Executive Summary

The fiscal year ending September 2015 (FY15) concluded the first 30 months of the fourth five-year renewal of Cooperative Agreement DE-NA0001944 with the U.S. Department of Energy (DOE). This annual report summarizes work carried out under the Cooperative Agreement at the Laboratory for Laser Energetics (LLE) during the past fiscal year including work on the Inertial Confinement Fusion (ICF) Campaign; laser, optical materials, and advanced technology development; operation of the Omega Laser Facility for the ICF and High-Energy-Density (HED) Campaigns, the National Laser Users' Facility (NLUF), the Laboratory Basic Science (LBS) Program, and other external users; and programs focusing on the education of high school, undergraduate, and graduate students during the year.

Inertial Confinement Fusion Research

One of LLE's principal missions is to conduct research in ICF with particular emphasis on supporting the goal of achieving ignition at the National Ignition Facility (NIF). This program uses the Omega Laser Facility and the full experimental, theoretical, and engineering resources of the Laboratory. During FY15, a record 2116 target shots were taken at the Omega Laser Facility (comprised of the 60-beam OMEGA UV laser and the four-beam, high-energy petawatt OMEGA EP laser). Nearly 42% of the facility's FY15 target shots were designated as ICF experiments or experiments in support of ICF. The OMEGA and OMEGA EP lasers attained an average experimental effectiveness of 94.5% and 95.5%, respectively, in FY15. LLE plays a lead role in validating 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 that support the demonstration of indirect-drive ignition on the NIF and is the lead laboratory for the validation of the polar-direct-drive (PDD) approach to ignition on the NIF. LLE has also developed, tested, and constructed a number of diagnostics currently being used at both the Omega Laser Facility and on the NIF. During this past year, progress in the inertial fusion research program continued in three principal areas: ICF experiments and experiments in support of ICF; theoretical analysis and design efforts aimed at improving direct-drive–ignition capsule designs (including polar-direct-drive–ignition designs) and advanced ignition concepts such as shock ignition and fast ignition; and development of diagnostics for experiments on the NIF, OMEGA, and OMEGA EP.

1. Inertial Confinement Fusion Experiments in FY15

The article starting on p. 1 reports on the use of a 263-nm Thomson-scattering beam to directly probe common two-plasmon–decay (TPD) electron plasma waves (EPW's) driven by between two and five 351-nm laser beams. When probing quarter-critical densities $\left(n_{\mathrm{c}}/4\right)$ for 351-nm light, a narrow high-intensity scattering feature was observed at a wavelength consistent with the maximum growth rate given by the linear TPD theory. Electron plasma waves corresponding to the Langmuir decay of backscattered TPD EPW's were observed, suggesting the Langmuir decay instability as a TPD saturation mechanism. Simulated Thomson-scattering spectra from three-dimensional (3-D) numerical solutions of the extended Zakharov equations of TPD are in excellent agreement with the experimental spectra and verify the presence of the Langmuir-decay instability.

Measurements of the conduction zone length (110$\pm$20 μm at t = 2.8 ns), the averaged mass ablation rate of the CD (7.95$\pm$0.3 μg/ns), shell trajectory, and laser absorption are used to quantify the electron thermal transport through the conduction zone in direct-drive cryogenic implosions (p. 7). Hydrodynamic simulations that use nonlocal thermal transport and cross-beam energy transfer models reproduce these experimental observables. Hydrodynamic simulations that use a time-dependent flux-limited model reproduce the measured shell trajectory and the laser absorption, but they overestimate the mass ablation rate by ~10% and underestimate the length of the conduction zone by nearly a factor of 2.

