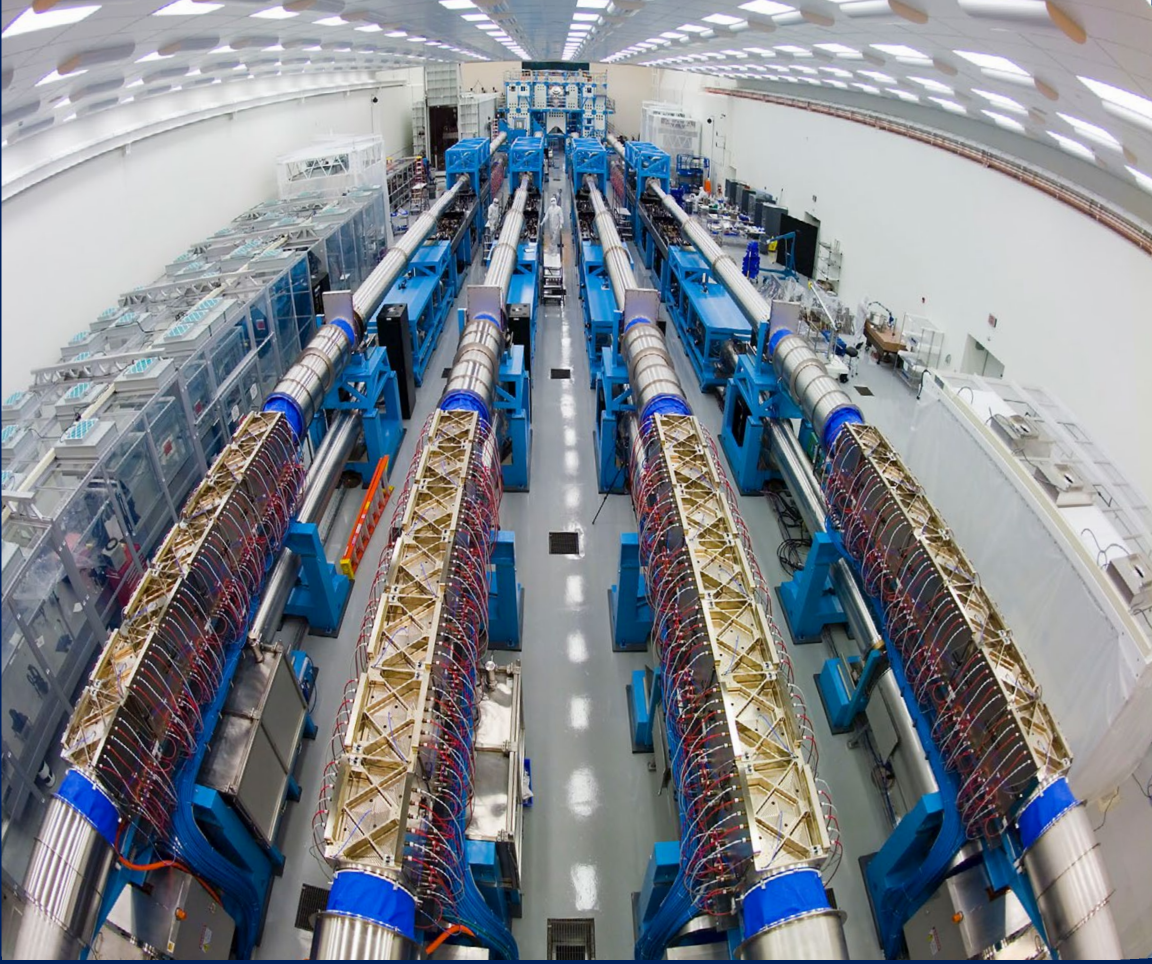
2024 FLUX established

OMEGA

OMEGA stands 10 meters tall and is approximately 70 meters in length. This system delivers pulses of laser energy to targets in order to measure the resulting nuclear and fluid dynamic events. OMEGA's 60 laser beams focus up to 30,000 joules of energy onto a target that measures less than 1 millimeter in diameter in approximately one billionth of a second. Scientists at LLE will continue to research what will one day hopefully prove vital to harnessing the power of the sun on earth.

