Executive Summary

The fiscal year ending September 2003 concluded the first year of the second five-year renewal of cooperative agreement DE-FC03-92SF19460 with the U.S. Department of Energy (DOE). This report summarizes research at the Laboratory for Laser Energetics (LLE) conducted during the year, the operation of the National Laser Users' Facility (NLUF), the status of the new OMEGA Extended Performance (EP) laser project, and programs concerning the education of high school, undergraduate, and graduate students during the year.

Progress in Laser Fusion Research

"Direct-Drive Cryogenic Target Implosion Performance on OMEGA" (p. 1) describes progress toward validating the predicted performance of direct-drive capsules that are hydrodynamically equivalent to the baseline direct-drive ignition design for the National Ignition Facility (NIF). These experiments measure the sensitivity of direct-drive implosion performance to parameters such as inner-ice-surface roughness, the adiabat of the cryogenic fuel during the implosion, laser power balance, and single-beam nonuniformity. These capsules have been imploded using ~17 to 23 kJ of 351-nm laser light with a beam-to-beam rms energy imbalance of less than 5% and full beam smoothing (1-THz bandwidth, 2-D smoothing by spectral dispersion, and polarization smoothing). Near 1-D hydrocode performance has been measured with a high-adiabat drive pulse on a capsule containing a 100-μm-thick layer of D_2 ice, and near 2-D hydrocode performance has been measured on a similar capsule with a low-adiabat drive.

The article beginning on p. 11 describes the growth of inner-surface modulations near peak compression in deuterium–helium 3 (D^3He)–filled spherical targets imploded on OMEGA by using differential imaging of titanium-doped layers placed at various distances from the inner surface of the shell. Time histories of shell temperature and density were measured with titanium K-shell absorption spectroscopy, and the shell areal density was estimated using 14.7-MeV D^3He proton spectra. These experiments provide a better quantitative understanding of the evolution of inner-shell modulations that grow due to the Rayleigh–Taylor instability and Bell–Plesset convergence effects in the deceleration phase of a spherical direct-drive implosion.

Improved target performance in direct-drive implosions using adiabat shaping with a high-intensity picket in front of the main-drive pulse is described analytically beginning on p. 18. The picket is used to increase the entropy of only the outer portion of the shell, reducing the growth of hydrodynamic instabilities, while the inner portion of the shell maintains lower entropy to maximize shell compressibility. Experiments have demonstrated an improvement in target yields by a factor of up to 3 for the pulses with the picket compared to the pulses without the picket. Results of the theory and experiments with adiabat shaping are also extended to future OMEGA and NIF cryogenic target designs.

LLE and Lawrence Livermore National Laboratory (LLNL) scientists used multiple OMEGA laser beams to study two-plasmon-decay instability, which is the predominant source of suprathermal electrons in direct-drive inertial confinement fusion experiments (p. 76). The authors show for the first time that the total overlapped intensity governs the scaling of the suprathermal-electron generation regardless of the number of overlapped beams, in contrast to conventional theories that are based on the single-beam approximation.

The classical Rayleigh–Taylor instability of the interface separating two homogeneous inviscid fluid layers undergoing uniform acceleration was examined (p. 81), giving particular attention to the effects of uniform isentropic compression of the fluids and geometrical convergence of the interface and to the role of these effects in the implosion of inertial confinement fusion (ICF) capsules. The formulation presented makes a formal distinction between perturbation behavior under acceleration and perturbation behavior as modified by compression and by convergence of a cylindrical or spherical interface.

The theoretical basis for laser-induced adiabat shaping in ICF spherical targets by a technique referred to as "relaxation" is presented beginning on p. 91. In this approach, the density profile of the capsule's shell is shaped using a weak prepulse followed by a main pulse with a high-intensity foot. The required laser pulse shape is easier to implement on current laser systems than the alternate technique described in the article. Rayleigh–Taylor growth rates are reduced without significantly degrading 1-D capsule performance.