A concept to support direct-drive inertial confinement fusion experiments on the NIF in its indirect-drive beam configuration—polar direct drive—has been proposed (p. 13). Ignition in PDD geometry requires direct-drive–specific beam smoothing, phase plates, and repointing the NIF beams toward the equator to ensure symmetric target irradiation. The first experiments to study the energetics and preheat in PDD implosions utilize the NIF in its current configuration, including beam geometry, phase plates, and beam smoothing. Results from these initial experiments are presented, including measurements of shell trajectory, implosion symmetry, and the level of hot-electron preheat in plastic and Si ablators. Experiments are simulated with the 2-D hydrodynamics code *DRACO,* including a full 3-D ray trace to model oblique beams and models for nonlocal electron transport and cross-beam energy transport (CBET).

Recent experiments carried out on the OMEGA laser to produce strong shocks in solid spherical targets with direct laser illumination are reported (p. 48). The shocks are launched at pressures of several hundred Mbars and reach Gbar pressures upon convergence. The results are relevant to validate the shock-ignition scheme and to develop an OMEGA experimental platform to study material properties at Gbar pressures. The experiments investigate the strength of the ablation pressure and the hot-electron production at incident laser intensities of ~2 to 6×10^{15} W/cm^2 and demonstrate ablation pressures exceeding 300 Mbar, which is crucial to developing a shock-ignition target design for the National Ignition Facility.

Studies of the migration of tritium to the surfaces of aluminum 6061; oxygen-free, high-conductivity copper; and stainless-steel 316 from the bulk metal using low-pressure Tonks–Langmuir argon plasma are reported (p. 62). The plasma is shown to be effective at removing tritium from metal surfaces in a controlled manner. Tritium is removed in decreasing quantities with successive plasma exposures, which suggests a depletion of the surface and near-surface tritium inventories. A diffusion model was developed to predict tritium migration from the bulk and its accumulation in the water layers present on the metal surface. This model reproduces the rate of tritium regrowth on the surface for all three metals and can be used to calculate the triton solubility in the water layers present on metal surfaces. The ratio of surface to bulk solubilities at the water layer/bulk metal interface uniquely determines the concentration ratio between these two media. Removing the tritium-rich water layers induces tritium to migrate from the bulk to the surface. This process is driven by a concentration gradient that develops in the bulk because of the perturbation on the surface.

The article beginning on p. 171 reports on LLE's newly commissioned hydrogen Isotope Separation System (ISS). The ISS uses two columns—palladium on kieselguhr and a cold molecular sieve—that act in a complementary manner to separate the hydrogen species by mass. The 4-sL/day–throughput ISS yields tritium purities exceeding 99.9%. Outfitting LLE with ISS expands the Laboratory's capabilities to explore fusion-reaction physics over a very broad range of deuterium–tritium ratios in a controlled manner.

Interferometric strain measurements with a fiber-optic probe are presented (p. 195). Experience at LLE has shown that broadband-based vibrations make it difficult to position cryogenic inertial confinement fusion targets. These effects must be mitigated for NIF-scale targets; to this end an active vibration stabilization system was proposed. A single-mode optical-fiber strain probe and a novel fiber-contained heterodyne interferometer have been developed as a position feedback sensor for the vibration control system. A resolution limit of 54.5 nϵ is measured with the optical-strain gauge, limited by the lock-in amplifier. Experimental measurements of the sensor showing good agreement with reference resistive-strain-gauge measurements are presented.

2. Theoretical Design and Analysis

The comprehensive knowledge of the properties of high-energy-density plasmas crucial to understanding and designing low-adiabat ICF implosions through hydrodynamic simulations is discussed (p. 29). The warm-dense-matter (WDM) properties used in hydrocodes of deuterium–tritium (DT) mixtures and ablator materials, such as the equation of state (EOS), thermal conductivity, opacity, and stopping power, were usually estimated by models where many-body and quantum effects were approximately taken into account in the WDM regime. To examine the accuracy of these models, the static, transport, and optical properties of warm dense DT plasmas were systematically calculated using first-principles (FP) methods over a wide range of densities and temperatures that cover the ICF "path" to ignition. This research shows that the lower the adiabat of DT capsules, the more variations in hydro simulations. The FP-based properties of DT are essential to designing ICF ignition targets. Future work on FP studies of ICF ablator materials is discussed.

