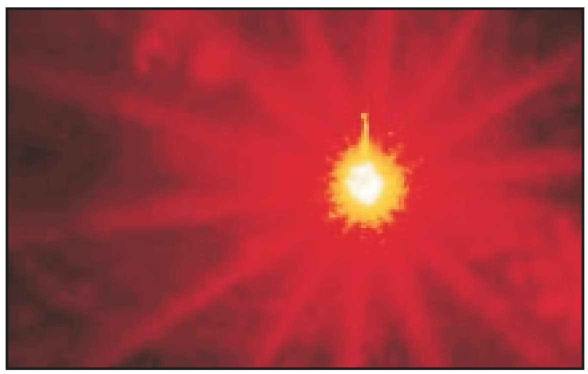
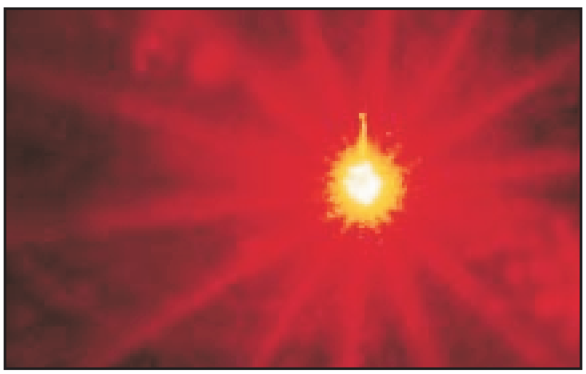
A Unique National Resource



LABORATORY FOR
LASER ENERGETICS
UNIVERSITY OF
ROCHESTER



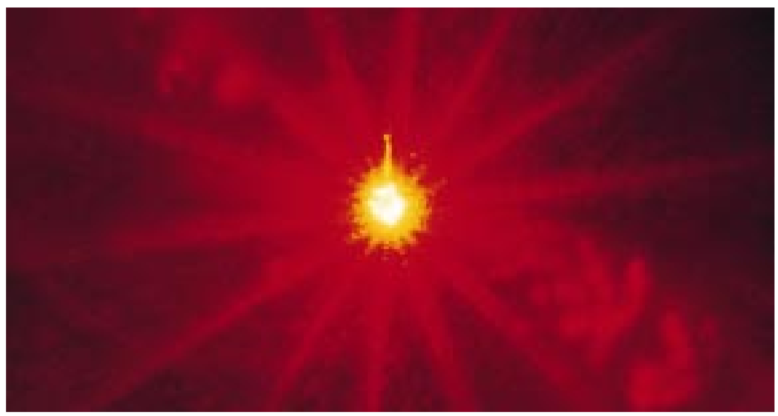
The Laboratory for Laser Energetics (LLE) of the University of Rochester is a unique national resource for research and education in science and technology. The Rochester area has a history of innovation and provides a unique setting for LLE within a technologically sophisticated community. Established in 1970 as a center for the investigation of the interaction of intense radiation with matter, the Laboratory has the five-fold mission (a) to conduct implosion experiments and basic physics experiments in support of the National Inertial Confinement Fusion (ICF) Program; (b) to develop new laser and materials technologies; (c) to provide graduate and undergraduate education in electro-optics, high-power lasers, high-energy-density physics, plasma physics, and nuclear fusion technology; (d) to operate the National Laser Users' Facility; and (e) to conduct research and development in advanced technology related to high-energy-density phenomena.

THE INERTIAL CONFINEMENT FUSION PROGRAM

The ultimate objective of LLE's ICF Program is to demonstrate the feasibility of ICF as an inexhaustible energy source. Funded as a cooperative venture by industry, New York State, the Federal Government, and the University, LLE's ICF Program has an exceptional record of innovation and invention. Key accomplishments include the following:

