Executive Summary

The fiscal year ending in September 2007 concluded the fifth year of the five-year renewal of Cooperative Agreement DE-FC52-92F19460 with the U.S. Department of Energy. This annual report serves as the final report for the Agreement and summarizes progress in laser-fusion research at the Laboratory for Laser Energetics (LLE) during the past fiscal year. It also reports on LLE's progress on laser, optical materials, and advanced technology development; work on the OMEGA EP (extended performance) laser project; operation of OMEGA for the National Laser Users' Facility (NLUF) and other external users; and programs focusing on the education of high school, undergraduate, and graduate students during the year.

Progress in Laser-Fusion Research

The laser-fusion research program at the University of Rochester's Laboratory for Laser Energetics (LLE) is focused on the National Nuclear Security Administration's (NNSA's) Campaign-10 inertial confinement fusion (ICF) ignition and experimental support technology, operation of facilities (OMEGA), and the construction of OMEGA EP—a high-energy petawatt laser system. While LLE is the lead laboratory for research into the direct-drive approach to ICF ignition, it also takes a lead role in certain indirect-drive tasks within the National Ignition Campaign.

During this past year progress in the laser-fusion research program was made in three principal areas: OMEGA direct-drive and indirect-drive experiments and targets; development of diagnostics for experiments on OMEGA, OMEGA EP, and the National Ignition Facility (NIF); and theoretical analysis and design efforts aimed at improving direct-drive-ignition capsule designs and advanced ignition concepts such as fast ignition and shock ignition.

1. National Ignition Campaign Experiments

In FY07, LLE scientists in collaboration with scientists from the Massachusetts Institute of Technology (MIT) Plasma Science and Fusion Center (PSFC) inferred, for the first time, a neutron-averaged areal density in excess of 200 mg/cm^2 from direct-drive cryogenic D_2 implosions on the OMEGA laser. This set of measurements completed an NNSA Level-2 milestone and demonstrated conclusively that hydrogen can be compressed to fuel densities required for both indirect- and direct-drive-ignition capsules. The neutron-averaged areal density was inferred from the energy loss of secondary protons produced in the core along five different directions. The measured particle spectra were in close agreement with *LILAC* 1-D code predictions, indicating that the fuel assembly proceeded according to 1-D simulations up to the peak density of the implosions, i.e., ~140 g/cc (or approximately 700 times the density of liquid deuterium). Results of these experiments were presented at the 49th Annual Meeting of the American Physical Society Division of Plasma Physics and have been submitted for publication.

Experiments were conducted on OMEGA to investigate the energy coupling and implosion symmetry achieved in an indirect (hohlraum)-driven target using a multicone geometry and elliptical phase plates (p. 212). Indirect-drive-ignition target designs planned for the National Ignition Facility (NIF) aim at concurrent objectives of minimizing laser-energy losses due to stimulated Brillouin scattering (SBS) or stimulated Raman scattering (SRS) and maximizing the capsule drive symmetry. The OMEGA experiments, which used specially designed phase plates that produced elliptical irradiation patterns on the hohlraum wall, demonstrated significant improvement in coupling. The improved coupling correlates with reduced losses from SRS and SBS. In the same experiments, the implosion symmetry was investigated for the first time using a multicone laser drive smoothed with phase plates.

OMEGA planar direct-drive experiments investigated the role of preheat in the stabilization of the Rayleigh–Taylor (RT) instability. Compression of an ICF target is very sensitive to any preheat experienced by the driven target. Nonlocal-electron preheat is a potentially major source of preheat for ICF targets (caused by electrons with energies of ~10 keV and hot electrons with energies of ~100 keV). The RT-instability growth rate of target modulations at the ablation surface is sensitive to preheat because the increased ablation velocity (caused by target decompression) reduces the RT growth. The experiments showed significant reduction in the RT growth rate for short-wavelength (i.e., less than 30-μm) perturbations driven by high-intensity (1×10^{15} W/cm^2) compared to lower-intensity (5×10^{14} W/cm^2) UV irradiation. These results were presented at the 49th Annual Meeting of the American Physical Society Division of Plasma Physics and will be submitted for publication.

