Executive Summary

The fiscal year ending September 2002 (FY02) concluded the fifth year of the first renewal of cooperative agreement DE-FC03-92SF19460 with the U.S. Department of Energy (DOE). The cooperative agreement was renewed for an additional five-year period in January 2003. This report—the final one for the first five-year cooperative agreement renewal—summarizes progress and research at the Laboratory for Laser Energetics (LLE), operation of the National Laser Users' Facility (NLUF), and programs concerning the education of high school, undergraduate, and graduate students during the year.

Inertial Confinement Fusion Research

LLE is the lead laboratory for research on direct-drive laser fusion for application and a gain demonstration on the National Ignition Facility (NIF). The NIF is currently under construction at the Lawrence Livermore National Laboratory (LLNL). We have emphasized a number of important areas this past year that should bear directly on the potential success of a direct-drive ignition and burn experiment on the NIF. "First Results from Cryogenic Target Implosions on OMEGA" (p. 49) describes initial results from direct-drive spherical cryogenic target implosions on the 60-beam OMEGA laser system. These experiments are part of the scientific base leading to direct-drive ignition implosions planned for the NIF. Results shown include neutron yield, secondary-neutron and proton yields, the time of peak neutron emission, and both time-integrated and time-resolved x-ray images of the imploded core. The experimental values are compared with 1-D numerical simulations. The target with an ice-layer nonuniformity of σ_{rms} = 9 μm showed 30% of the 1-D predicted neutron yield. These initial results are encouraging for future cryogenic implosions on OMEGA and the NIF.

Precision target fabrication is required for a successful ignition demonstration or quality cryogenic experiments on OMEGA. The development of polyimide shells suitable for inertial confinement fusion (ICF) cryogenic experiments on OMEGA is described in an article on target fabrication research beginning on p. 167. We have also determined the associated mechanical properties needed to define the processing conditions for operating the OMEGA Cryogenic Target Handling System (CTHS). Overall, polyimide targets offer a viable alternative to plasma polymer capsules currently in use. The principal advantages of the polyimide material are its high radiation resistance for tritium application and its excellent mechanical properties, which lessen the demanding specifications for the equipment needed to provide cryogenic targets. The single biggest limitation to using polyimide, based on PMDA-ODA chemistry, is the low permeability of the material at room temperature. Methods to increase the permeability are described.

The effects of textures on hydrogen diffusion in nickel was investigated (p. 125). Deuterium and tritium—isotopes of hydrogen—are the primary fuels for ICF, so determining and controlling their rate of diffusion through containment materials are important to the design of ICF facilities. When polycrystalline metals have texture, the preferential orientation of the metals affects hydrogen absorption and diffusion. Hydrogen permeation results show that there are significant differences among the three main textures of nickel membranes. Plating current density has a strong influence on texture development of nickel deposits. The texture of deposits can be easily manipulated by controlling plating conditions. In the experiments performed, textured Ni membranes were prepared using electrodeposition, and the effects of fabrication on their diffusion rates were determined.

In preparation for cryogenic experiments with tritium, we describe LLE's Tritium Recovery System, which is used to clean up the various exhaust streams and to control tritium activity in the gloveboxes (p. 25). This system is optimized for minimum environmental impact and maximum personnel safety. It uses the best-available technologies to extract tritium from inert gas streams in the elemental form. The rationale for the selection of various technologies is discussed in detail. This approach reduces the volumes of effluent that require treatment to the extent practical and also avoids the need to oxidize HT to HTO with its higher radiotoxicity, thereby contributing to safety.

Laser–plasma interactions (LPI) are potentially damaging sources of loss, conversion, and scattering of laser light on a target. We discuss results from pF3D—a parallel, three-dimensional LPI code developed at LLNL for modeling indirect-drive plasmas, which was recently modified for use under direct-drive conditions (p. 93). Unlike indirect drive, modeling direct drive requires simulation of inhomogeneous supersonic flows and density profiles that include a critical surface. The treatment of the critical surface is particularly problematic in codes employing the paraxial approximation for the light waves. The first results of the modified code included realistic simulations motivated by long-scale-length exploding-foil experiments conducted on LLE's 30-kJ, 351-nm, 60-beam OMEGA laser system and intended to represent future NIF direct-drive conditions.

