Executive Summary

The fiscal year ending September 2012 (FY12) concluded the fifth year of the third five-year renewal of Cooperative Agreement DE-FC52-08NA28302 with the U.S. Department of Energy (DOE). This annual report serves as the final report for the Agreement and summarizes progress in inertial fusion research at the Laboratory for Laser Energetics (LLE) during the past fiscal year including work on the National Ignition Campaign (NIC). It also reports on LLE's progress on laboratory basic science research; laser, optical materials, and advanced technology development; operation of OMEGA and OMEGA EP for the NIC and high-energy-density (HED) campaigns, 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 Inertial Confinement Fusion (ICF) Research

One of LLE's principal missions is to conduct research in inertial confinement fusion (ICF) with particular emphasis on supporting the goal of achieving ignition on the National Ignition Facility (NIF). This program uses the Omega Laser Facility. During FY12, a total of 1920 target shots were taken at the Omega Laser Facility (including the 60-beam UV laser OMEGA and the four-beam, high-energy petawatt laser OMEGA EP. More than 43% of the facility's target shots in FY12 were designated as NIC experiments or experiments in support of NIC. During the last five years of the current Cooperative Agreement, 8204 target shots were taken on the Omega Laser Facility in support of the National Nuclear Security Administration (NNSA) missions. The OMEGA and OMEGA EP lasers attained average experimental effectiveness of 96.7% and 95.5%, respectively, in FY12.

LLE plays a lead role in the validation of the performance of cryogenic target implosions, essential to all forms of ICF ignition. LLE is responsible for a number of critical elements within the Integrated Experimental Teams (IET's) supporting the demonstration of indirect-drive ignition on the NIF and is the lead laboratory for the validation of the polar-drive approach to ignition on the NIF. LLE has also developed, tested, and constructed a number of diagnostics that are being used on the NIF for the NIC. During this past year, progress in the inertial fusion research program continued in three principal areas: NIC experiments and experiments in support of NIC; development of diagnostics for experiments on the NIF, OMEGA, and OMEGA EP; and theoretical analysis and design efforts aimed at improving direct-drive–ignition capsule designs (including polar-drive–ignition designs) and advanced ignition concepts such as shock ignition and fast ignition.

1. National Ignition Campaign Experiments in FY12

In this volume we report (p. 1) on direct-drive implosion experiments performed on the OMEGA laser that have shown a reduction in measured laser-to-capsule coupling efficiency of 10% to 20% compared to simulations. This reduction is attributed to cross-beam-energy transfer (CBET). CBET scatters energy via stimulated Brillouin scattering from the central portion of an incoming laser beam to an outgoing laser beam. One-dimensional hydrodynamic simulations including CBET show good agreement with all observables in the OMEGA implosion experiments. Three strategies to mitigate CBET are identified: the use of narrow beams, multicolor lasers, and higher-Z ablators. Experiments on OMEGA using narrow laser beams have demonstrated improvements in implosion performance.

Measurements of the hot-electron generation by the two-plasmon–decay (TPD) instability under plasma conditions relevant to direct-drive inertial confinement fusion are reported (p. 20). Density scale lengths of ~400 μm at quarter-critical electron density in planar CH targets allow the TPD instability to be driven to saturation for laser intensities greater than ~3.5×10^{14} W/cm^2. In the saturated regime, ~1% of the laser energy is converted to hot electrons. The hot-electron temperature is observed to increase rapidly from 25 keV to 90 keV as the laser intensity is increased from 2 to 7×10^{14} W/cm^2. This increase in hot-electron temperature is compared to predictions from nonlinear Zakharov models.

Time-resolved K_α spectroscopy was used in an experiment conducted on the OMEGA EP laser (p. 15) to infer the hot-electron equilibration dynamics in high-intensity laser interactions with thin-foil solid targets. The measured K_α-emission pulse width increases from ~3 to 6 ps for laser intensities from ~10^{18} to 10^{19} W/cm^2. Collisional energy-transfer model calculations suggest that hot electrons with mean energies from ~0.8 to 2 MeV are contained inside the target. The inferred mean hot-electron energies are broadly consistent with ponderomotive scaling over the relevant intensity range.

The thermal conductivity of solid D_2 was measured by the 3ω method, in which a wire embedded in the medium serves as both a heater and a temperature sensor (p. 48). Accurate values of conductivity were obtained for solid D_2 in the temperature range of 13.4 K to 18.6 K. In this temperature range, normal and ortho D_2 are found to have the same conductivity.