The speed and heating of convergent shocks are of fundamental importance for the design of ignition and high-gain ICF capsules. Strong, spherically converging shocks are formed by the rapid deposition of energy on the capsule's surface (laser energy in the case of direct-drive or x rays in the case of indirect-drive targets). All of the generated shocks must propagate through hot, already-shocked material; this adds uncertainty in the shock speed and strength. In collaboration with MIT PSFC, the products of two nuclear-reaction types induced by the central collapse of convergent shocks were measured temporally and spectrally on OMEGA (p. 148). Observations of these products provided information about the speed and heating of the shocks, as well as the state of the imploding capsule at the time of shock collapse. Comparison of these data to predictions from 1-D hydrodynamic simulations revealed numerous differences that will be used in the future to develop improved models for these implosions.

A comprehensive set of experiments was completed on OMEGA (p. 1) to track the flow of laser energy in a target. Time-resolved measurements of laser absorption in the corona were performed on imploding directly driven capsules. The mass ablation rate was inferred using time-resolved Ti K-shell spectroscopy of stationary (nonimploding), solid CH spherical targets that were configured with a buried tracer layer of Ti. Shock heating was also measured. A detailed comparison of the experimental results and the simulations indicates that a time-dependent flux limiter in the thermal transport model is required to simulate the laser-absorption measurements.

In another collaborative OMEGA experiment with MIT PSFC, nuclear measurements of fuel–shell mix in inertial confinement implosions were carried out (p. 14). The extent of fuel–shell mix was probed in imploded capsules containing a deuterated plastic (CD) layer and filled with pure ^{3}He. Spectral measurements of the high-energy protons produced by the D-^{3}He fusion reaction were used to constrain the level of mix at shock time, to demonstrate that some of the fuel mixes with the CD layer, and that capsules with a higher initial fill density or thicker shells are less susceptible to the effects of mix.

2. *Target Diagnostics for OMEGA, OMEGA EP, and the NIF*

To improve the understanding and predictions of the shock-heated and compressed temperature and density conditions in the main fuel layer of an imploding capsule, exploratory experiments were undertaken on OMEGA by LLE scientists in collaboration with Rutherford Appleton Laboratory, Oxford University, and LLNL scientists to measure the temperature and ionization conditions in shock-heated and compressed targets using noncollective spectrally resolved x-ray scattering (p. 191). The shock-heated shell is predicted to have plasma conditions in the warm dense matter (WDM) regime. Measuring WDM conditions is challenging because the temperature of the plasma is too low (~10 eV) to emit x rays and dense plasmas cannot be optically probed. The experiments succeeded in determining an upper limit of $Z = 2$ and $T_e = 20$ eV for the ionization and electron temperature, respectively, of directly driven, Br-doped CH foils. The experiments demonstrated that x-ray scattering is a promising technique to probe spatially averaged plasma conditions in the DT shell of an imploding target during the laser irradiation to determine the shell adiabat.

Current designs for both direct-drive-ignition (DDI) and indirect-drive-ignition (IDI), high-gain ICF targets require a layer of condensed (cryogenic) hydrogen fuel that adheres to the inner surface of a spherical ablator. NIF ignition capsules (both DDI and IDI) require a total root-mean-square (rms) deviation of less than 1 μm in the uniformity of the DT-ice layer. Measurement of the ice-layer radius over the entire surface of the capsule with submicron resolution is required to verify that this specification has been met. LLE scientists developed an improved system for three-dimensional characterization of spherical cryogenic capsules using ray-trace analysis of multiple shadowgraph views (p. 46). A 3-D ray-tracing model was incorporated into the backlit optical shadowgraph analysis (the primary diagnostic for ice-layer characterization of transparent targets at LLE). The result was an improved self-consistent determination of the hydrogen/vapor surface structure for cryogenic targets.