The article beginning on p. 77 reports on efforts to estimate the level of alpha heating and determine the onset of the burning-plasma regime, which are essential to finding the path toward thermonuclear ignition. Using a simple model of the implosion, it is shown that a general relation can be derived connecting the burning-plasma regime to the yield enhancement caused by alpha heating and experimentally measurable parameters such as the fractional alpha energy or, equivalently, the Lawson ignition parameter. A general alpha-heating curve is found, independent of the target and suitable to assess the performance of all laser-fusion experiments whether direct or indirect drive. The onset of the burning-plasma regime inside the hot spot of current implosions on the NIF requires a fusion yield of ~50 kJ.

The efforts to obtain an accurate EOS of polystyrene (CH), which is required to design reliable ICF capsules using CH/CH–based ablators, are described beginning on p. 117. With first-principles calculations, the EOS of CH was extended over a wide range of plasma conditions (ρ = 0.1 to 100 g/cm^3 and T = 1000 to 4,000,000 K). When compared with the widely used *SESAME* EOS table, the first-principles equation of state (FPEOS) of CH is significantly different in the low-temperature regime, in which strong coupling and electron degeneracy play an essential role in determining plasma properties. Hydrodynamic simulations of cryogenic target implosions on OMEGA using the FPEOS table of CH have predicted an ~5% reduction in implosion velocity and an ~30% decrease in neutron yield compared to the usual *SESAME* simulations. This is attributed to the ~10%-lower mass ablation rate of CH predicted by the FPEOS. Simulations using the FPEOS of CH show better agreement with measurements of Hugoniot temperature and scattered light from ICF implosions.

We report on investigations of the hydrodynamic scaling of the deceleration phase of direct-drive inertial fusion implosions for OMEGA and equivalent NIF–size targets (p. 125). It is shown that the deceleration-phase Rayleigh–Taylor instability (RTI) does not scale hydro-equivalently with implosion size. This is because ablative stabilization resulting from thermal conduction and radiation transport in a spherically converging geometry is different on the two scales: NIF-scale implosions show lower hot-spot mass ablation velocity, allowing for higher RTI growth, whereas stabilization resulting from density-gradient enhancement, caused by reabsorption of radiation emitted from the hot spot, is higher on NIF implosions. Since the RTI mitigation related to thermal conduction and radiation transport show opposite trends with the scaling, the effective degradation of implosion performance caused by the deceleration RTI is similar for OMEGA and equivalent NIF targets. It is found that a minimum threshold for the no-α Lawson ignition parameter of $\chi_\Omega \approx 0.2$ at the OMEGA scale is required to demonstrate hydro-equivalent ignition at the NIF scale for symmetric direct-drive implosions.

3. Diagnostics

Measurements are presented of the ablation-front trajectory and low-mode nonuniformity in direct-drive implosions using x-ray self-emission shadowgraphy (p. 83). The shadowgraphy technique uses time-resolved images of soft x rays (>1 keV) emitted from the coronal plasma of the target imaged onto an x-ray framing camera to determine the position of the ablation front. Methods used to accurately measure the ablation-front radius ($\delta R = \pm 1.15$ μm), image-to-image timing [$\delta(\Delta t) = \pm 2.5$ ps], and absolute timing ($\delta t = \pm 10$ ps) are presented. Angularly averaging the images provides an average radius measurement of $\delta(R_{\mathrm{av}}) = \pm 0.15$ μm and an error in velocity of $\delta V/V = \pm 3\%$. This technique was applied at the Omega Laser Facility and the National Ignition Facility.

High-Energy-Density Science

The shock-wave equation of state was measured in fused silica up to 1600 GPa (p. 139). The properties of silica are important to geophysical and high-pressure equation-of-state research. The most-prevalent crystalline form, α-quartz, has been extensively studied to TPa pressures. Recent experiments with amorphous silica, commonly referred to as fused silica, have provided Hugoniot and reflectivity data up to 630 GPa using magnetically driven aluminum impactors. This article presents measurements of the fused-silica Hugoniot over a range from 200 to 1600 GPa using laser-driven shocks with an α-quartz standard. These data are in very good agreement with those obtained with a different driver and standard material. A new shock velocity/particle relation is derived to fit the experimental data.