The properties of compressed titanium are studied (p. 107) using laser-launched shocks and extended x-ray absorption fine structure (EXAFS). The EXAFS absorption spectrum is produced when backlighting a CH-coated Ti foil by the spectrally smooth radiation from a CH shell imploded on the 60-beam OMEGA laser system. Fitting an EXAFS model to the data indicates compression by a factor of 1.3, in agreement with shock-speed measurements and with hydrodynamic simulations. The rate of decay of the modulation with wave number is shown to include a significant contribution from static disorder, in addition to thermal vibration, due possibly to an α-Ti to ω-Ti crystal phase transition.

Filling and cooling thin-walled (<3-μm) cryogenic capsules with deuterium–tritium fuel is a critical phase of operation for providing direct-drive targets. Permeation filling at room temperature to high pressures subjects the capsules to a buckling force. In addition, during cooling to 20 K, buckling and burst forces develop due to transient thermal gradients, thermal expansion differences, and changing permeability of the capsule wall. The article beginning on p. 118, quantifies the forces on the capsule by modeling the thermal conditions inside the permeation cell. Results of cooldown cycles of OMEGA cryogenic targets agreed well with the simulation, and a cooling program was devised whereby the time for a capsule to reach the frozen state was reduced by 30%.

A report on the seminal work to experimentally validate the reduction in the Rayleigh–Taylor (RT) growth rate using a prepulse, or picket, preceding the main laser-drive pulse in planar-target experiments begins on p. 139. The experimental results showed that a high-intensity picket (~50% of the drive-pulse intensity) significantly reduced the RT growth rate for a 20-μm-wavelength surface perturbation but had no effect on the growth rates of longer-wavelength perturbations (30 and 60 μm). Both the 20- and 30-μm-wavelength perturbations showed no appreciable growth rate, however, with a prepulse intensity equal to the drive-pulse intensity. These results suggest that the acceleration-phase RT growth rates for short-wavelength, laser-induced imprint perturbations may be virtually eliminated in spherical implosions by modifying the drive pulse to include a high-intensity picket on the leading edge. This work will be applied to spherical implosions in the near future.

An in-depth, analytic analysis of laser-induced adiabat shaping in inertial fusion implosions shows that the adiabat profile between the ablation surface and the fuel–shell interface induced by a decaying shock follows a simple power law of the shell areal density (p. 147). Significantly, the calculated profiles are nearly identical to those observed in 1-D hydrodynamic simulations. This similarity suggests that the calculated profiles can be used to quickly and easily design an optimal laser prepulse to maximize the adiabat ratio between the inner- and outer-shell surfaces, leading to improved hydrodynamic stability.

"Polar direct drive (PDD)"—a new topic of research this year—examines (p. 212) the feasibility of using the x-ray-drive beam configuration at the National Ignition Facility (NIF) to achieve direct-drive ignition. The baseline x-ray-drive beam configuration was designed to illuminate a vertically oriented hohlraum with beams arrayed symmetrically around the polar regions of the target chamber. The authors realized that nearly symmetric direct-drive illumination could be achieved by repointing some of the polar beams toward the equator of the capsule and adjusting the beam-spot sizes and energies. The article describes the current status of work focusing, in particular, on beam-pointing strategy. The long-term impact of this work within the national ICF program is potentially of great importance if ignition conditions can be achieved on the NIF using the PDD concept.

In stockpile stewardship–related work, the article beginning on p. 220 provides the latest experimental results on the equation of state (EOS) of hydrogen at pressures of a few megabars, temperatures of a few electron volts, and compressions of up to several times liquid density. A better understanding of the hydrogen EOS is important for the accurate simulation of direct and indirect ignition target designs on the NIF. At present, there are several different models for the hydrogen EOS, and it is exceptionally difficult to measure experimental observables with sufficient accuracy to discriminate among the models. The experimental results reported here are based on a new re-shock technique that is more sensitive to differences between the EOS models.

An important new diagnostic system (described beginning on p. 230) for direct-drive-implosion studies on OMEGA is the proton temporal diagnostic (PTD), which was designed to measure the fusion reaction history in capsule implosions containing D^3He fuel. By measuring the temporal emission history and final energy spectrum of this high-energy proton, it is possible to study the areal-density evolution of the shell during the shock and compressive burn phases of an implosion. Existing range-filter spectrometers routinely measure the high-energy proton spectra from both D_2 and D^3He implosions. This data can now be combined with the temporal emission history of the new PTD to provide new constraints on the multidimensional hydrocodes used to understand implosion performance on OMEGA.