Other LPI research (p. 181) included a linear model of anomalous stimulated Raman scattering from electron-acoustic waves in laser-produced plasmas. Stimulated Raman scattering (SRS) from heavily Landau-damped plasma waves and from electron-acoustic (EA) waves has recently been attributed to nonlinear Bernstein–Green–Kruskal (BGK) wave modes. These phenomena find a simpler, more comprehensive explanation in terms of linear waves in a locally flattened distribution function. The flattening arises from Landau damping of SRS plasma waves (in the case of anomalous SRS) or from perturbations at the EA phase velocity that are then maintained by SRS. Local flattening allows undamped linear EA waves to propagate, as in the original description of these waves by Stix.

"Time-Integrated Light Images of OMEGA Implosions" (p. 1) describes visible-light photographs of imploding OMEGA targets. These beautiful images are used to communicate LLE's mission to the general public. A closer examination of the images revealed a one-to-one correspondence between he bright spots in the image and each of the 60 laser beams. The intensity of the bright spots has been related to refraction and absorption in the plasma surrounding the imploding target. These photographs are now proving to be the basis of a new laser–plasma interaction diagnostic.

Theoretical work (p. 6) presents an analytical model of the nonlinear bubble evolution of single-mode, classical Rayleigh–Taylor (RT) instability at arbitrary Atwood numbers. The model follows the continuous evolution of bubbles from the early exponential growth to the nonlinear regime when the bubble velocity saturates.

The time dependence of electron thermal flux inhibition in direct-drive laser implosions is described beginning on p. 73. The article reports calculations of the nonlocal electron thermal conduction in direct-drive CH target implosions with square pulses by a one-dimensional Fokker–Planck solver combined with a hydrodynamic code. The results show that the electron thermal flux inhibition at the critical surface is time dependent, confirming that a larger flux limiter must be used for shorter-duration pulses. Also, the growth of the Rayleigh–Taylor instability for short-wavelength perturbations is shown to be smaller due to the longer density scale length.

Drive lasers, with known, single-mode modulations, produce nonuniform shocks that propagate into CH targets. The article beginning on p. 68 describes the perturbation of a target by nonuniformities in the drive laser. An optical probe beam is used to measure the arrival of these modulated shocks at various surfaces in the target. Experiments at moderate laser intensities ($\lesssim 10^{13}$ W/cm^2) exhibit behavior that is predicted by hydrocodes and simple scaling laws. This technique may be used to observe various dynamic effects in laser-produced plasmas and shock-wave propagation.

Experiments that control all aspects of nonuniformities in target manufacture, irradiation, and precision drive conditions are required to prepare for a direct-drive ignition experiment on the NIF. A recent experiment (p. 108) has tested the ability of a direct-drive ICF laser pulse shape to vary the adiabat within a target shell. A picket pulse was added to a pulse shape designed to implode a cryogenic shell of D_2 with a ratio α of internal pressure to Fermi-degenerate pressure of 5. The effect of a picket is to strengthen the shock in the outer portion of the shell so that the ablation interface has a large α and the fuel maintains its $\alpha = 5$, resulting in increased stability and improved capsule performance.

Implosion experiments with enhanced beam balance (p. 116) have implemented a new technique that determines the beam peak intensities at target chamber center on a full-power target shot by simultaneously measuring the x-ray flux produced by all 60 beams seen separated on a 4-mm-diam, Au-coated spherical target. Up to nine x-ray pinhole camera images are electronically recorded per shot from which beam-to-beam variations in peak intensity are determined, taking into account view angle and x-ray conversion efficiency. The observed variations are then used to correct the beam energies to produce a more-uniform irradiation. The authors present the results of implosion experiments with enhanced beam balance and comparisons to experiments with standard beam balance.

An investigation of the radial structure of shell modulations near peak compression of spherical implosions (p. 151) required the measurement of the structure of shell modulations at peak compression of implosions using absorption of titanium-doped layers placed at various distances from the inner surface of 20-μm-thick plastic shells filled with D^3He gas. The results show that the peak-compression, time-integrated areal-density modulations are higher at the inner shell surface, which is unstable during the acceleration phase of an implosion, than in the central part of the shell. The outer surface of the shell, which is unstable during the acceleration phase of an implosion, has a modulation level comparable to that of the inner shell surface.