Lasers, Optical Materials, and Advanced Technology

The mechanical characterization of optical oxide thin films was performed using nano-indentation (p. 91). The results are explained based on the deposition conditions used. These oxide films are generally deposited to have a porous microstructure that optimizes laser-induced–damage thresholds, but changes in deposition conditions lead to varying degrees of porosity, density, and possibly the microstructure of the thin film. This can directly explain the difference in the mechanical properties of the film studied here and those reported in the literature. Of the four single-layer thin films tested, alumina was observed to demonstrate the highest values of nano-indentation hardness and elastic modulus.

The work reported beginning on p. 97 investigated the thermal fluctuations in hybrid superconductor/ferromagnetic NbN/NiCu bilayers, as well as in pure superconducting NbN 2-D nanostripes, to understand the origin of dark counts in superconducting nanostripes when operated as single-photon detectors. In 2-D superconductors, the dynamics of vortex motion play a significant role in the formation of a transient normal state, leading to dark-count events in current-biased nanostripes. By introducing a weak ferromagnetic overlayer on top of pure NbN, the vortex dynamics were controlled, which subsequently made it possible to discriminate between several proposed theoretical models.

Beginning on p. 104, it was demonstrated both numerically and experimentally that a phase modulator, acting as a time lens in the Fourier-lens configuration, can induce spectral broadening, narrowing, or shifts depending on the phase of the modulator cycle. These spectral effects depend on the maximum phase shift that can be imposed by the modulator. Numerical simulations show that the pulse spectrum could be compressed by a factor of 8 for a 30-rad phase shift. Experimentally, spectral shifts over a 1.35-nm range and spectral narrowing and broadening by a factor of 2 were demonstrated using a lithium niobate phase modulator with a maximum phase shift of 16 rad at a 10-GHz modulation frequency. All spectral changes were accomplished without employing optical nonlinear effects such as self- or cross-phase modulation.

We show that the macrostructure of chemical-vapor–deposited (CVD) zinc sulfide (ZnS) substrates is characterized by cone-like structures that start growing at the early stages of deposition (p. 110). As deposition progresses, these cones grow larger and reach centimeter size in height and millimeter size in width. This article describes the magnetorheological finishing (MRF) process of polishing four CVD ZnS substrates, manufactured by four different vendors, with conventional magnetorheological (MR) fluid at pH 10 and zirconia-coated–CI (carbonyl iron) MR fluids at pH 4, 5, and 6. The surface-texture evolution of the substrates as they were MRF polished with the different fluids is reported. The performances of the zirconia-coated–CI MR fluid at pH 4 are shown to be significantly higher than that of the same fluid at pH levels of 5 and 6 and moderately higher than that of a conventional MR fluid at pH 10.

Temporal-contrast measurements of a white-light–seeded noncollinear optical parametric amplifier are reported (p. 145). Ultra-intense optical parametric chirped-pulse systems require front ends with broad bandwidth and high temporal contrast. Temporal cross-correlation measurements of a white-light–seeded noncollinear optical parametric amplifier (NOPA) show that its prepulse contrast exceeds the 120-dB dynamic range of the broadband NOPA-based cross-correlator.

Computational chemistry modeling and the design of photoswitchable alignment materials for optically addressable liquid crystal devices were investigated (p. 150). Photoalignment technology based on optically switchable "command surfaces" has been receiving increasing interest for liquid crystal optics and photonics device applications. Azobenzene compounds in the form of low-molar-mass, water-soluble salts deposited either directly onto the substrate surface or after dispersion in a polymer binder have been almost exclusively employed for these applications. Past research in this area followed an inefficient, mostly empirical materials design and development approach. Recent computational chemistry advances now afford unprecedented opportunities to develop efficient predictive capabilities that will lead to new photoswitchable alignment layer materials. In this article, computational methods based on the density functional theory and time-dependent density functional theory were employed to study the impact of molecular structure on optical switching properties in photoswitchable methacrylate and acrylamide polymers functionalized with azobenzene and spiropyran pendants. Using these new computational methods, materials can be efficiently designed with low switching energies, enhanced bistability, write/erase fatigue resistance, and high laser-damage thresholds.