- Early experiments demonstrated the presence of parametric instabilities in infrared laser-matter interactions (1970-1973).
- Theoretical calculations showed the benefits of short-wavelength laser irradiation for laser-fusion targets (1973-1974).
- LLE conducted the first direct measurements of compressed fuel density in laser-driven targets (1975-1976).
- LLE made the first detailed measurements of ablation and preheat using x-ray line emission (1975-1976).
- The first comprehensive measurements of harmonic and subharmonic emission from spherical targets were conducted in 1975-1976.
- LLE's Materials Group led the development of a high-gain phosphate laser glass with a low nonlinear index of refraction for high-power glass laser systems (1976-1978).
- Construction of the 24-beam OMEGA uniform-irradiation facility was completed in 1980.
- LLE invented highly efficient third-harmonic-generation schemes for high-power glass lasers (1980).
- Beginning in 1980, LLE conducted the first extensive laser-matter interaction experiments with ultraviolet (351-nm) irradiation.
- Conversion of all 24 beams of OMEGA to 351-nm operation was completed in 1985.
- Spherical-target compression experiments demonstrated high neutron yield and high fuel density with 351-nm irradiation (1985-1988).
- In 1985, experiments resulted in a record yield of 2×10^{11} DT neutrons.
- LLE was the first to demonstrate compressions in excess of 100 times liquid deuterium-tritium density (>20 g/cm^3) in thermonuclear fuel using cryogenic targets (1988).
- LLE pioneered the SSD (smoothing by spectral dispersion) beam-smoothing technique to produce uniform beam profiles for high-power, frequency-tripled glass lasers.
- LLE routinely demonstrated precision control of beam energy and power balance with the 24-beam OMEGA system (1988-1992).
- LLE's Optical Materials Group received the R&D 100 award from *Research and Development Magazine* for a liquid crystal polarizer, named one of the top 100 technical research and development products nationwide (1989).
- LLE completed construction of the 60-beam, upgraded OMEGA laser in 1995.
- Implosion experiments using the upgraded laser produced a new record yield of 1.3×10^{14} DT neutrons (1995).
- LLE received the 1996 Popular Mechanics Design & Engineering Award for the OMEGA laser system.
- Indirect-drive and Stockpile Stewardship experiment support for Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Naval Research Laboratory, and Sandia National Laboratory began on the OMEGA laser in 1997.
- LLE Implemented high-bandwidth frequency tripling on the OMEGA laser in 1997.
- In 1998 new high-density x-ray diagnostics were implemented, giving the ability to measure cold, compressed shells without backlighting.
- LLE's Optical Manufacturing Group developed and implemented a special optical-coating process for the National Ignition Facility (NIF) optics in 1998. As a result, LLE has begun its support of coating NIF optics.
- In 1999 LLE integrated the OMEGA Cryogenic Target-Handling System into the OMEGA facility.
- LLE began its support of CEA-DAM (the Military Applications Division of the French Atomic Energy Commission) in 1999.
- Developed moderate-gain, direct-drive designs for the National Ignition Facility in March 1999.

The 60-beam OMEGA system is a 30-kJ, ultraviolet (351-nm), pulse-shaped, direct-drive laser with on-target irradiation nonuniformities approaching the 1% to 2% level. This facility will be used (1) to explore target physics at near-ignition conditions (i.e., ion temperatures in excess of 2 to 3 keV and fuel density-radius products $\geqslant 0.2$ g/cm^2); (2) to investigate the hydrodynamics of energy-scaled, high-performance targets; and (3) to perform laser-plasma interaction experiments using large-scale-length plasmas and laser intensities relevant to high-performance, direct-drive target implosions.



Fusion reactions take place in targets filled with deuterium/tritium and irradiated with the 30-kJ OMEGA laser.

An array of hexagonally stacked lenses is used to homogenize light in applications where uniform and incoherent radiation is required, such as optical lithography and laser fusion.

Optical replication and optical lithography are used to manufacture a new generation of optical elements that provide great flexibility in the design of imaging systems.

EDUCATIONAL OPPORTUNITIES

From LLE's formation in 1970, education has been one of its most important missions. Students at all levels, from bachelor's degree to Ph.D. candidates, are integrated into the ongoing research of the Laboratory. These students come from many departments and colleges throughout the University. Over the years, more than 800 students have received training at LLE, with over 133 receiving a Ph.D. degree. Current graduate student research includes investigation of parametric instabilities in plasmas, thermal transport in high-temperature plasmas, nonlinear optical phenomena, and picosecond phenomena in solids.

Graduates of the UR/LLE program are making significant contributions as scientists at many of the most prestigious research institutions in the country, including national laboratories, industrial laboratories, and universities.

LLE has a High School Summer Research Program that actively educates and trains a limited number of high school students entering their senior year of study. The goals of this program are to provide the students with an opportunity to experience research in science and technology in a realistic environment and to instill in the students an enthusiasm about scientific and technical careers.

LLE's capabilities in microfabrication support both the inertial fusion and advanced technology development programs.