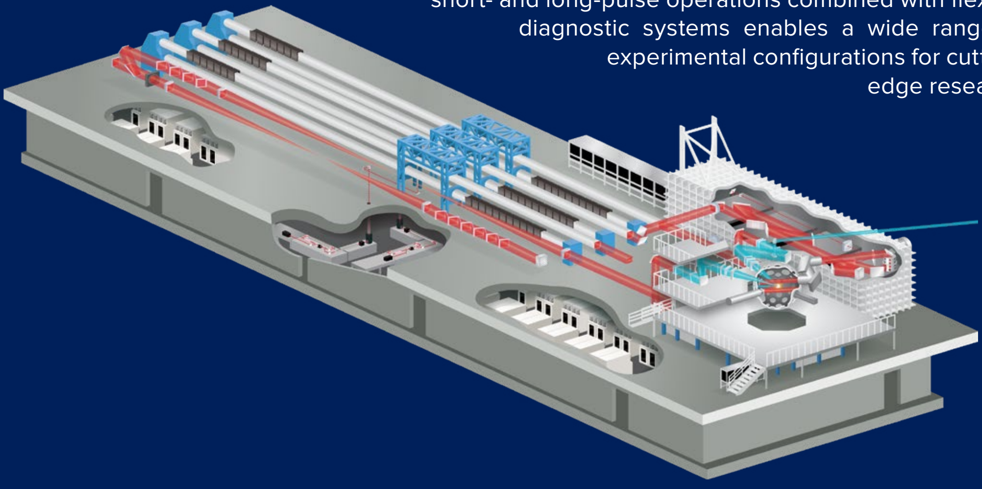


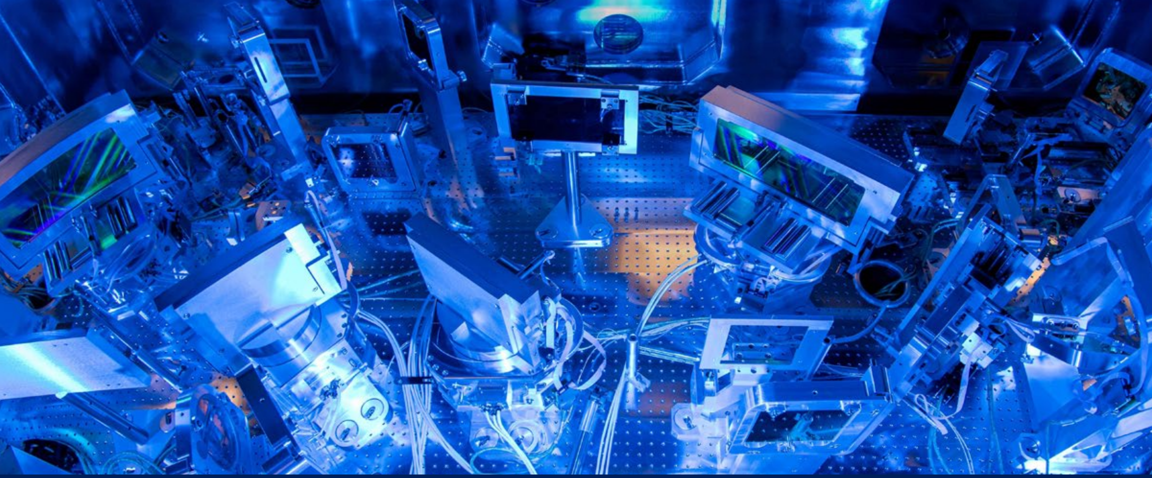




OMEGA EP

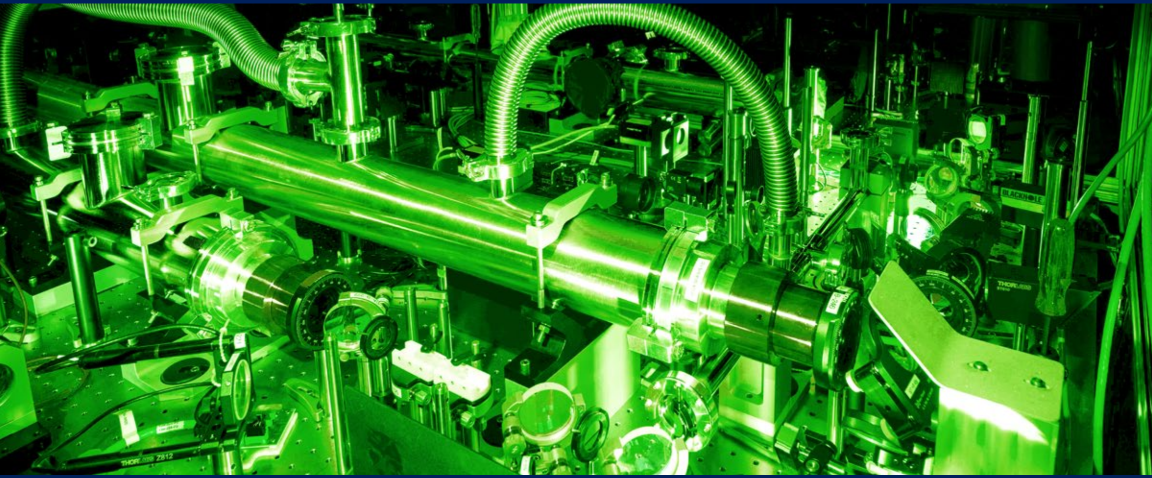
The OMEGA EP Laser System, in operation since 2008, extends the performance and capabilities of the facility. OMEGA EP has four frequency-tripled, kilojoule-class, independently configurable National Ignition Facility (NIF)-scale beamlines, two of which can be compressed for short-pulse, petawatt-class operation. The combination of high intensity and high energy in short- and long-pulse operations combined with flexible diagnostic systems enables a wide range of experimental configurations for cutting-edge research.