Neutron core imaging will be used on NIF implosions to identify ignition-failure mechanisms such as poor implosion symmetry or inadequate convergence/areal density. Neutron imaging on OMEGA is obtained by placing an appropriate aperture in front of a spatially sensitive neutron detector [see, for example, the report on the Commissariat à l'Énergie Atomique (CEA) work on p. 270]. Similar systems will be used on the NIF. LLE, in collaboration with CEA, LLNL, and LANL, has conducted an optimization study (p. 203) to understand the effects and trade-offs of the neutron-imaging system's component tolerances on the overall quality of the system.

3. Theoretical Analysis and Design

Ignition target designs based on a wetted-foam ablator offer higher coupling efficiency for NIF DDI capsules than is possible with conventional solid-DT-ablator capsules. Simulations were carried out on the performance of wetted-foam targets driven by 1 MJ on the NIF (p. 26). A stability analysis was performed using the two-dimensional hydrodynamic code *DRACO*. A nonuniformity budget analysis was constructed and suggests that two-dimensional smoothing by spectral dispersion (SSD) or an alternative scheme using multiple frequency modulators (presented at the 49th Annual Meeting of the American Physical Society Division of Plasma Physics) may reduce single-beam nonuniformities to levels required for ignition.

To produce ignition with direct-drive targets at the 1-MJ level, NIF capsules require relatively thin shells (initial aspect ratio ~5) driven at high velocities ($\sim 4 \times 10^7$ cm/s). The performance of such implosions is sensitive to the growth of RT instability on the ablation front. Low-velocity implosions with low in-flight aspect ratio (IFAR) have good stability properties during the acceleration phase. However, such targets would fail to ignite for moderate driver energies because the hot-spot temperature and pressures are too low. In collaboration with the University of Rochester Fusion Science Center (FSC), we have investigated (p. 234) the possibility of using a spherically converging shock wave propagating through the shell during the coasting phase of the implosion to enhance the compression of the hot spot and significantly improve ignition conditions. The ignitor shock is launched at the end of the laser pulse and must collide with the return shock near the inner shell surface. We show that a two-step ignition scheme can be configured by combining a fuel-assembly laser pulse and a shock-driving power spike. Such configurations can lead to a significant reduction in the energy required for ignition and high gain.

Fast ignition is another two-step ignition scheme that uses fast electrons (or protons) to heat an assembled high-density fuel core. In direct-drive fast ignition, the high-energy driver used for the compression is a conventional short-wavelength ($\lambda < 0.53~\mu$m) laser while a high-intensity laser (power ~ petawatts) with a longer wavelength ($\lambda > 0.53~\mu$m) is used to produce the high-energy charged particles. During FY07 we conducted comprehensive hydrodynamic simulations of ignition and burn for direct-drive fast-ignition fusion targets (p. 74). The simulations show that even modest-sized UV-laser drivers (for the target compression), with an energy of ~100 kJ, can produce a fuel assembly yielding maximum gain close to ~60 with the appropriate ignition laser pulse. At a total energy of ~1 MJ, the total gain of the optimized fast-ignition target is ~160 for an ignition pulse of ~100 kJ. The basis of these designs will be tested on OMEGA EP beginning in FY09.

Lasers, Optical Materials, and Advanced Technology

In recent years, the output power of fiber lasers has increased to levels in excess of a kilowatt. These lasers are widely used in high-power applications such as material processing and industrial manufacturing. Nonlinear effects such as SBS and SRS and self-focusing can limit the power scalability in fibers. Self-focusing can lead to beam-quality degradation through a process called filamentation. Filamentation has been studied extensively in semiconductor lasers over the past two decades; however, little such work has been done in fiber lasers. A theoretical model for the filamentation effect in a large-mode-area (LMA) fiber laser is discussed starting on p. 55. This model predicts the output-power thresholds at which the filamentation will occur for a given set of optical-fiber parameters; a simplified threshold expression is also provided. The results are consistent with previous experiments.