A comprehensive review of the cryogenic-deuterium and deuterium–tritium implosions that have been performed on the OMEGA Laser System over the last decade is presented (p. 72). The success of ignition target designs in inertial confinement fusion (ICF) experiments critically depends on the ability to maintain the main fuel entropy at a low level while accelerating the shell to ignition-relevant velocities of $V_{\text{imp}} > 3 \times 10^7$ cm/s. The fuel entropy is inferred from the experiments by measuring fuel areal density near peak compression. Measured areal densities up to $\langle \rho R \rangle_{\text{n}} = 300$ mg/cm^2 (larger than 85% of predicted values) have been demonstrated in the cryogenic implosion with V_{imp} approaching 3×10^7 cm/s and peak laser intensities of 8×10^{14} W/cm^2. Scaled to the laser energies available at the National Ignition Facility, implosions hydrodynamically equivalent to these OMEGA designs are predicted to achieve $\langle \rho R \rangle_{\text{n}} = 1.2$ g/cm^2, sufficient for ignition demonstration in direct-drive ICF experiments.

A study of the effect of medium-*Z* doping of plastic ablators on laser imprinting and Rayleigh–Taylor instability growth in direct-drive implosions on the OMEGA Laser System is presented (p. 103). The targets were spherical plastic (CH) shells that were volume doped with a varied concentration of Si (4.3% and 7.4%) and Ge (3.9%). The targets were imploded by 48 beams with a low-adiabat, triple-picket laser shape pulse with a peak intensity of 4×10^{14} W/cm^2 and x-ray radiographed through a 400-nm opening in the side of the target. The results show that volumetric impurity doping strongly reduces the shell's density modulation and instability growth rate. Simulations using the two-dimensional (2-D), radiation–hydrodynamics code *DRACO* show good agreement with the measurements.

A technique to measure a shell's trajectory in direct-drive inertial confinement fusion implosions is presented (p. 109). The x-ray self-emission of the target was measured with an x-ray framing camera. Optimized filtering limited the x-ray emission from the corona plasma, isolating a sharp intensity gradient to the ablation surface. This technique enables one to measure the radius of the imploding shell with an accuracy of better than 1 nm and to determine a 200-ps average velocity to better than 2%.

The results of collaborative (LLE, University of Bordeaux, France, CEA, CNRS, CELIA, MIT, and LLNL) OMEGA shock-ignition experiments that use a novel beam configuration with separate low-intensity compression beams and high-intensity spike beams are discussed (p. 113). Significant improvements in the performance of plastic-shell, D_2 implosions were observed with repointed beams. The analysis of the coupling of the high-intensity spike beam's energy into the imploding capsule indicates that absorbed hot-electron energy contributes to the coupling. The backscattering of the laser energy was measured to reach 36% at single-beam intensities of ~8×10^{15} W/cm^2. Hard x-ray measurements revealed a relatively low hot-electron temperature of ~30 keV independent of intensity and timing. At the highest intensity, stimulated Brillouin scattering occurs near and above the quarter-critical density and the two-plasmon–decay instability is suppressed.

Measurements of strong-shock generation in the presence of pre-plasmas with relevance to shock ignition are reported (p. 137). A planar target was irradiated with a laser pulse consisting of a pre-plasma–generating foot followed by a high-intensity spike, driving a strong shock into the target. The observed shock dynamics inferred from velocity interferometer for any reflector (VISAR) and streaked optical pyrometer (SOP) measurements are reproduced well using 2-D *DRACO* simulations, indicating that plastic-ablator shocks of up to 70-Mbar strength have been generated.

The first x-ray Thomson-scattering (XRTS) measurement of shock-compressed liquid deuterium performed at the Omega Laser Facility is reported (p. 143). The noncollective, spectrally resolved, inelastic XRTS employs 2.96-keV Cl Ly_α line emission. Microscopic property measurements of shocked deuterium show an inferred spatially averaged electron temperature of 8±5 eV, an electron density of 2.2×10^{23} cm^{-3}, and an ionization of 0.8 (–0.25, +0.15). Two-dimensional hydrodynamic simulations using equation-of-state models suited for the extreme parameters also occurring in ICF research and planetary interiors are consistent with the experimental results.

The measurement of magnetic fields induced by the Rayleigh–Taylor (RT) instability in planar plastic foil with ultrafast proton radiography is presented (p. 159). Thin plastic foils were irradiated with ~4-kJ, 2.5-ns laser pulses focused to an intensity of $\sim 10^{14}$ W/cm^2. Target modulations were seeded by laser nonuniformities and amplified during target acceleration by the RT instability. The experimental data show the hydrodynamic evolution of the target and the generated MG-level magnetic fields in the broken foil, which are in good agreement with predictions from 2-D magneto-hydrodynamic simulations.