Measurements of the neutron emission from ICF implosions provide important information about target performance that can be compared directly with numerical models. For room-temperature target experiments on OMEGA, the neutron temporal diagnostic (NTD), originally developed at LLNL, is used to measure the neutron burn history with high resolution and good timing accuracy. Since the NTD is mechanically incompatible with cryogenic target experiments because of the standoff required to remain clear of the Cryogenic Target Handling System, a new cryogenic-compatible neutron temporal diagnostic (cryoNTD) has been designed for LLE's standard ten-inch-manipulator (TIM) diagnostic inserters (p. 156). The instrument provides high-resolution neutron emission measurements for cryogenic implosions. The first experimental results of the performance of cryoNTD are presented and are compared to NTD measurements of room-temperature direct-drive implosions.

We have inferred the growth of target areal density near peak compression in direct-drive spherical target implosions with 14.7-MeV deuterium–helium^3 (D^3He) proton spectroscopy on the OMEGA laser system (p. 133). The target areal density grows by a factor of ~8 during the time of neutron production (~400 ps) before reaching 123±16 mg cm^{-2} at peak compression in an implosion of a 20-μm-thick plastic CH target filled with 4 atm of D^3He fuel.

The use of carbon activation as a diagnostic for tertiary neutron measurements is reported beginning on p. 161. The yield of tertiary neutrons with energies greater than 20 MeV has been proposed as a method to determine the areal mass density of ICF targets. Carbon activation is a suitable measurement technique because of its high reaction threshold and the availability of high-purity samples. The isotope ^{11}C decays with a half-life of 20.3 min and emits a positron, resulting in the production of two back-to-back, 511-keV gamma rays upon annihilation. The present copper activation gamma-detection system can be used to detect tertiary-produced carbon activation because the positron decay of ^{11}C is nearly identical to the copper decay used in the activation measurements of 14.1-MeV primary deuterium–tritium (DT) yields. Because the tertiary neutron yield is more than six orders of magnitude lower than primary neutron yield, the carbon activation diagnostic requires ultrapure carbon samples, free from any positron-emitting contamination. Carbon purification, packaging, and handling procedures developed in recent years that reduce the contamination signal to a level low enough for OMEGA are presented. Potential implementation of a carbon activation system for the NIF is also discussed.

Experiments have been performed on OMEGA as part of the Stockpile Stewardship Program to investigate the equation of state of carbonized resorcinol foam, a porous material. A theory that models equation-of-state measurements of porous materials is presented beginning on p. 57. Using the impedance-matching method, the foam Hugoniot was calculated from the well-known equation of state of aluminum and from measured shock speeds over the range of 100 kbar to 2 Mbar.

Laser and Optical Materials Research

A reduced-autocorrelation phase plate design for OMEGA and the NIF has been demonstrated (p. 11). Direct-drive ICF for the NIF requires that the time-averaged rms laser nonuniformity be below the 1% level. The lower spatial frequencies of laser nonuniformity are dangerous to the hydrodynamic stability of the ICF target. A reduced autocorrelation phase design shifts the speckle energy up into the higher spatial frequencies where smoothing by spectral dispersion (SSD) and thermal smoothing in the target corona are most efficient. A novel design method for calculating a reduced correlation phase plate is presented, and the smoothing performance results are compared to a standard phase plate.

We have demonstrated precision spectral sculpting of broadband FM pulses amplified in a narrowband medium (p. 79). Amplification of broadband frequency-modulated (FM) pulses in high-efficiency materials such as Yb^{+3}:SFAP results in significant gain narrowing, leading to reduced on-target bandwidths for beam smoothing and to FM-to-AM conversion. Applying precision spectral sculpting, with both amplitude and phase shaping, before amplifying the broadband FM pulses in narrowband gain media compensated for these effects. The spectral sculpting, for center-line small-signal gains of 10^4, produced amplified pulses that have both sufficient bandwidths for on-target beam smoothing and temporal profiles that have no potentially damaging amplitude modulation.

A new highly stable, diode-pumped, cavity-dumped, compact Nd:YLF regenerative amplifier (regen) of continuously shaped nanosecond pulses with a gain of ~10^9 for the front-end laser system of OMEGA is discussed beginning on p. 103. High output energy, long-term energy and temporal pulse shape stability, and high-quality beam profile have been demonstrated. Reliability, simplicity, modular design, and compactness are key features of this new diode-pumped regenerative amplifier.