Although the damage threshold of fiber lasers is increased with the use of LMA's, their increased mode area in traditional step-index fibers introduces higher-order transverse modes that can potentially degrade the laser beam. Many designs of LMA fibers for high-power applications have been developed for beam-quality control. These design features have included internal structures, external structures, refractive-index, and gain-dopant designs in multimode fibers. However, the impact of transverse spatial-hole burning (THSB) on beam quality has largely been ignored. As a beam with nonuniform transverse intensity distribution propagates through the fiber, the gain becomes more saturated where the intensity is highest. As the gain sampled by each transverse mode changes, the net beam profile, and thus the beam quality, changes. At high power this effect becomes pronounced due to heavily saturated population inversion. We report (p. 120) on measurements of the beam-quality factor for an ASE source based on an ytterbium-doped LMA multimode fiber as a function of pump power. A localized multimode model is presented containing spatially resolved gain and a modal decomposition of the optical field. Numerical simulations are performed with this model and compared to the experimental results. The comparison validates the model and demonstrates TSHB's impact on beam quality.

We report on comprehensive experimental and theoretical studies of the time-resolved generation and detection of coherent acoustic phonons (CAP's) in very high quality GaN single crystals (p. 88). These studies were performed using a femtosecond, two-color, all-optical pump/probe technique. Very good agreement is observed between the theoretical modeling and experimental measurements, indicating that this approach makes it possible to successfully generate nanoscale acoustic waves at the surface of bulk semiconductors and, simultaneously, to nondestructively probe the material's structure deep below the surface. This approach should be very promising in producing and detecting CAP waves in a large variety of bulk semiconductor materials.

Holographic volume Bragg gratings (VBG's) represent a new class of robust, highly efficient, and spectrally selective optical elements that are recorded in photo-thermo-refractive glass. VBG's have extremely high spectral and angular dispersions that are higher than any dispersive elements previously used. VBG's are stable at elevated temperatures, have a high optical-damage threshold similar to that of bulk glass materials, and have a high diffraction efficiency and low losses, allowing their use in laser resonators. In collaboration with scientists from OptiGrate and the College of Optics and Photonics/CREOLE, University of Central Florida, we report (p. 115) on the demonstration of instrument-limited suppression of out-of-band amplified spontaneous emission (ASE) in a Nd:YLF diode-pumped regenerative amplifier (DPRA) using a VBG element as a spectrally reflective element. A VBG with 99.4% diffraction efficiency and a 230-pm-FWHM reflection bandwidth produced a 43-pm-FWHM output spectral width in an unseeded DPRA compared to 150-pm FWHM in the same DPRA with no VBG.

In a second article (p. 135) by the same collaborative team as above we report on analytical and experimental studies of pump-induced temporal contrast degradation in optical parametric chirped-pulse amplifiers (OPCPA's). OPCPA systems will be playing an increasingly important role in the exploration of the new regimes of laser–matter interaction at intensities in excess of 10^{22} W/cm^2. Such experiments can be adversely affected by laser light present before the main pulse. The temporal contrast of the laser pulse is the ratio of the peak power of the main pulse to the power of the light in some predetermined temporal range before the main pulse. Incoherent laser and parametric fluorescence can significantly degrade the contrast of the pulse. In this report we quantify the effect of incoherent pump-pulse ASE on contrast degradation in OPCPA systems and present an experimental technique using VBG crystals to mitigate this problem.

Polycrystalline ceramics such as chemical-vapor–deposited (CVD) silicon carbide, polycrystalline alumina, and aluminum oxynitride display a great potential for advanced optical applications in severe environments that require high hardness, high toughness, and excellent thermal properties. These materials are nominally fully dense, and there is growing interest in grinding and ultimately polishing them to nanometer levels of surface microroughness. We have developed a procedure (p. 98) for estimating subsurface damage depth induced by deterministic microgrinding of hard polycrystalline optical ceramics with diamond-bonded tools. This estimate comes from tracking the evolution of surface microroughness with the amount of material removed by multiple MRF spots of increasing depth into the surface. This technique also provides information regarding the specimen microstructure (i.e., grain size), mechanical properties (hardness and fracture roughness), and the grinding conditions (i.e., abrasive size used), from extended spotting with the MRF process.