The two-plasmon–decay common-wave process has been demonstrated at the Omega Laser Facility (p. 172). The total energy in hot electrons produced in a planar target is measured to be the same when using one or two laser beams and significantly reduced with four beams for a constant overlapped intensity. This is caused by multiple beams sharing the same common electron plasma wave in the two-plasmon–decay (TPD) instability. A model, consistent with the experimental results, predicts that multiple laser beams can only drive a resonant common TPD electron plasma wave in the region of wave numbers bisecting the beams. In this region, the gain is proportional to the overlapped laser-beam intensity.

The current understanding of multibeam laser–plasma instabilities including CBET and TPD for direct-drive ignition is reviewed (p. 181). CBET is driven by multiple laser beams and can significantly reduce the hydrodynamic efficiency in direct-drive experiments on OMEGA. Reducing the radii of the laser beams significantly increases the hydrodynamic efficiency at the cost of an increase in low-mode nonuniformities. The combination of zooming and dynamic bandwidth reduction will provide a 30%-effective increase in the drive energy on OMEGA direct-drive implosions. TPD instability can also be driven by multiple laser beams. Both planar and spherical experiments were performed to study the hot electrons generated by TPD at the Omega Laser Facility. The fraction of laser energy converted to hot electrons scales with the hot-electron temperature for all geometries and over a wide range of intensities. At ignition-relevant intensities, the fraction of laser energy converted to hot electrons is measured to decrease by an order of magnitude when the ablator material is changed from carbon–hydrogen to aluminum. The TPD results are compared with a multibeam linear theory and a nonlinear Zakharov model.

We report on investigations of stress-radiation–induced swelling in plastic capsules (p. 191). The process of filling targets with DT for cryogenic experiments on the OMEGA laser induces small-scale features on the inner surface of the plastic capsules. Each feature was a cluster of low-level domes (<0.1 nm high) with individual lateral dimensions smaller than 5 nm that collectively covered lateral dimensions of up to 300 nm^2. These features were observed only when a high-radiation dose was combined with high stress in the plastic wall, as occurs when the capsules are permeation filled and transferred at cryogenic temperatures. No porosity or void structure was observed in or below these domes. It is speculated that the domes' swelling is caused by a radiation-induced bond scission and chemical restructuring that reduces the plastic density in localized regions.

Measurements carried out as a collaboration among scientists from LLE, MIT, and General Atomics (GA) of energetic protons in cone-in-shell fast-ignitor experiments on OMEGA are presented (p. 204). In these experiments, charged-particle spectrometers were used to measure a significant population ($>10^{13}$) of energetic protons (7.5 MeV maximum), indicating the presence of strong electric fields. These energetic protons, observed in directions both transverse and forward relative to the direction of the short-pulse laser beam, have been used to study aspects of coupling efficiency of the fast ignitor. Forward-going protons were less energetic and showed no dependence on laser intensity or whether the cone tip was intact when the short-pulse laser was fired. Maximum proton energies transverse to the cone-in-shell target scale with incident on-target laser intensity (2 to 6×10^{18} W/cm^2), as described by the ponderomotive scaling ($\sim I^{1/2}$). It is shown that these protons are accelerated from the entire cone surface, possibly due to return currents, rather than from the cone tip alone. The proton-inferred lower bound on the hot-electron temperature was hotter than the ponderomotive scaling by a factor of 2 to 3.

2. Theoretical Design and Analysis

A description of low-adiabat, cryogenic deuterium–tritium, and warm-plastic-shell polar-drive (PD)–implosion designs for the OMEGA laser begins on p. 57. The designs are at two different on-target laser intensities, each at a different in-flight aspect ratio (IFAR). The first design permits one to study implosion energetics and target performance closer to ignition-relevant intensities (7×10^{14} W/cm^2 at the quarter-critical surface), where nonlocal heat conduction and laser–plasma interactions can play an important role, but at lower values of IFAR (~22). The second design permits one to study implosion energetics and target performance at a lower intensity (3×10^{14} W/cm^2) but at higher IFAR (~32), where the shell instability can play an important role. The higher-IFAR designs are accessible on the existing OMEGA Laser System, only at lower intensities. Implosions at ignition-relevant intensities can be obtained only by reducing target radius, although only at smaller values of IFAR. Polar-drive geometry requires that the laser beams be repointed to improve shell symmetry. The higher-intensity designs optimize target performance by repointing beams to a lesser extent and compensate for the reduced equatorial drive by increasing beam energies for the repointed beams and using custom beam profiles that improve equatorial illumination at the expense of irradiation at higher latitudes. These designs will be studied when new phase plates for OMEGA, corresponding to the smaller target radii and custom beam profiles, are obtained. Implosion results from the combined set of high-intensity and high-IFAR implosions should yield valuable data to validate models of laser-energy deposition, heat conduction, nonuniformity growth, and fuel assembly in PD geometry.