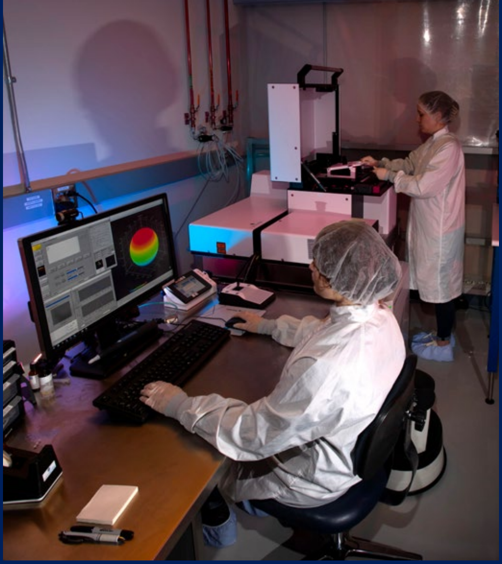
Multi-Terawatt (MTW) Laser Facility

The MTW Laser Facility comprises a hybrid laser glass–OPCPA (optical parametric chirped-pulse amplification) laser that has delivered picosecond pulses since 2004, plus an all-OPCPA optical parametric amplifier line (OPAL) that demonstrated first light with femtosecond pulses in 2020. Both systems deliver laser pulses for studying high-energy-density physics and developing short-pulse laser technologies and experimental target diagnostics. MTW provides hands-on training through experimental campaigns that support graduate student research, develop early-career scientists, and provide diagnostic innovation to support other facilities.



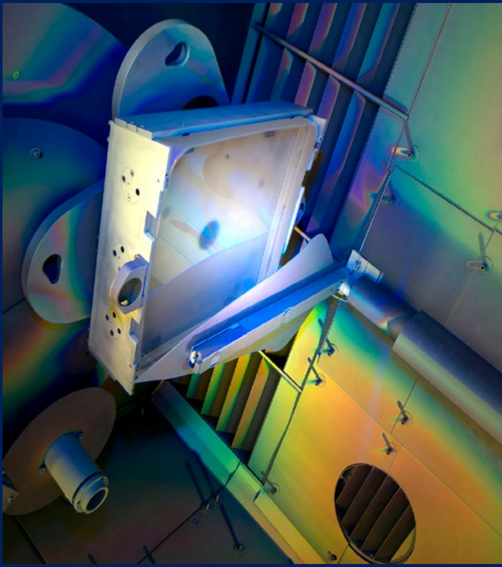
FLUX Laser

The Fourth-generation Laser for Ultra-broadband eXperiments (FLUX) laser produces a beam that can be used on OMEGA to demonstrate broadband laser–plasma instability mitigation and laser-irradiation uniformity improvements. FLUX presents a potential path for experimental breakthroughs at unprecedented bandwidths.



Target Fabrication

To meet the demands of our broad user base, LLE's Target Fabrication Facility manufactures over 2500 precision targets per year, while continuing to develop new target-production methods and conducting routine metrology of targets at micron resolution. The facility is home to various types of microscopy (scanning electron, atomic force, confocal, stereo, compound, and 3D x-ray tomography), a world-leading two-photon polymerization 3D printer, and multiple assembly stations.