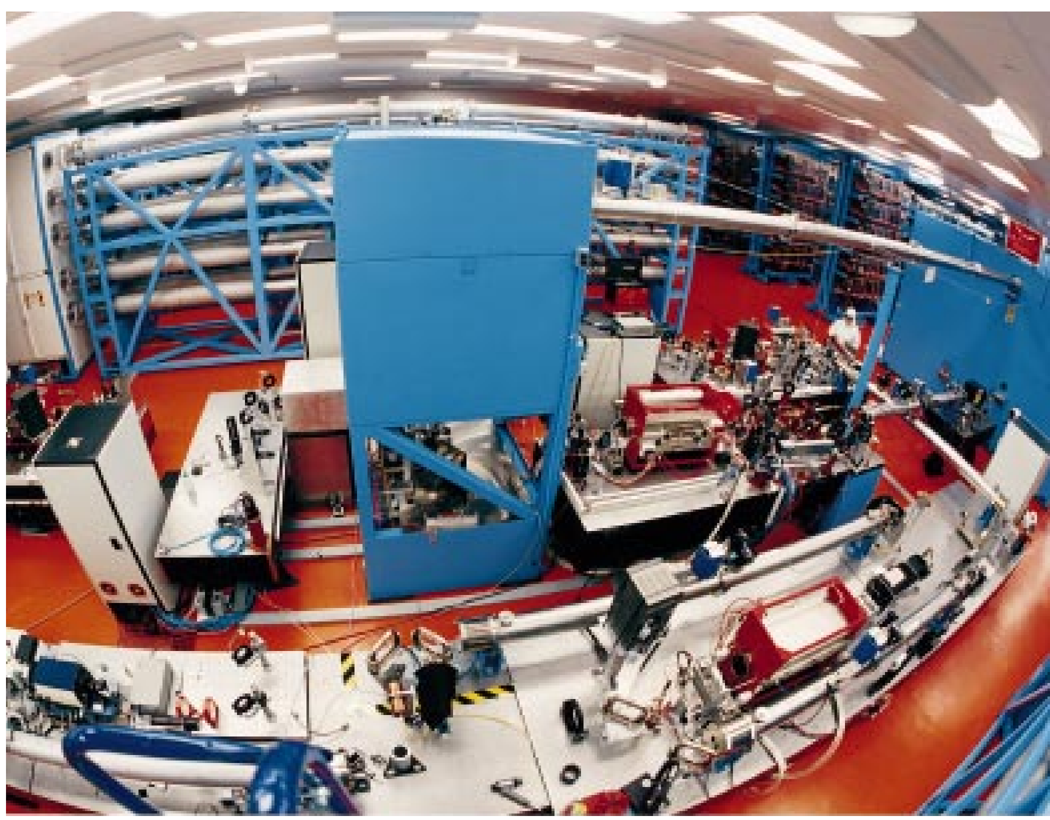
THE NATIONAL LASER USERS' FACILITY

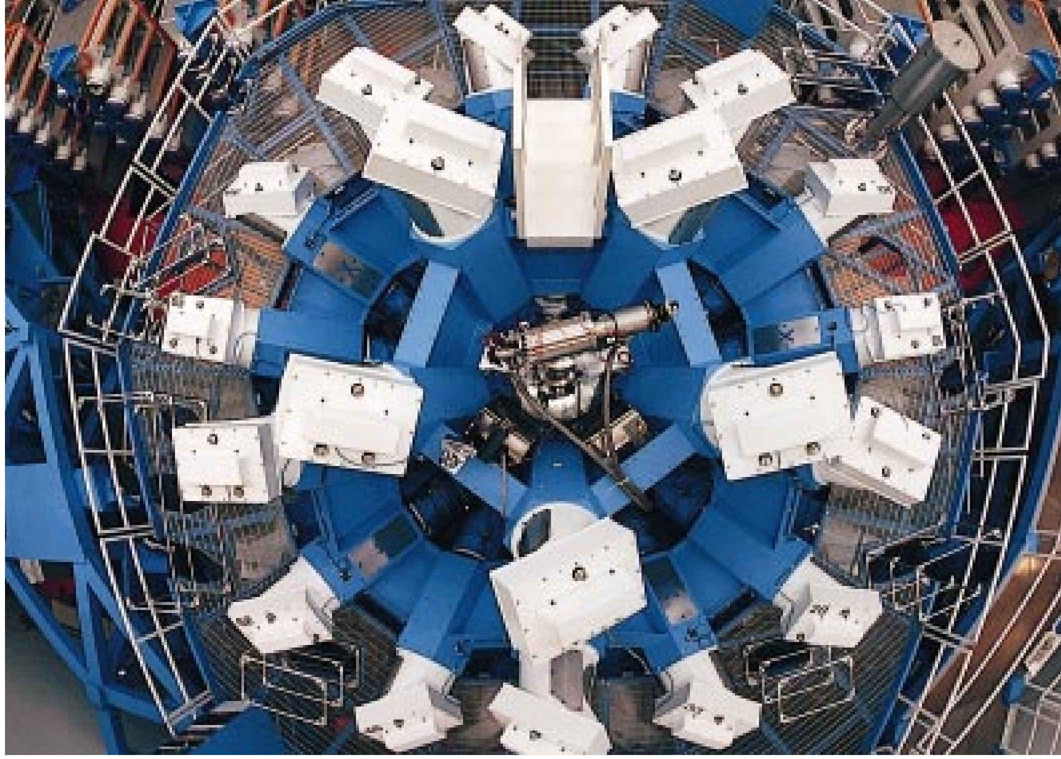
LLE has provided qualified researchers with a unique environment for experiments in inertial fusion and high-energy-density physics through access to the National Laser Users' Facility (NLUF). In addition to investigations of inertial fusion physics, approved experiments have been conducted in plasma physics, x-ray laser physics, XUV spectroscopy, and instrumentation development.