3. Diagnostics

We report on the design and implementation of a narrow-band x-ray imager for a Cu K_α line at ~8 keV using a spherically bent quartz crystal for the OMEGA EP laser (p. 34). The quartz crystal is cut along the 2131 (211) planes for a 2*d* spacing of 0.3082 nm, resulting in a Bragg angle of 88.7°, very close to normal incidence. An optical system is used to remotely align the spherical crystal without breaking the vacuum of the target chamber. The images show a high signal-to-background ratio of typically >100:1 with laser energies ≥1 kJ at a 10-ps pulse duration and a spatial resolution of less than 10 nm.

A single-shot, electro-optic data-acquisition system with a 600:1 dynamic range for the NIF Dante instrument has been demonstrated (p. 129). The prototype system uses multiple optical wavelengths to allow for the multiplexing of up to eight signals onto one photodetector and provides optical isolation and a bandwidth of 6 GHz.

The high-resolution spectroscopy used to measure ICF neutron spectra to infer the areal density (ρR) of cryogenic DT implosions on OMEGA is described in detail in an article starting on p. 165. Neutron time-of-flight (nTOF) techniques are used to measure the spectrum of neutrons that elastically scatter off the dense deuterium (D) and tritium (T) fuel. High signal-to-background data have been recorded on cryogenic DT implosions using a well-collimated 13.4-m line of sight and an nTOF detector with an advanced liquid scintillator compound. An innovative method to analyze the elastically scattered neutron spectra was developed using well-known cross sections of the DT nuclear reactions. The measured areal densities are consistent with alternative ρR measurements and 1-D simulations.

A reflective optical transport system has been built for ultraviolet Thomson scattering from electron plasma waves on OMEGA (p. 178). A Schwarzschild objective that uses two concentric spherical mirrors coupled to a Pfund objective provides diffraction-limited imaging across all reflected wavelengths. This enables the operator to perform Thomson-scattering measurements of ultraviolet (0.263-μm) light scattered from electron plasma waves.

Lasers, Optical Materials, and Advanced Technology

The design of an ultra-intense optical parametric chirped-pulse–amplification (OPCPA) system at 910 nm is presented in an article starting on p. 30. Technologies are being developed for large-scale systems based on deuterated potassium dihydrogen phosphate (DKDP) optical parametric amplifiers that could be pumped by kilojoule-class Nd:glass lasers such as OMEGA EP. Results from a prototype white-light–seeded chain of noncollinear optical parametric amplifiers (NOPA's) are reviewed. The development of a cylindrical Öffner stretcher that has advantages over standard stretchers for ultra-intense, high-contrast systems is described. Development of the laser's front end will result in the demonstration of a mid-scale optical parametric amplifier line (OPAL) that will use scalable technologies to produce 7.5-J, 15-fs pulses with a temporal contrast exceeding 10^{10}.

A new operation regime of NbN superconducting single-photon detectors (SSPD's) by integrating them with a low-noise, cryogenic, high-electron-mobility transistor and a high-load resistor is proposed (p. 39). The new SSPD operating scheme makes it possible to distinguish dark pulses from actual photon pulses in SSPD's and therefore gain a better understanding of the origin of dark counts generated by the detector. A statistical analysis of amplitude distributions of recorded trains of the SSPD photoresponse transients is used to obtain information on the spectral characteristics of incident photons and demonstrates that meander-type SSPD's exhibit some photon-number–resolving capability.

A low-temperature chemical cleaning approach has been developed (p. 149) to remove manufacturing residue from multilayer dielectric (MLD) pulse-compressor gratings to be used in the OMEGA EP Laser System. The method strips baked-on photoresist, metal contaminants, and debris without damaging the grating's delicate surface structure. Because targeted cleaning steps remove specific families of contaminants (heavy organics, light organics, metals, and oxides), the process can be adjusted to strip known quantities and types of material. After cleaning, grating samples showed excellent performance in short-pulse (10-ps) laser-damage testing at 1054 nm. Average in-air damage thresholds were 4.06±0.19 J/cm^2 and 3.32±0.22 J/cm^2 (beam normal) in the 1-on-1 and *N*-on-1 regimes, respectively, for a set of nine gratings cleaned at processing temperatures in the range of 40°C to 70°C. Post-cleaning diffraction efficiencies were consistently above 96%.