Studies of the temporal analog of reflection and refraction of optical beams (p. 162) have shown numerically as well as analytically that when an optical pulse approaches a temporal boundary across which the refractive index changes, it undergoes a temporal equivalent of reflection and refraction of optical beams at a spatial boundary. The main difference is that the role of angles is played by changes in the frequency. The frequency dependence of the dispersion of the material in which the pulse is propagating plays a fundamental role in determining the frequency shifts experienced by the reflected and refracted pulses. The analytic expressions obtained for these frequency shifts are used to find the condition under which an analog of total internal reflection may occur at the temporal boundary.

Research on ultrahigh responsivity of optically active, semiconducting asymmetric nanochannel diodes (ANCD's) is discussed beginning on p. 167. The fabrication and optical characterization of novel semiconducting asymmetric nanochannel diodes are studied. It is demonstrated that ANCD's can be operated as very sensitive, single-photon–level, visible-light photodetectors. The test devices consisted of 1.5-μm-long, ~300-nm-wide channels that were etched in an InGaAs/InAlAs quantum-well heterostructure with a 2-D electron gas layer. The ANCD's I–V curves were collected by measuring the transport current both in the dark and under 800-nm-wavelength, continuous-wave–light laser illumination. In all of the devices studied, the impact of the light illumination was very clear and there was a substantial photocurrent, even for incident optical power as low as 1 nW. The magnitude of the optical responsivity in ANCD's with the conducting nanochannel increased linearly with a decrease in optical power over many orders of magnitude, reaching a value of almost 10,000 A/W at 1-nW excitation.

The single-shot high-resolution characterization of optical pulses by spectral phase diversity is discussed beginning on p. 177. The experimental trace is composed of the measured power of a plurality of ancillary optical pulses derived from the pulse under test by adding known amounts of chromatic dispersion. An assembly composed of splitters and dispersive delay fibers has been used to generate 64 ancillary pulses whose instantaneous power can be detected in a single shot. Pulse-shape reconstruction for pulses shorter than the photodetection impulse response has been demonstrated. The diagnostic is experimentally shown to accurately characterize pulses from a chirped-pulse–amplification system when its stretcher is detuned from the position for optimal recompression.

The magnetorheological (MR) finishing of single-crystal and chemical-vapor–deposited polycrystalline zinc sulfide (ZnS) via chemically and mechanically modified MR fluids has been investigated (p. 185). When polishing ZnS samples with pH 5 and pH 6 MR fluids, variations in the material removal rate (mrr) among the four single-crystal planes were found and surface artifacts were observed on the polycrystalline material. When polishing ZnS samples with the modified MR fluid at pH 4, however, minimal variation in mrr among the four orientations was observed and surface artifacts were reduced on the polycrystalline material.

Omega Laser Facility Users Group (OLUG)

The Seventh Omega Laser Facility Users Group (OLUG) Workshop, held on 22–24 April 2015, attracted 110 researchers (capacity limited) from around the world. OLUG consists of over 400 members from 55 universities and 35 research centers and national laboratories from 21 nations covering 4 continents.

The purpose of the 2.5-day workshop was to facilitate communications and exchanges among individual OMEGA users, and between users and 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 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 from the users to LLE management about ways to improve and keep the facility and future experimental campaigns at the cutting edge.

A total of 63 students and postdoctoral fellows, 46 of whom were supported by travel grants from the National Nuclear Security Administration (NNSA), participated in the workshop. The content of their presentations encompassed the spectrum from target fabrication to simulating aspects of supernovae; the presentations generated spirited discussions, probing questions, and friendly suggestions. In total, there were 70 contributed papers, most of which were presented by students.