Laser and Optical Materials Research

A high-conversion-efficiency optical parametric chirped-pulse amplification (OPCPA) system using a spatiotemporally shaped pump pulse to maximize the conversion efficiency of the OPCPA process has been demonstrated (p. 33). Highly stable, 5-mJ pulses have been produced at a 5-Hz repetition rate with 29% overall pump-to-signal conversion efficiency. This system is a test bed for a similar OPCPA design that will be used for pulse injection in a short-pulse, petawatt-class laser.

Novel glassy liquid crystals with tunable spectral characteristics have been developed for photonic applications (p. 50). The authors also describe the molecular design of photoresponsive systems that combine reversible spectral tunability with superior fatigue resistance and thermal stability.

The article beginning on p. 67 describes the design and performance of a thin-film-deposition system used to produce multilayer dielectric thin-film coatings with highly uniform thickness over a full NIF aperture. This system meets the NIF specifications.

A number of professors from The Institute of Optics and a scientist from LLE have demonstrated the operation of a single-photon source (p. 97)—a key hardware element of quantum information technologies—via photon antibunching in the fluorescence of single terrylene molecules embedded in a cholesteric liquid crystal host. Planar-aligned cholesteric layers provide a one-dimensional photonic band gap, allowing an enhancement of the source efficiency.

The development and application of a numerical model that systematically investigates the performance of an optical parametric chirped-pulse amplification (OPCPA) system are described beginning on p. 167. The model uses both Gaussian and super-Gaussian spatial and temporal pump laser pulse shapes and includes the effects of pump–signal spatial walk-off and spatiotemporal noise. The results of this numerical investigation show that good energy stability, good beam quality, and high overall conversion efficiency can be obtained by carefully designing the OPCPA configuration and optimizing the spatiotemporal profile of the pump laser.

The nonlinear propagation of light through a plasma (p. 179) near the critical density is examined using a model that includes filamentation, forward stimulated Brillouin scattering (SBS), backward SBS, the reflection of light from the critical-density surface, and the absorption of light. Because the model incorporates nonparaxial propagation of light, it can describe the reflection of light from the critical-density surface and the propagation of crossing laser beams. The model successfully describes experimentally observed features of scattered light and is well suited to describe the oblique incidence of laser beams on a critical-density surface.

Conventional magnetorheological finishing (MRF) techniques have been used (p. 239) to improve the surface finish and figure of several standard polymer optics. Since these optics are generally soft with high linear expansion coefficients and poor thermal conductivities, they are typically used as manufactured even though, in some instances, it would be desirable to have much better surface finishes. In this article, the authors show that the rms surface roughness of four different optical polymers can be reduced significantly using MRF.

The conceptual development and experimental demonstration of the coherent summation of multiple gratings to form a larger grating are described beginning on p. 207. The most-promising reflection-grating technology for short-pulse, high-energy petawatt-class laser systems utilizing chirped-pulse amplification (CPA) is a holographically formed grating combined with a multilayer dielectric (MLD) coating. The aperture size and damage threshold of such gratings determine the ultimate short-pulse energy capability of these laser systems. Current state-of-the-art gratings would limit a laser such as OMEGA EP to an energy of less than 1 kJ per beam. While it may be possible in the future to manufacture very large gratings, tiling the MLD gratings available today represents an extremely attractive alternative for the OMEGA EP. The key result presented in this article is the conclusive demonstration of subpicosecond pulse compression using tiled gratings. This is truly an enabling technology for the high-energy, short-pulse lasers planned for the coming decade.

A method has been developed that will modulate both the phase and amplitude of a laser beam with a single-phase-only spatial light modulator (SLM) using a carrier spatial frequency and a spatial filter (p. 225). With this technique, the authors show that dynamic corrections to a laser-beam profile are possible.