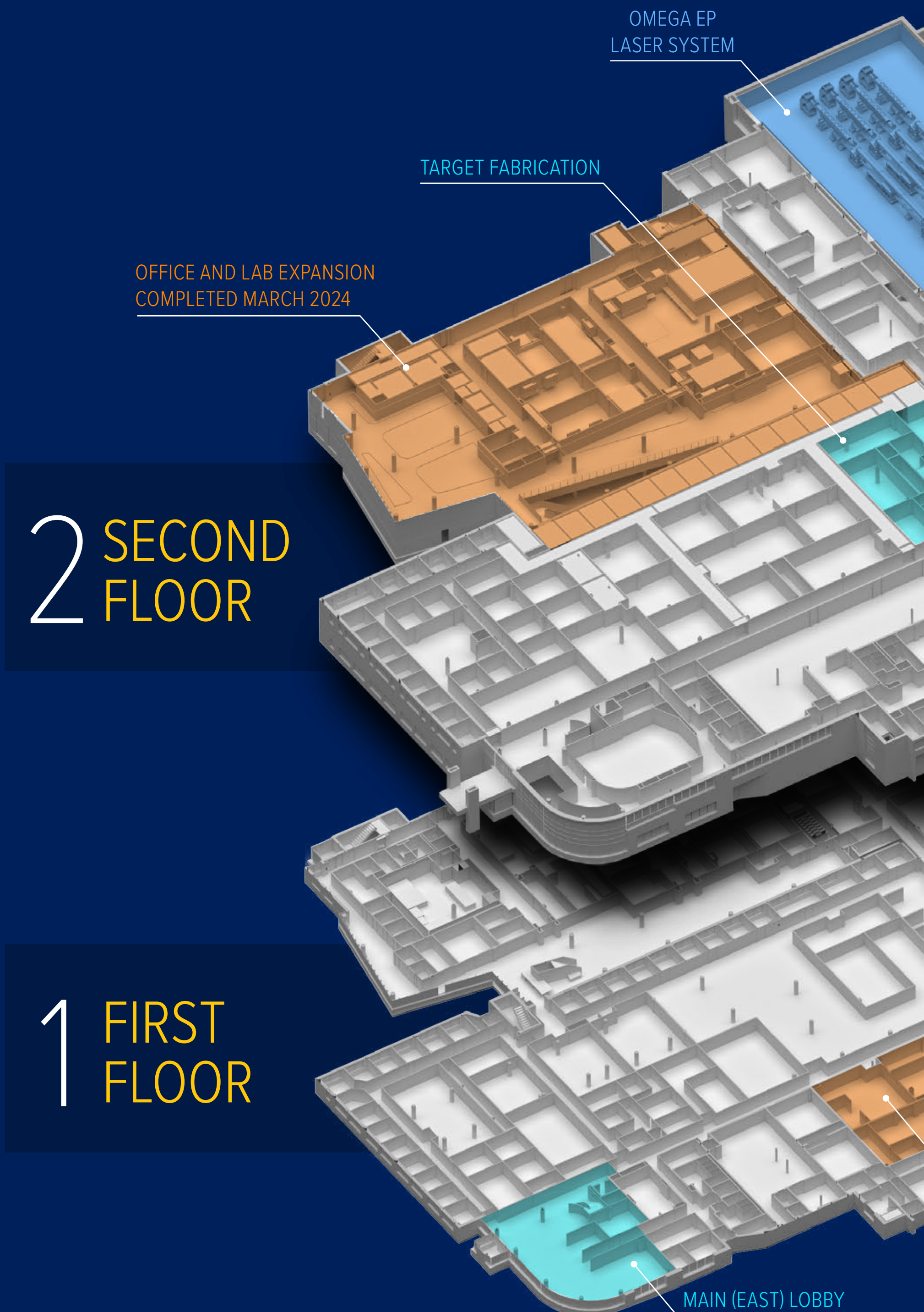
Optical Manufacturing

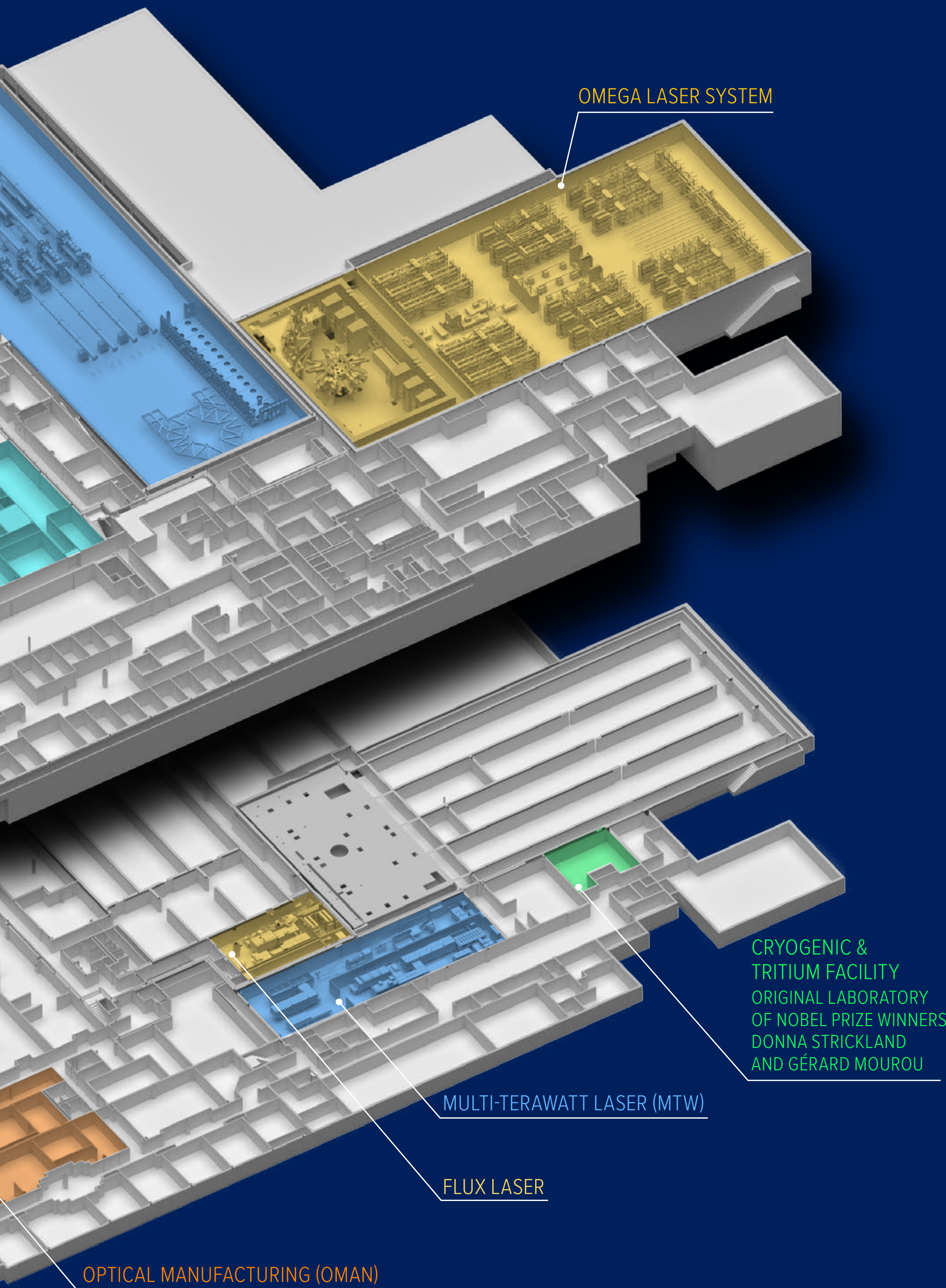
LLE's Optical Manufacturing (OMAN) Facility manufactures high-damage-threshold–coated optics to maintain Omega. OMAN also develops new optical thin-film components such as echelons and glancing-angle deposition (GLAD) coatings. OMAN's specialized fabrication shop produces one-off custom components to help support research and development projects at LLE and other facilities around the world.