To study the connection between the pulsed-laser energy absorption process and film damage morphology we used a SiO_2-thin-film system with absorbing gold nanoparticles (p. 30). We show that, at low laser fluences (below the threshold where damage can be detected optically), the probability of crater formation and the amount of the material vaporized are almost independent of the particle size. Inhomogeneities in the particle environment are responsible for variances in the observed particle/damage crater correlation behavior. In the proposed damage mechanism, the initial absorption is confined to the nanoscale defect. Energy absorbed by the defect quickly heats the surrounding matrix, changing it from a transparent to an absorbing medium, which creates a positive-feedback mechanism that leads to crater formation.

Advanced Technology

A series of thin, hydrogenated amorphous carbon films have been deposited using the saddle-field deposition configuration (p. 44). These films are a precursor to depositing tritiated films. Smooth, low-porosity films up to 15 μm thick and with densities up to 2 g/cm^3 have been grown. The internal structure of the films is featureless. Operating pressure plays an important role in modulating the film quality, growth rate, and density. Eliminating the substrate bias reduces negative ion incorporation in the films to help increase film density and improve film quality.

A theoretical investigation of a semiconductor quantum dot interacting with a strongly localized optical field, as encountered in high-resolution, near-field optical microscopy, is reported (p. 139). The strong gradients of these localized fields suggest that higher-order multipolar interactions will affect the standard electric dipole transition rates and selection rules. For a semiconductor quantum dot in the strong confinement limit, Zurita-Sanchez and Novotny have calculated the interband electric quadrupole absorption rate and the associated selection rules, finding that the electric quadrupole absorption rate is comparable with the absorption rate calculated in the electric dipole approximation.

The femtosecond response of a freestanding LT-GaAs photoconductive switch is discussed beginning on p. 88. A novel, freestanding LT-GaAs photoconductive switch has a femtosecond response time. The switch was formed by patterning a 1-mm-thick layer of a single-crystal LT-GaAs into a 5-μm by 15-μm bar. The bar was separated from its GaAs substrate and placed across a gold coplanar transmission line deposited on a Si wafer. The switch was excited with 110-fs-wide optical pulses, and its photoresponse was measured with an electro-optic sampling system. Using 810-nm optical radiation, 470-fs-wide electrical transients (640-GHz bandwidth) were recorded.

An investigation of the electric-field-induced motion of polymer cholesteric liquid crystal flakes in a conductive fluid is described beginning on p. 83. Polymer cholesteric liquid crystal flakes suspended in a fluid with non-negligible conductivity can exhibit motion in the presence of an ac electric field. The platelets have a strong selective reflection, which is diminished or extinguished as the flakes move. Flake motion was seen within a specific frequency bandwidth in an electric field as low as 5 mV_{rms}/mm.

New results on the time-resolved dynamics of the superconducting-to-resistive transition in dc-biased epitaxial $YBa_2Cu_3O_{7-x}$ (YBCO) microbridges, excited by nanosecond-long current pulses, are reported beginning on p. 40. The resistive switching was induced by the collaborative effect of both the Cooper-pair bias current and the quasiparticle pulse excitation, which together always exceeded the bridge critical current, forming the supercritical perturbation. The experimental dynamics was analyzed using the Geier and Schön (GS) theory, which was modified to include the dc bias. The resistive state was established after a delay time t_d, in agreement with the GS model, which depended in a nonlinear way on both the excitation pulse magnitude and the bridge dc bias.

A great deal of interest has been generated by the discovery of superconductivity in hexagonal magnesium borides because of not only MgB_2's high critical temperature and current density but also its lower anisotropy, larger coherence length, and higher transparency of grain boundaries to current flow.

We have for the first time fabricated MgB_2 superconducting films on flexible substrates (p. 130). Our process to deposit these films on large-area foils (up to 400 cm^2) and, after processing, cut them into any shapes (e.g., stripes) with scissors or bend them multiple times showed that the films suffer no observed degradation of their superconducting properties.

We describe measurements of the time delay of the resistive-state formation in superconducting NbN stripes illuminated by single optical photons (p. 186). A 65(±5)-ps time delay in the onset of a resistive-state formation in 10-nm-thick, 200-nm-wide NbN superconducting stripes exposed to single photons was measured. This delay in the photoresponse decreased down to zero when the stripe was irradiated by multiphoton (classical) optical pulses. The NbN structures were kept at 4.2 K, well below the material's critical temperature, and were illuminated by 100-fs-wide optical pulses. The time-delay phenomenon is explained within the framework of a model based on photon-induced generation of a hotspot in the superconducting stripe and subsequent, supercurrent-assisted resistive-state formation across the entire stripe cross section. The measured time delays in both the single-photon and two-photon detection regimes agree well with the Tinkham model's theoretical predictions of the resistive-state dynamics in narrow, ultrathin superconducting stripes.