Key to the success of a multipetawatt laser such as OMEGA EP is the ability to produce meter-scale, high-optical-quality, high-damage-resistance, high-efficiency, multilayer dielectric diffraction (MLD) gratings. The specific requirements for OMEGA EP are a diffraction efficiency greater than 95%, peak-to-valley wavefront quality of less than $\lambda/10$ waves, and a laser damage threshold greater than 2.7 J/cm^2 for 10-ps pulses. The multilayer dielectric grating consists of a film of SiO_2 etched to form a grating structure with 1740 lines per millimeter. The structure resides on top of a multilayer dielectric high-reflector stack composed of alternating layers of SiO_2 and HfO_2. The cleanliness of this structure is of paramount importance to its survivability. An article starting on p. 228 describes the results of an investigation conducted by LLE to further optimize a final MLD diffraction grating cleaning process called "piranha clean" that will increase laser-damage resistance to meet LLE specifications.

Status and Progress of OMEGA EP

The OMEGA EP project is in its fifth year. In FY07 an allocation of $2.25 million completed the $89 million funding required for the project. The project will be completed in April 2008.

The first quarter of FY07 was highlighted by the start of shot operations. Propagating shots on Beamline 1 were used to characterize spatially resolved gain profiles for the amplifier chain. The amplifiers and laser diagnostics met all performance objectives with high reliability. Beamline 1 was also tested for amplification of the broadband short-pulse source. The spectral transmittance of a chirped-pulse source beam with 8-nm bandwidth was characterized. Analysis of the spectral transmittance data indicated that there were no spectral anomalies in the four-pass beamline. This is a favorable and important result for the short-pulse performance of the OMEGA EP beamlines.

In the second quarter of FY07, progress was highlighted by the completion of the spatial-filter vacuum vessel subsystem. These tubes are a vital component of the architecture of the beamline, used to transport and image the high-power beam from one portion of the laser to the next. There are 108 individually welded and machined tube sections, custom fabricated to OMEGA EP requirements. Center sections include access features to the pinhole regions that proved to be very useful during the initial alignment and commissioning operations. Also during this second quarter the grating compressor internal structures, on the project critical path, started to arrive at LLE.

Acquisition of the grating compressor internal structure concluded in the third quarter, approximately one year behind initial plans. Delays in the acquisition are largely attributable to managing potential contamination sources. Contamination in any form is a serious threat to the performance of the compressor optics—a threat that was minimized through the control of materials and fabrication processes. Ultimately, the tables were successfully cleaned to the LLE-required precision cleaning standard and installed during the third quarter. This allowed the installation of the internal assemblies to begin. All eight of the tiled-grating assemblies were completed and tested offline in preparation for the compressor loading. Also during the third quarter, two of the remaining three beams were activated to ~3-kJ IR energy at the beamline output calorimeters.

During the fourth quarter of FY07 the fourth and final beamline was activated to ~3-kJ IR energy level. Loading of grating compressor optics continued, along with the assembly and installation of the UV diagnostic systems. At the end of FY07, 68 of the 104 optical assemblies were loaded into the grating compressor chamber. Alignment was completed through the four main alignment paths to the primary compressor optics. Each of the two Fizeau interferometer arms that will be used to verify grating tiling within the vacuum vessel was completed as were the up-collimators that send full aperture infrared beams to the grating and transport paths. The optical alignment made good progress in part due to the internal structure design flexibility, allowing temporary alignment fixtures to be placed in a variety of locations.

Overall, the project completed most objectives for FY07 and continues to make satisfactory progress toward project completion. In addition to having operated the beamlines with trained and qualified operators, the project is successfully operating all key enabling technologies. Development is complete, engineering is complete, and by the end of the year all of the following project elements will have achieved operating status:

- optical parametric chirped-pulse-amplification front-end sources
- deformable mirrors and wavefront-control systems
- plasma-electrode Pockels cells (double pulse)
- 40-cm-aperture disk amplifiers
- 41-cm × 141-cm-aperture tiled gratings
- diffractive color correctors
- frequency-conversion crystals

National Laser Users' Facility (NLUF) and External Users' Programs

More than half (54%) of the OMEGA shots in FY07 were dedicated to external users including the NLUF programs, LLNL, LANL, SNL, CEA, and AWE (Atomic Weapons Establishment).