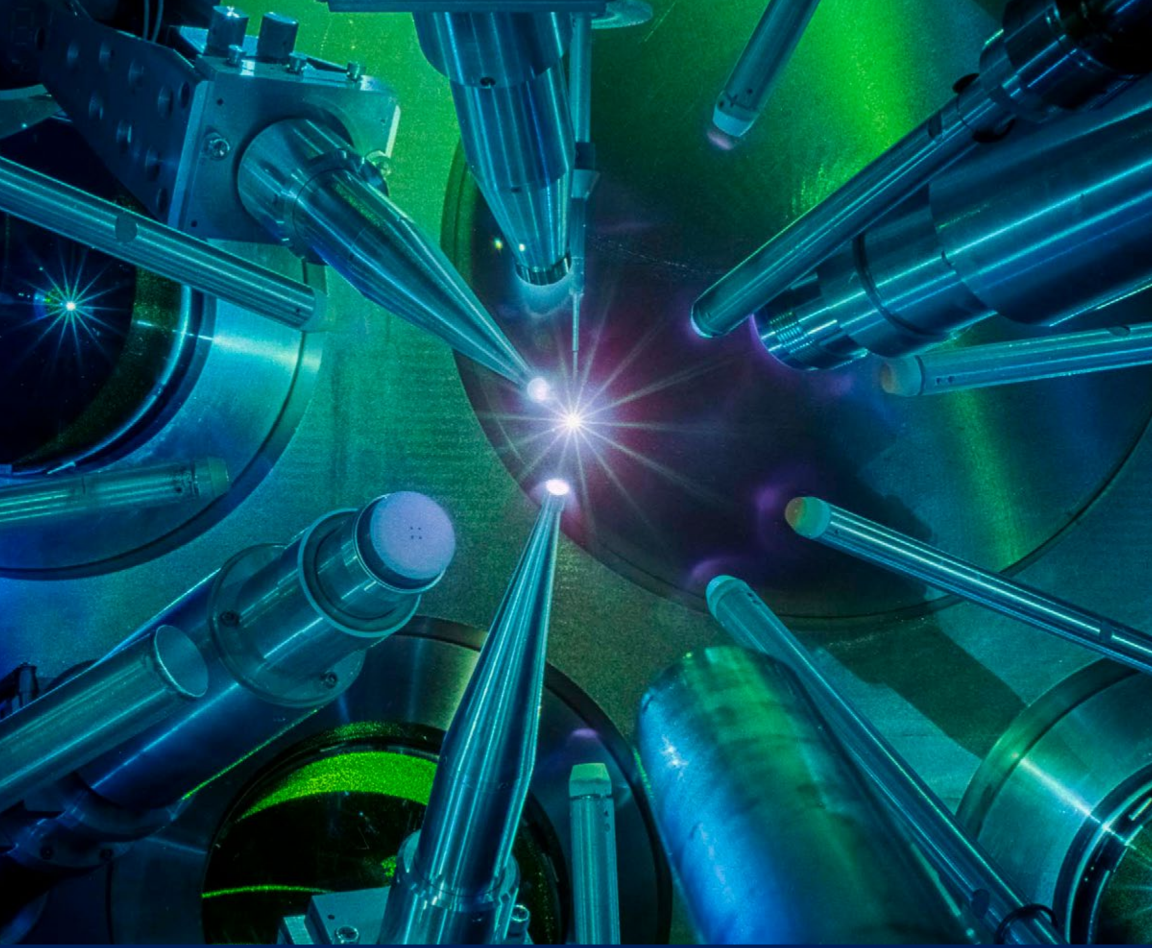
Cryogenic & Tritium

LLE's world-class Cryogenic and Tritium Facility prepares cryogenic targets composed of frozen hydrogen isotopes deposited inside 1-mm round plastic shells. The warm gas is first compressed to high pressure, allowing it to permeate into the shells, which are then cooled to –253°C. The targets are transferred to special mobile cryostat carts using robotic equipment in a complex mechanical system, and a uniform ice layer is developed before the targets are moved to OMEGA. The facility produces 50 cryogenic targets and 150 room-temperature targets annually.