OMEGA System Performance

Increased user demand was met in FY02 by expanding the available shot time during select weeks. Ten weeks were extended to four shot days by shooting one 8-h day, two 12-h days, and one 16-h day. This adjustment raised the total executed shots by 11%—from 1289 in FY01 to 1428 in FY02 (see Table 92.V, p. 193). Shaped-pulse cryogenic implosions highlighted the ongoing development of direct-drive cryogenic capability. A total of 21 spherical cryogenic D_2 targets were shot on OMEGA. Some of the cryogenic target shot time was devoted to characterization and system reliability improvements. Planar cryogenic target capability was also activated, and many shots were executed under LLE's Stockpile Stewardship Program (SSP) campaign. Highlights of other achievements and active projects as of the end of FY02 include the following:

- An IR streak camera with pulse-shape analysis software became a key operational tool to optimize pulse-shape performance. Combined with some changes to the control system for pulse-shape setup and upgrades to the regenerative oscillator hardware, the changes have resulted in dramatic improvements to delivered-pulse-shape performance.

- Infrared amplification occurs across a large variety of gain stages. By far, the highest gain stage is the regenerative (regen) amplifier, with 1×10^5 gain. One of the flash-lamp-pumped laser regens for OMEGA was replaced by a diode-pumped version that operates consistently without feedback stabilization. This diode-pumped laser improves pulse-shape performance. The remaining regens on OMEGA will be changed over to the new design in FY03.

- The distributed polarization rotator (DPR)—one of the key optics for beam smoothing on target—was modified for remote removal and reinstallation. The cassette-style removal system retracts the optic from the UV beamline into a protective housing. Having the capability to insert or remove these components improves flexibility for reconfiguring to indirect-drive setups. The full 60-beam complement of actuators will be completed early in FY03.

- The OMEGA laser is designed to provide a high degree of uniformity and flexibility in target illumination. The ability to impose a controlled asymmetric on-target irradiation pattern was developed and used extensively. This capability is used to benchmark multidimensional hydrodynamic simulations by imposing known nonuniform compression conditions on spherical targets. It is also used to modify laser-irradiation conditions for beam-to-beam x-ray yield balance.

- Modifications to the stage-A alignment sensors on OMEGA have streamlined an item of flexibility frequently exploited by LLE principal investigators. The backlighter driver alignment handoff to the OMEGA beamlines was re-engineered to expedite configuration setups that require the use of this source.

- Scientists and engineers from Lawrence Livermore National Laboratory along with LLE collaborators successfully implemented a green (second harmonic, 527 nm) target irradiation capability on one of the 60 OMEGA beams. This capability utilizes the existing OMEGA frequency-conversion crystals with the tripler detuned so that maximum 527-nm conversion is achieved.

- A revised set of direct-drive phase plates was designed and is being fabricated to further optimize irradiation uniformity for spherical implosions. These optics are going to be available in mid-FY03 and are expected to have improved smoothing characteristics in the mid-spatial-frequency range.

National Laser Users' Facility and External Users' Programs

FY02 was a record year for external user activity on OMEGA. As reported in the section beginning on p. 194, a total of 698 target shots were taken on OMEGA for external users' experiments in FY02. This is the highest number of target shots ever taken by external users on OMEGA in a single year and represents a 16% increase in external user shots over FY01. The external user shots accounted for 49% of the total OMEGA target shots in FY02. External users' experiments were carried out by eight collaborative teams under the National Laser Users' Facility (NLUF) Program as well as collaborations led by scientists from Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Sandia National Laboratory (SNL), the Nuclear Weapons Effects Testing (NWET) Program, and the Commissariat à l'Énergie Atomique (CEA) of France.

1. NLUF Programs

FY02 was the second of a two-year period of performance for the eight NLUF programs approved for FY01–FY02 experiments. The eight NLUF campaigns received a total of 118 target shots on OMEGA in FY02.