National Laser Users' Facility and External Users' Programs

Under the facility governance plan that was implemented in FY08 to formalize the scheduling of the Omega Laser Facility as an NNSA User Facility, Omega Facility shots are allocated by campaign. The majority (67.6%) of the FY12 target shots were allocated to the National Ignition Campaign (NIC) conducted by integrated teams from the national laboratories and LLE and to the high-energy-density campaigns conducted by teams led by scientists from the national laboratories. Nearly 29% of the facility shots in FY12 were allocated to basic science experiments. Half of these were dedicated to university basic science under the National Laser Users' Facility (NLUF) Program, and the remaining shots were allotted to the Laboratory Basic Science (LBS) Program, comprising peer-reviewed basic science experiments conducted by the national laboratories and by LLE including the Fusion Science Center (FSC). The Omega Facility is also being used for several campaigns by teams from the Commissariat à l'Énergie Atomique (CEA) of France and the Atomic Weapons Establishment (AWE) of the United Kingdom. These programs are conducted on the facility on the basis of special agreements put in place by the DOE/NNSA and the participating institutions.

During FY12 the facility users included 11 collaborative teams participating in the NLUF Program; 12 teams led by LLNL and LLE scientists participating in the LBS Program; many collaborative teams from the national laboratories conducting experiments for the NIC; investigators from LLNL and LANL conducting experiments for high-energy-density–physics programs; scientists and engineers from CEA, AWE, and the Center for Radiative Shock Hydrodynamics (CRASH) of the University of Michigan.

1. NLUF Programs

In FY12, the Department of Energy (DOE) issued a solicitation for NLUF grants for the period FY13–FY14. A record of 23 proposals were submitted to DOE for the NLUF FY13–FY14 program. These proposals requested a total of ~62 shot days of Omega Facility time in each of the two fiscal years. An independent DOE Technical Evaluation Panel reviewed the proposals on 11 July 2012 and recommended that 11 proposals receive DOE funding and 28 days of shot time on OMEGA in both FY13 and FY14. Table I lists the successful NLUF proposals for FY13–FY14. FY12 was the second of a two-year period of performance for the NLUF projects approved for the FY11–FY12 funding and OMEGA shots. Eleven NLUF projects were allotted Omega Laser Facility shot time and conducted a total of 277 target shots on the facility. The work of the NLUF programs in FY12 is summarized beginning on p. 224.

2. Laboratory Basic Science Program (LBS)

In FY12, LLE issued a solicitation for LBS proposals to be conducted in FY13. A total of 32 proposals were submitted with requests for a total of 68 shot days of Omega Facility time in FY13 for these proposed experiments. An independent review committee reviewed the proposals and recommended that 16 proposals receive 28 shot days at the Omega Laser Facility in FY13. Table II lists the successful LBS proposals. Fifteen LBS projects were allotted Omega Facility shot time and conducted a total of 273 target shots at the facility in FY12. This work is summarized beginning on p. 244.

3. FY12 LLNL Omega Facility Programs

In FY12, LLNL conducted several campaigns on the OMEGA and OMEGA EP Laser Systems, as well as campaigns that used the OMEGA and OMEGA EP beams jointly. Overall, LLNL led 335 target shots involving OMEGA and 121 target shots involving OMEGA EP. Approximately 38% of the total number of shots (124 OMEGA shots and 39 OMEGA EP shots) supported the NIC. The remaining 211 OMEGA shots and 82 OMEGA EP shots were dedicated to experiments for HED physics.

Table I: NLUF proposals approved for shots at the Omega Laser Facility for FY13–FY14.