TOURING LLE


OMEGA EP
LASER SYSTEM
TARGET FABRICATION
OFFICE AND LAB EXPANSION
COMPLETED MARCH 2024
2 SECOND FLOOR
1 FIRST FLOOR
MAIN (EAST) LOBBY


OMEGA LASER SYSTEM
CRYOGENIC &
TRITIUM FACILITY
ORIGINAL LABORATORY
OF NOBEL PRIZE WINNERS
DONNA STRICKLAND
AND GÉRARD MOUROU
MULTI-TERAWATT LASER (MTW)
FLUX LASER
OPTICAL MANUFACTURING (OMAN)



FUSION

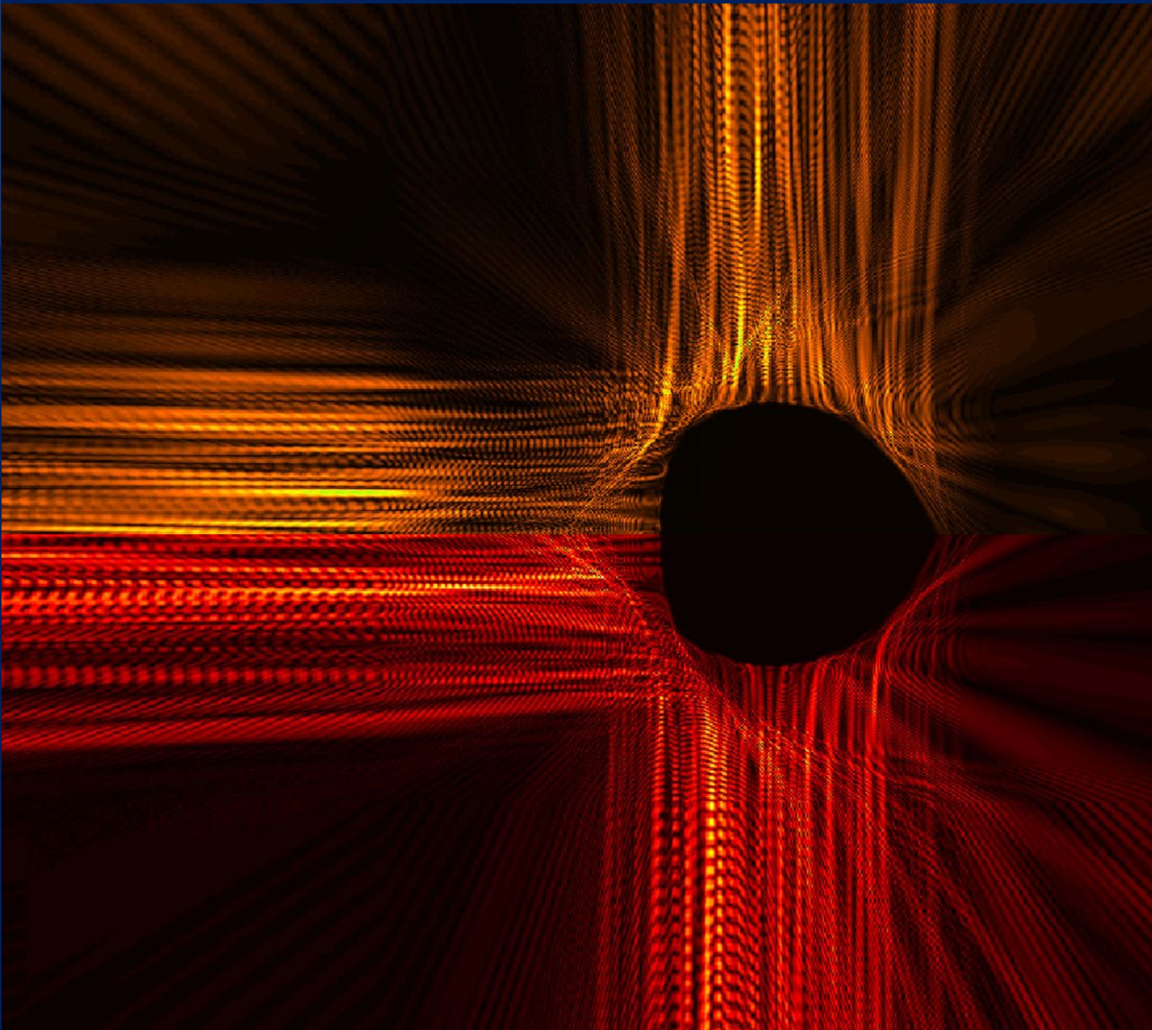
Both national security and energy security benefit from the advancement of fusion as a means of creating high-yield sources of clean energy. The National Nuclear Security Administration has invested in LLE's Omega Laser Facility, the Z Pulsed Power Facility at Sandia National Laboratories, and Lawrence Livermore National Laboratory's National Ignition Facility to not only achieve ignition but also to advance capabilities to hundreds of megajoules of output. As a leader of laser direct-drive fusion—an approach that can couple significant energy to a deuterium–tritium (DT) fuel capsule—LLE will play an important part in ultimately shaping the future of our global energy resources.