Advanced Technology

A new class of ultrafast, superconducting single-photon detectors for counting both visible and infrared photons is examined beginning on p. 38. The detection mechanism is based on photon-induced hotspot formation, which forces supercurrent redistribution and leads to the appearance of a transient resistive barrier across an ultrathin, submicrometer-width, superconducting stripe. Applications for these devices range from noncontact testing of semiconductor CMOS VLSI circuits to free-space quantum cryptography and communications.

New detectors have been used to measure the temporal response characteristics of fast metal–semiconductor–metal ultraviolet photodiodes fabricated on GaN with finger width and pitch ranging from 0.3 μm to 5 μm (p. 46). These detectors are attractive because they are relatively easy to fabricate and have no response in the visible region of the spectrum. A temporal response of less than 26 ps at low illumination is observed.

Near-field Raman spectroscopy and imaging of single-walled carbon nanotubes (SWNT) with unprecedented spatial resolution of less than 30 nm are presented beginning on p. 61. This high-resolution capability is applied to resolve local variations in the Raman spectrum along a single SWNT that would be hidden in far-field measurements.

The ultrafast voltage transients in optically thick YBCO superconducting microbridges driven into the resistive flux state by nanosecond-wide supercritical current pulses and synchronously excited by femtosecond optical pulses have been investigated (p. 186). Using a flexible experimental setup, the authors are able to describe the dynamics of the YBCO photoresponse and demonstrate that a YBCO superconductor in the flux-flow state can operate as a GHz-rate, high-power, optically triggered switch for microwave-based telecommunication applications.

Ultrafast photodetectors fabricated on high-energy-nitrogen–implanted gallium-arsenide (GaAs) have been tested (p. 192). By direct comparison these novel photodetectors have been shown to be significantly more sensitive than commercially available low-temperature GaAs photodevices used extensively for high-speed applications.

Tritiated amorphous silicon (a-Si:T) devices have been developed (p. 196). By incorporating tritium—the radioactive isotope of hydrogen—into standard hydrogenated amorphous silicon (a-Si:H) devices, it may be possible to establish a new family of devices in which the energy output of the tritium decay is integrated with the optoelectronic properties of a-Si:H (e.g., photovoltaics and active matrix displays). This article describes the fabrication process and shows unequivocally that tritium bonds stably in amorphous silicon.

A qualitative understanding of the greenhouse effect has long been available through models based on globally and time-averaged quantities. University of Rochester Physics Department faculty and LLE scientists have examined a simple 864-cell climatological model that reproduces yearly average temperatures obtained earlier from one of these global models and predicts a locally distributed nonradiative flux when observed temperatures are employed as input data (p. 128). The model emphasizes vertical radiative energy transport within each cell and is a useful stepping stone for learning about radiative energy transfer into and out of Earth's atmosphere.

Status and Progress on the OMEGA EP Project

The OMEGA EP (Extended Performance) Project began on 1 April 2003 with $13 million FY03 funding. The National Nuclear Security Administration's (NNSA's) approval of Mission Need followed in May 2003. The University of Rochester authorized funding for an 82,000-sq-ft addition to LLE adjacent to the OMEGA laser to house the new laser beams. The building construction began in August 2003 and will be completed in January 2005. In September 2003, NNSA elected to proceed with the design and construction of the first two beams of the EP system. NNSA also authorized starting a selection of long-lead material procurements, which has led to the completion of the designs and solicitation packages for several key elements. As an example, the large vacuum vessel that will hold the diffraction-grating compression system will be procured in advance of the building's completion. This 70-ft-long vessel will be installed during the building construction to sequence it correctly prior to the activation of the facility's clean room systems.

OMEGA EP will couple short-pulse laser technology with the 60-beam compression facility by the end of FY07. Since the early 1990s when OMEGA was constructed, progress in laser technology has included the development of high-power, high-energy laser systems using chirped-pulse amplification (CPA) and the NIF multipass architecture. Incorporating these new technologies will modernize OMEGA and significantly expand the range of high-energy-density (HED) physics experiments carried out during the second half of this decade and beyond. The primary system requirement to meet mission need is the addition of two short-pulse (1- to 100-ps), high-power, high-energy beams to OMEGA with greater than 2 kJ per beam, motivated by two specific needs:

- To provide OMEGA with a short-pulse, high-energy backlighting capability for new HED physics experiments under conditions that also allow the development of backlighting techniques for the NIF; and
- To carry out integrated fast-ignition experiments on OMEGA using its unique cryogenic target implosion capability.