Principal Investigator	Institution	Project Title
F. N. Beg	University of California, San Diego	Systematic Study of Fast-Electron Energy Deposition in Imploded Plasmas with Enhanced OMEGA EP Laser Contrast and Intensity
R. P. Drake	University of Michigan	Experimental Astrophysics on the OMEGA Laser
T. Duffy	Princeton University	Dynamic Compression of Earth and Planetary Materials Using OMEGA
W. Fox	University of New Hampshire	Dynamics and Instabilities of Magnetic Reconnection Current Sheets in High-Energy-Density Plasmas
P. Hartigan	Rice University	Astrophysical Dynamics in the Laboratory: Mach Stems and Magnetized Shocks
R. Jeanloz	University of California, Berkeley	Journey to the Center of Jupiter, Recreating Jupiter's Core on OMEGA
H. Ji	Princeton University	Study of Particle Acceleration and Fine-Scale Structures of Collisionless Magnetic Reconnection Driven by High-Energy Petawatt Lasers
B. Qiao	University of California, San Diego	Dynamics of High-Energy Proton Beam Focusing and Transition into Solid Targets of Different Materials
R. D. Petrasso	Massachusetts Institute of Technology	Studies of Laboratory Astrophysics, Inertial Confinement Fusion, and High-Energy-Density Physics with Nuclear Diagnostics
A. Spitkovsky	Princeton University	Generation of Collisionless Shocks in Laser-Produced Plasmas
R. B. Stephens	General Atomics	Investigation of the Dependence of Fast-Electron Generation and Transport on Laser Pulse Length and Plasma Materials

The objectives of the LLNL-led NIC campaigns conducted on the Omega Facility included the following:

- *Thermal Conductivity Study of CH/Be and CH/D_2 Interfaces by Refraction-Enhanced X-Ray Radiography*
- *High-Resolution Measurements of Velocity Nonuniformities Created by Microscopic Perturbations in NIF Ablator Materials*
- *Measuring the Adiabatic Index of Polystyrene Using Counter-Propagating Shocks and X-Ray Thomson Scattering*
- *Ablator Opacity Measurements*
- *Multipump Stimulated Raman Scattering*
- *Comparison of Plastic and High-Density Carbon Ablator Performance*
- *Shock Release of ICF-Relevant Materials*

The LLNL-led HED campaigns included the following research:

1. *Material Dynamics and Equation of State*
   a. *Tantalum Rayleigh–Taylor Experiments*
   b. *Iron Rayleigh–Taylor Experiments*
   c. *Double-Pulse Radiography Development*
   d. *Diffraction Studies on Shocked Tantalum*
   e. *Ta X-Ray Diffraction*
   f. *Hydrogen Equation of State*
   g. *XAFS Study of Ramp-Compressed Fe, Ta, and Mo*
   h. *Tin Melt*
   i. *Gigabar Equation of State*
   j. *Equation of State for Foams Using OMEGA EP*
   k. *Advanced X-Ray Diffraction Techniques*

2. *Radiation Transport*
   a. *Heated Wall*
   b. *Crystal Window*

3. *High-Temperature Plasma Opacity*
   a. *High-Temperature Plasma Opacity Experiments on OMEGA and OMEGA EP*

4. *Burn Physics*
   a. *Non-LTE Transport and Nuclear Lifetimes*

Table II: Approved FY13 LBS proposals.

Principal Investigator	Affiliation	Project Title
P. M. Celliers	LLNL	Equation of State and Optical Properties of Dense Silica: Shock Study of Coesite and Stishovite
H. Chen	LLNL	Exploring Pair Plasma and Their Applications Using OMEGA EP
J. R. Davies	LLE	Fast-Electron Control with Magnetic Field in Hohlraum
J. H. Eggert	LLNL	HED Condensed Matter: Magnesium and Aluminum
G. Fiksel	LLE	Magnetic Reconnection and Particle Energization in High-Energy-Density Plasmas in the Presence of an External Magnetic Field
G. Fiksel	LLE	Magnetized ICF Implosions on OMEGA
R. F. Heeter	LLNL	"Gattling Gun" Long-Duration Radiation Sources on OMEGA EP for Sustained-Drive Hydrodynamics and Low-Density Atomic Physics Applications on OMEGA EP and the NIF
B. R. Maddox	LLNL	Direct Measurements of Dislocation-Based Plastic Flow in Quasi-Isentropically Compressed bcc Metals
H.-S. Park	LLNL	Astrophysical Collisionless Shock Generation by Laser-Driven Experiments
P. K. Patel	LLNL	Areal-Density Measurements of Cone-in-Shell Implosions Using Compton Radiography for Fast Ignition
Y. Ping	LLNL	Long-Term Dynamics of Hole Boring and Target Heating at Fast-Ignition-Relevant Conditions
S. P. Regan	LLE	Collective X-Ray Scattering from Shocked Liquid Deuterium
J. R. Rygg	LLNL	Extreme Chemistry, Equation of State, and Optical Properties of Dense Water at Terapascal Pressure
A. A. Solodov	LLE	Fast-Ignition Integrated Experiments with Low-*Z* Cone-Tip Targets
C. Stoeckl	LLNL	Spectroscopy of Neutrons Generated Through Nuclear Reactions with Light Ions in Short-Pulse Laser-Interaction Experiments
W. Theobald	LLE	Laser Channeling in Long-Scale-Length, Overdense Plasmas