FY07–FY08 NLUF Experiments

Fiscal year 2007 was the first year of a two-year period of performance for the NLUF projects approved for FY07–FY08 funding and OMEGA shots. A total of 121 shots were conducted for six NLUF projects. Their progress is detailed beginning on p. 242 in the following reports:

- *Recreating Planetary Core States on OMEGA in FY07*
  (R. Jeanloz, University of California, Berkeley)

- *Experimental Astrophysics on the OMEGA Laser*
  (R. P. Drake, University of Michigan)

- *Laboratory Experiments on Supersonic Astrophysical Flows Interacting with Clumpy Environments*
  (P. Hartigan, Rice University)

- *Multiview Tomographic Study of OMEGA Direct-Drive-Implosion Experiments*
  (R. Mancini, University of Nevada, Reno)

- *Monoenergetic Proton Radiography of Laser–Plasma-Generated Fields and ICF Implosions*
  (R. D. Petrasso and C. K. Li, Massachusetts Institute of Technology)

- *X-Ray Compton Scattering on Compressed Matter* (R. Falcone and H. J. Lee, University of California at Berkeley)

FY07 LLNL OMEGA Experimental Programs

In FY07, LLNL led 422 target shots on the OMEGA Laser System; this rate was 9.3% higher than the planned allocation. Approximately 57% of these LLNL-led shots were dedicated to advancing the National Ignition Campaign (NIC) in preparation for future experiments on the NIF; the remainder were dedicated to experiments for the high-energy-density science (HEDS) program. Objectives of the OMEGA NIC Campaigns included the following:

- *Laser–plasma interaction studies in physical conditions relevant for the NIF ignition targets*

- *Studies of the impact of x-ray flux originating from outside the laser entrance hole (LEH) on the radiation temperature of a hohlraum*

- *Characterization of the properties of warm, dense matter—specifically radiatively heated Be*

- *Studies of the physical properties of capsules based on Cu-doped Be and high-density carbon*

- *Determination of the ablator performance during the implosion of NIC-candidate ablators*

- *Experiments to detect and study second-shock-melting, high-density carbon*

- *High-resolution measurements of velocity nonuniformities created by microscopic pertubations in NIF ablator materials*

The LLNL HEDS campaigns included the following experiments:

- *Quasi-isentropic (ICE) drive used to study material properties such as strength, equation of state, phase, and phase-transition kinetics under high pressure*

- *Late-time hohlraum-filling studies*

- *Laser-driven dynamic hohlraum (LDDH) implosion experiments*

- *The development of an experimental platform to study nonlocal thermodynamic equilibrium (NLTE) physics using direct-drive implosions*

- *Opacity studies of high-temperature plasmas under LTE conditions*

- *Development of long-duration, point-apertured, point-projection x-ray backlighters*

- *Studies of improved hohlraum heating efficiency using cylindrical hohlraums with foam walls*

FY07 LANL OMEGA Experimental Programs

During FY07, LANL fielded a range of experiments on OMEGA to study ICF and high-energy-density laboratory plasma (HEDLP) physics. LANL conducted 192 target shots, 21.5% higher than the planned allocation.

As reported starting on p. 259, the LANL-led campaigns included the following experiments:

- *Studies of radiation transport in inhomogeneously mixed media where discrete particles of random size are randomly dispersed in a host material*

- *Off-Hugoniot experiments to explore the hydrodynamic evolution of embedded layers subject to radiative heating*

- *NIF Platform #5—aimed at developing x-ray diagnostic techniques to measure temperature in future NIF radiation transport experiments*

- *The "symergy" experiment to test the concept of using thin shells to quantify asymmetry during the foot of NIF ignition drive pulse*

- *The "convergent ablator" campaign, to characterize the ablator performance in scaled NIF capsules*