The Office of Inertial Fusion of the Department of Energy funds the operation of NLUF, thus making it possible for researchers to conduct experiments without a direct facility charge. In addition, the Department of Energy provides research funds directly to users for experiments in inertial fusion and related scientific areas. NLUF is administered by a full-time manager, who reports to the LLE Director.

All proposals are reviewed by the NLUF Steering Committee, which ranks them according to scientific merit. The Committee is appointed by the President of the University of Rochester, with Department of Energy approval. Members include outstanding scientists from universities, industry, and government.

The OMEGA laser driver line and injection optics along with portions of the laser system are seen in a view looking southwest in the laser bay.





A view of the OMEGA target bay from high above the target chamber shows critical components associated with the UV transport system.

ADVANCED TECHNOLOGY DEVELOPMENT

In addition to its program in inertial fusion research, LLE is performing state-of-the-art research addressing a number of other important new technologies. The spectrum of this advanced research includes microstructure analysis using laser and x-ray technologies; x-ray lithography for microfabrication; microkelvin atomic traps; ultrafast sensors for the visible and infrared; solar cell technology using porous silicon; high-speed electronics using terahertz sampling systems; femtosecond/picosecond pulse technology; image and data acquisition and processing systems; development of large-aperture, high-damage-resistance diffraction optics; and optics-related materials development, including liquid crystal optics and dielectric thin-film coatings for high-power lasers.

Some of the possible applications of this technology include homogeneous and heterogeneous catalysis, polymer micromechanics, photobiology, protein engineering, photobiological energy conversion, advanced data acquisition and control systems, high-speed computer component development, high-power and high-efficiency lasers, high-speed communications, and high-power switching.

Recent accomplishments at LLE include

- generation of picosecond bursts of radiation, ranging from the microwave to the x-ray region of the electromagnetic spectrum, synchronized to picosecond laser pulses and applied to solid-state physics, biology, and chemistry research;
- development of optical materials and coatings for high-power, short-wavelength laser operations;
- instrument and technique development for nondestructive measurement of the thermal conductivity and the interfacial thermal resistance of dielectric thin film coatings;
- development of high-efficiency, large-aperture, high-power diffraction gratings and phase plates;
- development of optical damage testing, magnetorheological finishing, and ultrasmooth polishing techniques;
- development of liquid- and light-sensitive pigment from polymer liquid crystal flakes;
- design and fabrication of liquid crystal wave plates and polarizers to apertures of 200 mm;
- a 100-μK atomic trap for sodium atoms;
- measurement of a 1-ps, 1-mV, single flux quantum from a Josephson junction;
- development and application of ultra-high-speed (10^{12}-Hz) sampling systems;
- development and application of pulsed (subnanosecond), high-resolution, x-ray diffraction technology;
- development of x-ray laser schemes;
- demonstration of high-resolution x-ray lithography using a laser-produced plasma as an x-ray source;
- development of high-repetition-rate, high-efficiency, solid-state lasers;
- application of solid-state switching technology to picosecond, time-resolved spectroscopy;
- development of real-time, high-speed data acquisition and processing systems using advanced hardware/software concepts; and
- development of highly efficient schemes for frequency conversion of high-power, solid-state lasers from the infrared to the ultraviolet using nonlinear crystals.