The system that is currently being designed meets the Mission Need Requirements and in a later phase of the project can, for a modest incremental cost, significantly extend the HED physics possibilities. The primary design consists of two NIF-like laser beamlines, with a pulse compression chamber, and relies heavily on proven CPA and NIF technology and LLE's engineering design capability. An auxiliary target chamber, funded through a grant from New York State, will be incorporated, and, later in the program, two additional long-pulse beamlines will be added, subject to available funding. The first two beams will use CPA to provide high-energy short pulses that can be routed into either the OMEGA or the auxiliary OMEGA EP target chamber. Later, all four beams can be operated in long-pulse mode (1 to 10 ns) with 20 kJ (minimum) of UV energy into the OMEGA EP target chamber. This flexibility significantly extends the HED physics capabilities of OMEGA, maintaining LLE's ability to perform forefront HED science.

National Laser Users' Facility and External Users' Programs

During FY03, the number of target shots dedicated to external users of OMEGA continued to increase as 733 target shots were provided. This represents 53% of the total target shots produced by the laser in the last year. External users' experiments were carried out by collaborative teams under the National Laser Users' Facility (NLUF) Program as well as by teams led by scientists from Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Sandia National Laboratory (SNL), and the Commissariat à l'Énergie Atomique (CEA) of France. Some of these collaborations included participants from AWE in the United Kingdom and other universities in the U.S. and U.K.

Seven of the nine NLUF programs approved in the last NLUF Review carried out a total of 123 target shots on OMEGA in FY03, and included experiments in the following areas: collapsing radiative shocks and compressible nonlinear hydrodynamics of importance to the study of various astrophysical phenomena; optical mixing controlled stimulated scattering instabilities; time evolution of capsule ρR and proton emission imaging of compressed cores; laboratory simulations of the interaction of supernova blast waves with interstellar clouds; dynamic properties of shock-compressed single crystals; laboratory simulations of planetary core conditions; and spatially and temporally resolved temperature and density measurements of the compressed cores of indirectly driven capsules.

Collaborative teams led by LLNL scientists carried out 390 target shots on OMEGA for ICF and high-energy-density sciences (HEDS) experiments, including diagnostic development for the NIF; x-ray scattering measurements on near-solid-density plasmas; x-ray conversion efficiency optimization using "cocktail" hohlraums; planar and spherically converging Rayleigh–Taylor instability measurements; laser–plasma interaction; development of techniques for measuring material properties at substantial pressures; preparation of NIF early-light (NEL) experiments; equation of state (EOS) of various materials; development of high-temperature hohlraums; double-shell capsules; propagation of radiation through low-density materials; and development of direct-drive configurations to create a dynamic hohlraum.

LANL scientists led collaborative teams in carrying out 158 target shots on OMEGA in the following areas:

Richtmyer–Meshkov instability (RMI) in convergent compressible, miscible plasma systems; asymmetric direct-drive implosions; neutron diagnostic development; double-shell-target implosions; supersonic jet experiments; x-ray backlighting development; studies of time-dependent mix in direct-drive targets; x-ray radiography development for ICF, HEDP and AGEX experiments; and shock propagation properties of beryllium ablators.

SNL scientists carried out 30 OMEGA target experiments to investigate ICF ablator x-ray burnthrough, shock propagation, and preheat issues associated with indirect-drive ablators.

A total of 32 OMEGA target shots were taken by CEA scientists for experiments in neutron diagnostic development and laser–matter interaction physics.

The impact of experiments conducted on OMEGA by the ICF and high-energy-density physics community has steadily increased over the years. For example, approximately 27% of the total ICF/HED papers presented at the recent 45th Annual Meeting of the American Physical Society (APS) Division of Plasma Physics were based on work carried out on OMEGA by national laboratories, NLUF, and LLE scientists.