- *Laser–plasma interaction experiments*

- *The "Hi-Z" experiment to study the effects of instability growth and the resulting mix*

- *Studies of reaction history using a double laser pulse*

- *"DT ratio—^{3}He" experiment to investigate the effect of helium on yield and reaction history of DT implosions*

- *The "beta-mix" experiment to develop a radiochemical diagnostic to study mix in NIF experiments*

FY07 SNL OMEGA Experimental Programs

During FY07, SNL scientists led 15 target shots on the OMEGA laser—36% more than the nominal allocation. The SNL experiments focused on measurements of the high-density carbon ablation rate conducted on planar ablator samples driven by radiation from a halfraum. These experiments are reported on pp. 268–269.

FY07 CEA OMEGA Experimental Programs

During FY07, CEA scientists led 40 experiments on OMEGA (equal to the nominal allocation). Reports on the experiments begin on p. 270 and include the following:

- *Measurements of wall and laser-spot motion in cylindrical hohlraums*

- *Development of neutron imaging on OMEGA*

- *Neutron flux and duration measurements with CVD diamond detectors*

FY07 AWE OMEGA Experimental Programs

AWE scientists conducted 26 OMEGA target shots in FY07—30% more than the nominal allocation. The experiments were focused on studies of radiation transport through enclosed spaces with inwardly moving walls—key to understanding the physics of laser-heated hohlraums.

FY07 Laser Facility Report

The OMEGA facility conducted 1514 target shots for a variety of users in FY07 (see Fig. 1). The OMEGA Availability and Experimental Effectiveness averages for the year were 92.8% and 95.9%, respectively. Highlights of the year included the following:

- *A total of 27 D_2 and 17 DT low-adiabat cryogenic target implosions that required high-contrast pulse shapes were performed.*

- *An offline OMEGA frequency-conversion-crystal (FCC) tuning test bed was developed.*

- *More than 25 new or significantly modified target-diagnostic systems were qualified for use on the OMEGA Experimental Facility in FY07. These diagnostics supported LLE, LLNL, LANL, AWE, and CEA experiments.*

- *Significant modifications were made to the OMEGA Laser Facility in FY07 to integrate the OMEGA EP short-pulse beam into the OMEGA target chamber.*

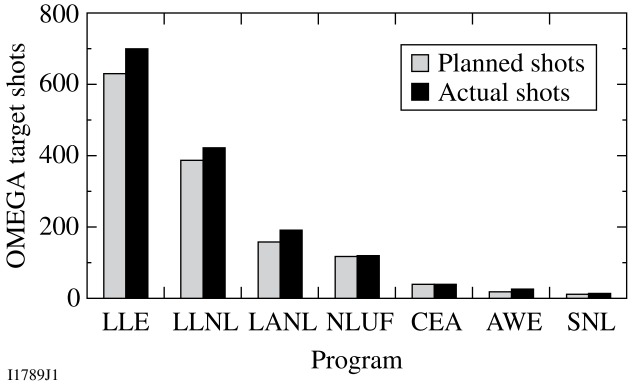

Figure 1
FY07 OMEGA target shot summary.

Education at LLE

As the only major university participant in the National ICF Program, education continues to be an important mission for the Laboratory. A report on this year's Summer High School Research Program is described in detail on p. 238. Fourteen students participated in this year's program. The William D. Ryan Inspirational Teacher Award was presented to Mr. Christian Bieg, a physics teacher at Fairport High School.

Graduate students are using the OMEGA laser for fusion research and other facilities for HED research and technology development. They are making significant contributions to LLE's research activities. Twenty-nine faculty from five departments collaborate with LLE's scientists and engineers. Presently, 77 graduate students are involved in research projects at LLE, and LLE directly sponsors 42 students pursuing Ph.D. degrees via the NNSA-supported Frank Horton Fellowship Program in Laser Energetics. Their 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.

Approximately 68 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, the University of Nevada, Reno, and the University of Wisconsin. These programs involve a total of approximately 16 graduate students, 27 undergraduate students, and 7 faculty members.

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