5. *Hydrodynamics*
   a. *Short-Pulse, UV Backlighting Development for the NIF*

6. *X-Ray Source Development and Application*
   a. *X-Ray Source Development with Nanostructured Materials*
   b. *Solar Cell Electrostatic Discharge*

4. FY12 LANL OMEGA Facility Programs

In FY12, Los Alamos National Laboratory (LANL) executed 244 total shots on OMEGA. LANL experiments contributed to the National Ignition campaign (NIC) in the following ways:

- *Measured the x-ray ablative Richtmyer–Meshkov growth of isolated defects on plastic ablators*
- *Studied branching ratios in DT fusion plasmas*
- *Continued neutron imaging and radchem scintillator development for the NIF*

High-energy-density (HED) campaigns included the following:

- *Studies of shear in a counter-propagating flow geometry and reshock-driven turbulent mixing*
- *Backlit defect implosion experiments to study effect of trench defect and polar direct drive*
- *Measurements of the effect of capsule asymmetries on neutron yield and ion temperature*
- *Imaging x-ray Thomson scattering platform development for dense plasmas and warm-dense-matter equation of state*
- *Measurement of a supersonic radiation wave and foam aerogel EOS*

OMEGA Laser Facility Users Group (OLUG)

A capacity gathering of 115 researchers from over 25 universities and laboratories and 9 countries met at the Laboratory for Laser Energetics (LLE) for the Fourth Omega Laser Facility

Users Group (OLUG) Workshop in April 2012. The purpose of the 2.5-day workshop was to facilitate communications and exchanges among individual Omega users and between users and the LLE management; to present ongoing and proposed research; to encourage research opportunities and collaborations that could be undertaken at the Omega Laser Facility and in a complementary fashion at other facilities [such as the National Ignition Facility (NIF) or the Laboratoire pour l'Utilisation des Lasers Intenses (LULI)]; to provide an opportunity for students, postdoctoral fellows, and young researchers to present their research in an informal setting; and to provide feedback to LLE management from the users about ways to improve the facility and future experimental campaigns.

The interactions were wide ranging and lively, as illustrated in the workshop report (p. 213). OLUG consists of 304 members from 33 universities and 25 centers and national laboratories; their names and affiliations can be found at www.lle.rochester.edu/media/about/docu-ments/OLUGMEMBERS.pdf. OLUG is by far the largest users group in the world in the field of high-energy-density (HED) physics and certainly one of the most active. During the first two mornings of the workshop, seven science and facility talks were presented. The facility talks proved especially useful for those not familiar with the art and complexities of performing experiments at the Omega Facility. But since the facility is constantly changing and improving, even experienced users significantly benefited from these updates.

The overview science talks, given by leading world authorities, described the breadth and excitement of HED science undertaken at the Omega Laser Facility. Approximately 50 students and postdoctoral fellows participated in the workshop; 42 of these participants were supported by travel grants from the National Nuclear Security Administration (NNSA). The content of their presentations ranged from target fabrication to simulating aspects of supernovae; the presentations generated spirited discussions, probing questions, and friendly suggestions. In total, there were 75 contributed posters, including 11 that focused on the Omega Facility. The invited and facility presentations, as well as OLUG's Findings and Recommendations, can be found at www.lle.rochester.edu/about/omega_laser_users_group.php.

FY12 Omega Facility Report

During FY12, the Omega Facility conducted 1494 target shots on OMEGA and 426 target shots on OMEGA EP for a record total of 1920 target shots (see Tables 132.V and 132.VI). OMEGA averaged 11.2 target shots per operating day with availability and experimental effectiveness averages for FY12 of 94.2% and 96.7%, respectively. OMEGA EP was operated extensively in FY12 for a variety of internal and external users. A total of 356 target shots were taken into the OMEGA EP target chamber and 70 joint target shots into the OMEGA target chamber. OMEGA EP averaged 6.1 target shots per operating day with Availability and Experimental Effectiveness averages for FY12 of 88.0% and 95.5%, respectively. Highlights of achievements in FY12 are detailed starting on p. 221 and include the following:

- Multi-FM Beam Smoothing on OMEGA EP
- Equivalent-Target-Plane Diagnostics on OMEGA EP
- OMEGA EP Short-Pulse Contrast Improvement
- OMEGA EP Spatial Profile Improvements on Beamlines 3 and 4
- OMEGA Pulse-Shape-Measurement Capabilities
- 4ω Probe Laser System
- Thomson-Scattering Spectrometer System on OMEGA