Significantly, OMEGA-related work dominated the ICF/HED invited papers given at the conference by accounting for 53% of these papers. These invited papers reported on some of the most important new work in the field, including implosions of cryogenic direct-drive capsules; measurements and simulations of mix in convergent geometries; high-gain, direct-drive targets; NIF direct-drive targets; ICF diagnostics; shock timing; laser–plasma interactions; shock compression; and other key aspects of ICF and HED.

The OMEGA-related invited papers presented at the APS meeting are listed below.

Presenter	Affiliation	Title
R. P. Drake	University of Michigan	Progress in Experimental Astrophysics at High-Energy Density
J. A. Frenje	MIT-PSFC	Measuring Shock-Coalescence Timing and ρR Evolution in D^3He Implosions on OMEGA
D. Cohen	Swarthmore College	Tracer Spectroscopy Diagnostics of Inertial Confinement Fusion Experiments on OMEGA
P. W. McKenty	UR/LLE	Direct-Drive Cryogenic Target Implosion Performance on OMEGA
S. Skupsky	UR/LLE	Polar Direct Drive
G. Gregori	LLNL	Electronic Properties Measurements in Solid Density Plasmas by Spectrally Resolved X-Ray Scattering
B. Yaakobi	UR/LLE	EXAFS Studies of Shock Compression and Heating in Ti and V
M. Stevenson	AWE, UK	Effects of Plasma Composition on Backscatter and Hot-Electron Production in Underdense Plasmas
R. Olson	SNL	Shock Propagation, Preheat, and X-Ray Burnthrough Measurements in NIF Ignition Capsule Ablator Materials
M. C. Herrmann	LLNL	An Investigation of Directly Driven Xenon-Filled Capsules
D. Wilson	LANL	Multi-Fluid Interpenetration Mixing in X-Ray and Directly Laser Driven ICF Capsule Implosions
C. R. Christensen	LANL	The Influence of Asymmetry on Mix in Direct-Drive ICF Experiments
K. Parker	AWE, UK	Observation and Simulation of Plasma Mix After Reshock in a Convergent Geometry

FY03 Laser Facility Report

User demand was met in FY03 by continuing to operate extended shifts during select weeks. Over 95% of planned target shots were executed for a total of 1381 shots (see Table 96.VI on p. 253). Shaped-pulse cryogenic implosions highlighted the ongoing development of direct-drive cryogenic capability. A total of 20 spherical and 51 planar cryogenic D_2 shots were performed. Highlights of other achievements and active projects as of the end of FY03 include the following:

- Installation of LLE-built, diode-pumped regenerative amplifiers on all three laser drivers improved pulse shape and energy stability. Production model regens were installed on both the main and backlighter drivers, replacing flashlamp-pumped units. Additionally, the prototype diode-pumped regen on the SSD driver was replaced with a production model. A concomitant increase in pulse-shape effectiveness from 93% in FY02 to 98% in FY03 resulted.

- Adiabat shaping using picket pulses improves the performance of direct-drive ICF targets. Picket-pulse development continued with the application of new techniques for improving picket pulse quality and stability. Improved picket-pulse prediction routines and IR streak cameras resulted in improved picket-pulse performance.

- Modifications to the laser-driver timing system provided the capability to more precisely delay individual drivers with increased range. All drivers are now capable of being delayed or advanced hundreds of nanoseconds with ~100-ps precision. This new capability has been utilized extensively to improve the effectiveness of experimental campaigns.

- The implementation of a new set of distributed phase plates (DPP's) provided improved irradiation uniformity for direct-drive spherical capsules. The new DPP's—designated SG4—produce a flatter intensity distribution on target than the previous set (SG3). In addition to producing a larger effective beam area on target, the SG4 DPP's have a smaller beam-to-beam shape variation than their predecessors.

- Distributed polarization rotators (DPR's) continued heavy use in FY03. All DPR's were modified for remote retraction and reinstallation, improving flexibility for reconfiguring to indirect-drive setups. Nonlinear losses in the UV were observed due to DPR reconversion. This phenomenon was investigated and corrective action initiated.