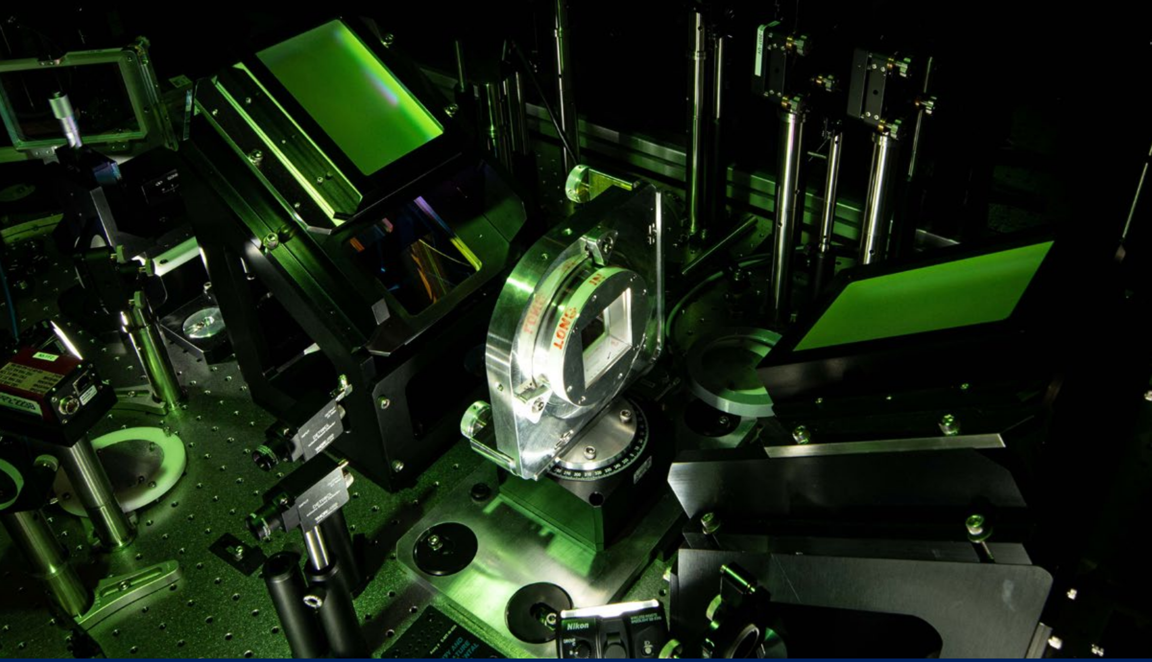
The direct-drive approach to inertial confinement fusion (ICF) allows LLE's 60-beam OMEGA Laser System to implode capsules and produce a plasma that, when compressed to 100 times the density of gold at 50 million degrees Celsius, achieves a percentage of the Lawson criterion. This, although insufficient for ignition, is sufficient to guide future developments and train students on the physics of ICF—a scientific grand challenge that integrates and motivates advanced capabilities in all aspects of technology. In direct drive, a 1-mm-diam, 30-μm-thick capsule is filled with DT gas and cooled to 20 degrees above absolute zero to form a perfectly spherical 30-μm-thick DT crystal. The OMEGA laser then uniformly irradiates the capsule, accelerating it in 1 ns to 400 km/s, and subsequent diagnostics measure the laser performance, the uniformity of the implosion, and all key parameters to explain performance.

PLASMA & HED PHYSICS

The success of inertial confinement fusion relies on the uninhibited propagation of laser beams through plasma and the heating and compression of materials to extreme conditions. Plasma and high-energy-density (HED) physics seek to understand these processes at a fundamental level. The plasma formed during a fusion implosion can rapidly rearrange itself in response to the laser beams, which can prevent the efficient deposition of laser energy. With the new broadband laser technology being developed at LLE, this efficiency will be substantially enhanced. Once the laser energy is deposited, it creates conditions that, outside of experimental facilities like OMEGA and OMEGA EP, would only exist in the extreme astrophysical environments found throughout the cosmos.

LLE plays a critical role in plasma and HED physics by adopting a multidisciplinary approach that combines the expertise of physicists, laser scientists, engineers, computer scientists, and operations. It is precisely this approach that enables LLE to chart new frontiers in the creation and manipulation of extreme states of matter for fundamental science and applications. By engaging and training the next generation of plasma and HED scientists, LLE hopes to realize a future that expands our understanding of the universe, brings fusion to the grid, and perhaps even probes the fabric of the cosmos through the development of compact particle accelerators.