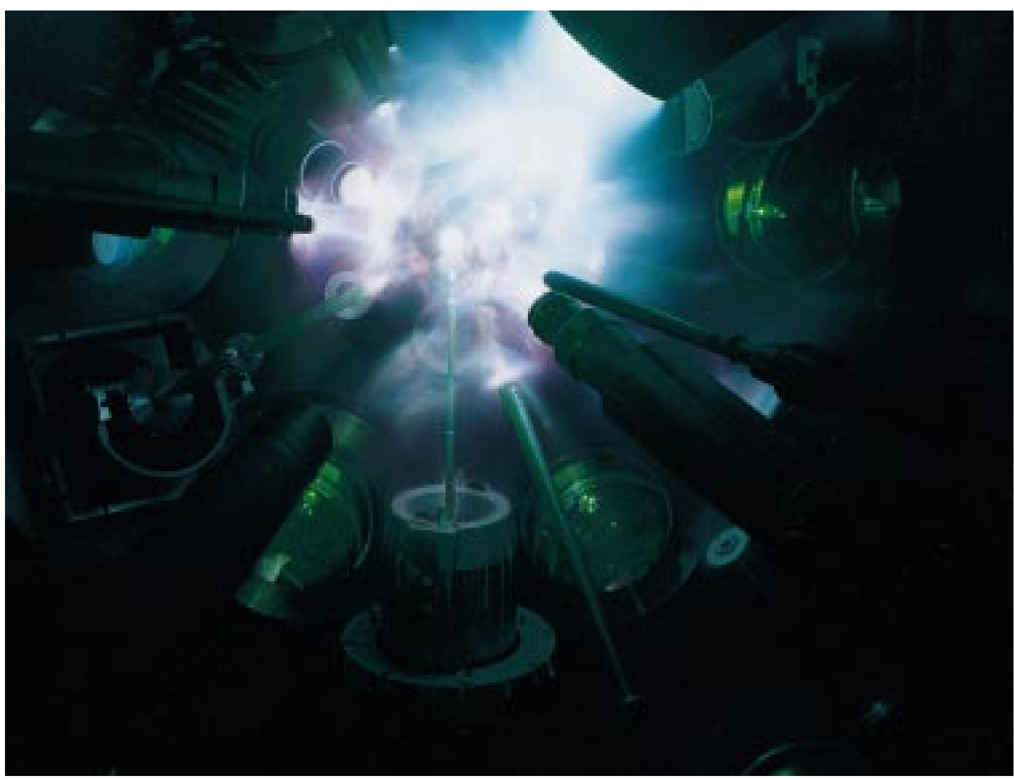
LLE scientists hold over 65 patents in the fields of laser amplifiers; active mirrors; fusion target fabrication and coating; ultrafast (picosecond and subpicosecond) optical pulses, switching, and sampling; x-ray lithography; Pockels cell drivers; beam smoothing by spectral dispersion; frequency tripling of laser light; liquid crystal devices; pulse shaping; pulse measurement; streak cameras; and many other laser-related technologies.

Over 14 licenses for the use of these patents in producing commercial products have been issued.

UNIVERSITY-INDUSTRY-GOVERNMENT COLLABORATION

The University of Rochester is a pioneer in university-industry-government collaborations in rapidly evolving technology development. At LLE there are opportunities for collaboration that will promote future scientific and technical advances. Companies such as the Empire State Electric Research Corporation, Exxon Research and Engineering Company, Clark/MXR, Spectra-Physics, Rochester Gas and Electric, General Electric Company, Northeast Utilities Service Company, Ontario Hydro, and Standard Oil Company have contributed resources to the program. Federal Government support has come from the United States Department of Energy and state support has come from the New York State Energy Research and Development Authority. Other government support has come from the Departments of the Army, Air Force, and Navy; the National Institutes of Health; the National Science Foundation; the Department of Agriculture; the Ballistic Missile Defense Organization; and the National Institute of Standards and Technology. In effect, LLE has become a new kind of national laboratory, continuing to seek partners in government and industry for exciting new programs.

An OMEGA transport mirror coated with a 351-nm high reflector is shown being prepared for final testing.



A view of a target implosion in the OMEGA target chamber.

For additional information
please visit our website at
www.lle.rochester.edu or contact:
Director's Office
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, NY 14623-1299
(585) 275-5286

UNIVERSITY OF
ROCHESTER