- The overall OMEGA irradiation uniformity on target was improved by using active repointing. Active repointing consists of evaluating the actual beam positions on target using x-ray images of the beam spots on a 4-mm, Au-coated pointing target and then repointing individual beams. Subsequent pointing shot offsets have been reduced from ~23 μm rms to 11 μm rms.

- To allow lower beam energy while preserving pulse shape, the use of frequency-conversion crystal doubler detuning has been implemented. Frequency-conversion crystal doubler detuning was used extensively in FY03 on limited beam sets.

- Scientists and engineers from Lawrence Livermore National Laboratory along with LLE collaborators successfully implemented a 4ω (fourth harmonic, 263 nm) target irradiation capability on one of the 60 OMEGA beams. Experiments utilizing the 4ω capability were conducted in FY03, and more extensive use is planned for FY04.

- Shot operations continued in parallel with construction of the new OMEGA EP building, which commenced in July 2003. Building construction activities were carefully monitored to ensure the stability of target positioning and beam pointing at shot time. An EP beam transport opening was also created in the east target bay wall for propagating future EP beamlines into the OMEGA target chamber.

Education at LLE

As the only major university participant in the National ICF Program, education continues to be an important mission for the Laboratory. Graduate students are using the world's most powerful ultraviolet laser for fusion research on OMEGA, making significant contributions to LLE's research activities. Twenty UR faculty from five departments collaborate with LLE's scientists and engineers. Presently 63 graduate students are pursuing graduate degrees at the Laboratory, and LLE is directly funding 45 University of Rochester Ph.D. students through the Horton Fellowship Program. The research includes theoretical and experimental plasma physics, high-energy-density physics, x-ray and atomic physics, nuclear fusion, ultrafast optoelectronics, high-power-laser development and applications, nonlinear optics, optical materials and optical fabrications technology, and target fabrication. Technological developments from ongoing Ph.D. research will continue to play an important role on OMEGA.

One hundred and sixty-one students have earned Ph.D. degrees at LLE since its founding. An additional 81 graduate students and 23 postdoctoral positions from other universities were funded by NLUF grants. The most-recent University of Rochester Ph.D. graduates and their thesis titles are

Philip Chen Huang-Ming	*Synthesis and Characterization of Novel Glassy Liquid Crystals*
Tanya Kosc	*Motion of Polymer Cholesteric Liquid Crystal Flakes in an Electric Field*
Raphael Panfili	*Double Ionization of Multi-Electron Atoms Exposed to Intense Femtosecond Laser Pulses*

Approximately 64 University of Rochester undergraduate students participated in work or research projects at LLE this past year. Student projects include operational maintenance of the OMEGA laser system; work in laser development, materials, and optical thin film coating laboratories; and programming, image processing, and diagnostic development. This is a unique opportunity for students, many of whom will go on to pursue a higher degree in the area in which they gained experience at the Laboratory.

In addition, LLE directly funds research programs within the MIT Plasma Science and Fusion Center, the State University of New York (SUNY) at Geneseo, and the University of Wisconsin. These programs involve a total of approximately 18 graduate and 23 undergraduate students from other universities.

For the past 15 years LLE has run a Summer High School Student Research Program (p. 250) in which this year 15 high school juniors spent eight weeks performing individual research projects. Each student is individually supervised by a staff scientist or an engineer. At the conclusion of the program, the students make final oral and written presentations on their work. The reports are published as an LLE report.

In 2003, LLE presented its seventh William D. Ryan Inspirational Teacher Award to Mr. Michael Carges, a former Physics Teacher at Pittsford-Mendon High School and currently at Greece Athena High School. Alumni of our Summer High School Student Research Program were asked to nominate teachers who had a major role in sparking their interest in science, mathematics, and/or technology. This award, which includes a $1000 cash prize, was presented at the High School Student Summer Research Symposium. Mr. Carges was nominated Joy Yuan and Siddhartha Ghosh, participants in the 2002 Summer Program.

Robert L. McCrory
Director