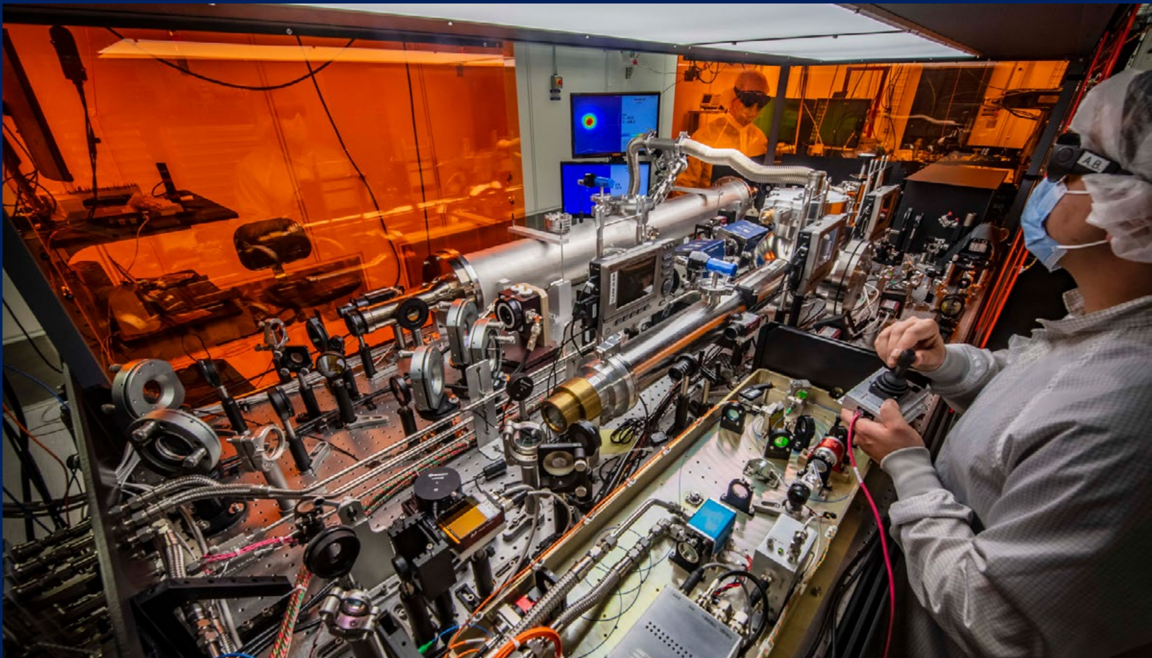




LASER TECHNOLOGY

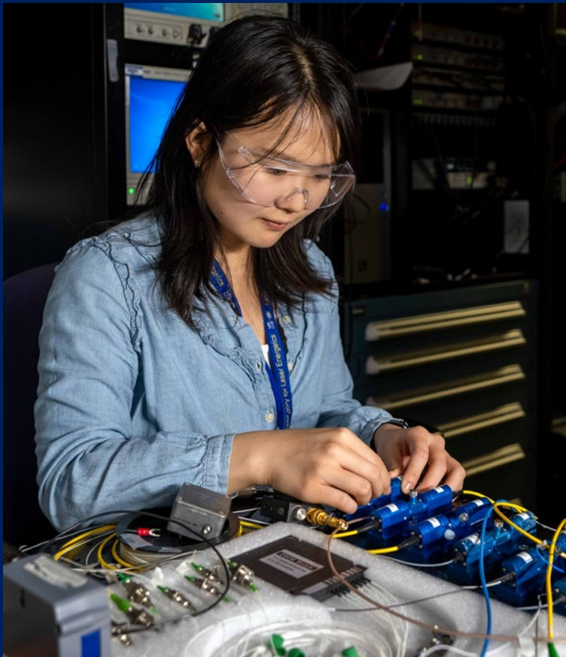
Laser science and technology research is a primary technical mission for LLE. To this end, LLE is exploring advanced laser technologies that have the potential to enhance future research capabilities both at the Laboratory and around the world. LLE is also developing the technology for the next generation of ultra-intense lasers (tens to 100 PW) that will drive new opportunities in advanced particle and light-source development.

Some areas of research and development currently underway at LLE include broadband laser technologies, kilojoule lasers with increased shot rates, short-pulse lasers for HED science, high-power laser designs, optical manufacturing, and optical materials technology.



EDUCATION

The University of Rochester's continued commitment to a strong educational mission is exemplified by the wealth of opportunities available to students at LLE. Students have participated in a number of educational opportunities, including integrated summer programs for high school students, internships for science and engineering undergraduates, and fully funded research opportunities and fellowships for graduate students. This unique collaborative effort has helped guide and empower over 500 students in the past five years, including 230 graduate students from the University of Rochester and many other academic institutions, among which 77 earned their PhD degrees. Many have gone on to lead flourishing careers at prestigious national laboratories, universities, and industrial research facilities across the country.



450
Employees work at LLE

80+
Undergraduate and high school students in 2023

160+
Graduate students performing research at LLE in 2023

21
PhDs completed in 2023

124
Research papers were published in 2023 on work completed at LLE

2800+
Research papers published by LLE since inception

153
LLE and Omega PhD graduates since 2013

2979
Targets were produced in 2023

2061
Target experiments were performed at the Omega Laser Facility in 2023

$120M
In FY24 sponsored research funding

137
Campaigns by external users in 2023

50+
Companies in partnership with Upstate New York Companies Optics and Photonics industry

$55M+
In purchases from over 1000 New York State vendors over the last ten years

1000
Jobs are supported by LLE's activities

$503M
Five-year Cooperative Agreement with US Department of Energy, FY24–FY28

$88M
Labor expense

NOBEL PRIZE IN PHYSICS

Profs. Donna Strickland and Gérard Mourou were awarded the 2018 Nobel Prize in Physics "for groundbreaking inventions in the field of laser physics" for pioneering chirped-pulse amplification (CPA) while at the University of Rochester's Laboratory for Laser Energetics in the 1980s. Prof. Strickland developed CPA as a graduate student with Prof. Mourou as her advisor in the Institute of Optics. Strickland the third woman ever to receive the prize in physics, joining Marie Curie (1903) and Maria Goeppert Mayer (1963). "We need to celebrate women physicists because we're out there," Strickland said. "I am honored to be one of those women." Together, their invention revolutionized laser science, enabling the amplification of ultrashort laser pulses by more than five orders of magnitude.

MORE FROM LLE

LLE's Quarterly Magazine: *LLE in Focus*

LLE in Focus shines a spotlight on the accomplishments, technological advances, and cutting-edge research performed at the Laboratory. Each issue features a specific theme and highlights graduate students, awards and honors, and updates from the facility. Richly illustrated and written in an accessible style, *LLE in Focus* is designed to engage with a wide audience of people to help explain and promote the important and collaborative work performed by scientists, students, and staff at LLE.

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