The Department of Energy (DOE) issued solicitations in mid-FY02 for NLUF proposals to be carried out in FY03–FY04. DOE raised the NLUF funding allocation to $800,000 for FY03 and is expected to increase it to $1,000,000 for FY04 to accommodate the high level of interest shown in the use of OMEGA to carry out experiments of relevance to the National Nuclear Security Agency (NNSA) Stockpile Stewardship Program.

A total of 13 NLUF proposals were submitted to DOE for consideration for FY03–FY04 support and OMEGA shot allocation. An independent DOE Technical Evaluation Panel reviewed the proposals and recommended that up to nine of the proposals be approved for partial funding and shot allocation during FY03–FY04. Table 92.VI (p. 195) lists the successful proposals.

2. FY02 NLUF Experiments

The eight NLUF programs carried out in FY02 included

- *Atomic Physics of Hot, Ultradense Plasmas*

- *Determination of Temperatures and Density Gradients in Implosion Cores of OMEGA Targets*

- *Studies of the Fundamental Properties of High-Energy-Density Plasmas*

- *High-Spatial-Resolution Neutron Imaging of Inertial Fusion Target Plasmas Using Bubble Neutron Detectors*

- *Examination of the "Cone-in-Shell" Target Compression Concept for Asymmetric Fast Ignition*

- *Supernova Hydrodynamics on the OMEGA Laser*

- *Studies of the Dynamic Properties of Shock-Compressed FCC Crystals by* In-Situ *Dynamic X-Ray Diffraction*

- *Optical Mixing of Controlled Stimulated Scattering Instabilities (OMC SSI) on OMEGA*

3. FY02 LLNL OMEGA Experimental Program

The LLNL program on OMEGA in FY02 totaled 406 target shots for target ignition physics, high-energy-density science, and NWET (Nuclear Weapons Effects Testing). This represents a 30% increase over the target shots taken by LLNL on OMEGA in FY01. Highlights of these experiments include laser–plasma interactions, cocktail hohlraums, x-ray Thomson scattering, albedo experiments, hot hohlraums, gas-filled radiation sources, dynamic hohlraums, nonideal implosions, double-shell implosion experiments, charged-particle spectrometry in indirect-drive implosions, and IDrive.

4. FY02 LANL OMEGA Experimental Program

The LANL program on OMEGA in FY02 comprised a total of 132 target shots in support of cylindrical mix (CYLMIX) experiments; the Stockpile Stewardship Program; asymmetric direct-drive implosions; double-shell implosions; hydrodynamic jet experiments in collaboration with AWE, LLNL, and LLE; shock-breakout measurements in collaboration with SNL; and development of phase-2 nuclear diagnostics for the NIF.

5. FY02 SNL OMEGA Programs

SNL carried out a total of 24 target shots on the OMEGA laser in FY02 and also participated in several of the campaigns led by other laboratories. The SNL-led campaigns included indirect-drive ablator shock coalescence; indirect-drive ablator shock velocity at 50 Mbar; indirect-drive ablator x-ray burnthrough measurements; and time- and spatially resolved measurements of x-ray burnthrough and re-emission in Au and Au:Dy:Nd foils.

6. CEA

CEA had four half-day dedicated shot opportunities on OMEGA during FY02. A total of 19 target shots were provided for experiments including tests of the LMJ three-ring symmetry and other aspects of indirect-drive targets. In addition, CEA participated in collaborative experiments on imaging the neutron core emission using the CEA-provided neutron-imaging system (NIS).

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-four faculty from five departments collaborate with LLE's scientists and engineers. Presently 57 graduate students are pursuing graduate degrees at the Laboratory, and LLE is directly funding 38 University of Rochester Ph.D. students through the Frank J. Horton Fellowship Program. The re-search includes theoretical and experimental plasma physics, high-energy-density plasma 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 fifty-four University of Rochester 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

Thomas Gardiner	*Astrophysics Stellar Evolution*
Andrei Kanaev	*Propagation of Laser Beams Smoothed by Spectral Dispersion in Long-Scale-Length Plasmas*
Feng-Yu Tsai	*Engineering Vapor-Deposited Polyimides*

Approximately 46 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; 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 12 years LLE has run a Summer High School Student Research Program (p. 190) 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 2002, LLE presented its sixth William D. Ryan Inspirational Teacher Award to Mr. James Keefer, a physics and chemistry teacher at Brockport 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. Keefer was nominated by Ms. Priya Rajasethupathy, a 2000 participant in the program.

Robert L. McCrory
Director