1. Experimental Operations and Diagnostics

In FY12, 26 new target diagnostics were commissioned on OMEGA and 8 on OMEGA EP. These included a suite of TIM-based scattered-energy calorimeters, the SXS crystal spectrometer for x-ray streak cameras, the first of the new PJX-2 streak cameras, a new high-speed video target viewing system, and an additional x-ray pinhole camera. The streaked optical pyrometer diagnostic measures the time-resolved laser-driven shocks on OMEGA. This system has been upgraded with a ROSS streak camera system and improved optical relay for higher resolution in increased signal strength. As in previous years, many of the new instruments were developed by or in collaboration with other laboratories, including LLNL, LANL, CEA, and General Atomics. Experimental facility improvements included the introduction of an image plate scanning capability on OMEGA, the addition of a second image plate scanner on OMEGA EP, and the commissioning of a set of fully integrated TIM-based target positioning systems on both OMEGA and OMEGA EP. Two of the OMEGA TIM's were retrofit with new EMI-resistant, OMEGA EP–type control systems, and updated TIM vacuum system operating software was installed on both OMEGA and OMEGA EP.

Education

As the only major university participant in the National ICF Program, education continues to be an important mission for the Laboratory. Laboratory education programs span the range of high school (p. 219) to graduate education.

1. High School Program

During the summer of 2012, 16 students from Rochester-area high schools participated in the Laboratory for Laser Energetics' Summer High School Research Program. The goal of this program is to excite a group of high school students about careers in the areas of science and technology by exposing them to research in a state-of-the-art environment. Too often, students are exposed to "research" only through classroom laboratories, which have prescribed procedures and predictable results. In LLE's summer program, the students experience many of the trials, tribulations, and rewards of scientific research. By participating in research in a real environment, the students often become more excited about careers in science and technology. In addition, LLE gains from the contributions of the many highly talented students who are attracted to the program. The students spent most of their time working on their individual research projects with members of LLE's technical staff. The projects were related to current research activities at LLE and covered a broad range of areas of interest including experimental concept development and diagnostics modeling, computational modeling of implosion physics, materials science, laser system development and diagnostics, isotope separation, and database development (see Table 132.IV).

Two-hundred and ninety-seven high school students have now participated in the program since it began in 1989. Thirty of the participating students have gone on to gain semi-finalist status at the Intel Science Talent Search national competition and four of the students have gained finalist status at this competition.

At a symposium conducted at the end of the summer program, LLE presented its 16th annual William D. Ryan Inspirational Teacher Award to Ms. Sage Miller, a mathematics and computer science teacher at Webster Schroeder and Webster Thomas High Schools. This award is presented to a teacher who motivated one of the participants in LLE's Summer High School Research Program to study science, mathematics, or technology and includes a $1000 cash prize. Teachers are nominated by alumni of the summer program. Ms. Miller was nominated by Troy Thomas and Avery Gnolek, participants in the 2011 program, both of whom credit her for their decisions to major in computer science.

2. Undergraduate Students Program

Forty-two undergraduate students participated in work or research projects at LLE this past year. Student projects include operational maintenance of the Omega Laser Facility; work in laser development, materials, and optical-thin-film-coating laboratories; computer programming; image processing; and diagnostics 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.

3. Graduate Student Programs

Graduate students are using the OMEGA Facility as well as other LLE facilities for fusion and HED physics research and technology development activities. These students are making significant contributions to LLE's research program. Twenty-six faculty from five University academic departments collaborate with LLE scientists and engineers. Presently, 74 graduate students are involved in research projects at LLE, and LLE directly sponsors 38 students pursuing Ph.D. degrees via the NNSA-supported Frank Horton Fellowship Program in Laser Energetics. Their research includes theoretical and experimental plasma physics, HED physics, x-ray and atomic physics, nuclear fusion, ultrafast optoelectronics, high-power-laser development and applications, nonlinear optics, optical materials and optical fabrication technology, and target fabrication. 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 6 graduate students, 25 to 30 undergraduate students, and 10 faculty members.

Over 300 graduate students have now conducted their graduate research work at LLE since the graduate research program began at the Laboratory. In addition, one-hundred-twenty graduate students and post-graduate fellows from other universities have conducted research at the LLE laser facilities as part of the NLUF program. Some 29 graduate students and 29 undergraduate students were involved in research on the Omega Facility as part of NLUF teams in FY12.

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