An important function of the workshop was to develop a set of Findings and Recommendations to help set and define future priorities for the Omega Laser Facility. Detailed reporting on the workshop and the Findings and Recommendations may be found in an article beginning on p. 202.

Education

As the only major university participant in the National ICF Program, education continues as an important mission for LLE. The Laboratory's education programs cover the range from high school (p. 210) to graduate education.

1. High School Program

During the summer of 2015, 12 students from Rochester-area high schools participated in the Laboratory for Laser Energetics' Summer High School Research Program (p. 210). 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 laser physics, computational modeling of implosion physics, experimental diagnostic development, liquid crystal chemistry, ultra-intense laser–matter interactions, optical design, tritium capture and storage, and interactive data analysis (see Table 144.XI, p. 211).

Three hundred and fifty-two high school students have now participated in the program since it began in 1989. This year's students were selected from nearly 70 applicants.

2. Undergraduate Student Program

Forty-one 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 LLE.

3. Graduate Student Programs

Graduate students are using the Omega Laser 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 members from five University of Rochester academic departments collaborate with LLE scientists and engineers. In FY15, 60 graduate students were involved in research projects at LLE, and LLE directly sponsored 35 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 330 graduate students have now conducted their graduate research work at LLE since its graduate research program began. In addition, 120 graduate students and post-graduate fellows from other universities have conducted research at the Omega Laser Facility as part of the NLUF program. Over 60 graduate students and undergraduate students were involved in research at the Omega Laser Facility as members of participating NLUF teams in FY15.

FY15 Omega Laser Facility Operations

During FY15, the Omega Laser Facility conducted 1380 target shots on OMEGA and 736 target shots on OMEGA EP for a total of 2116 target shots (see Tables 144.XII and 144.XIII, p. 212). OMEGA averaged 11.5 target shots per operating day with Availability and Experimental Effectiveness averages for FY15 of 94.5% and 95.5%, respectively.

OMEGA EP was operated extensively in FY15 for a variety of internal and external users. A total of 736 target shots were taken in the OMEGA EP target chamber and 43 joint target shots were taken in the OMEGA target chamber. OMEGA EP averaged 7.8 target shots per operating day with Availability and Experimental Effectiveness averages for FY15 of 95.3% and 95.8%, respectively.

Per the guidance provided by DOE/NNSA, the facility provided target shots for the ICF, HED, NLUF, and LBS programs. The facility also provided a small number of shots for CEA and for the Defense Threat Reduction Agency (DTRA) (see Fig. 1). Nearly 69% of the target shots in FY15 were taken for the ICF and HED programs.

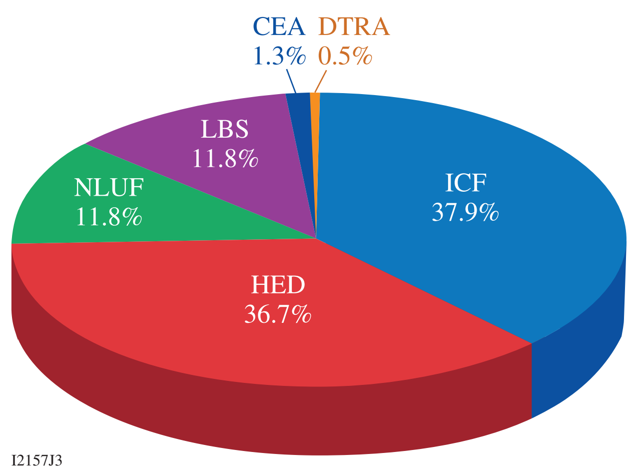

Figure 1
The distribution of non-maintenance Omega Laser Facility target shots by program in FY15.

Details of this work are contained in an article beginning on p. 212.

Highlights of the Omega Laser Facility activities in FY15 included the following:

- Cross-beam energy transfer mitigation
- SG5 phase-plate procurement
- Neutron timing diagnostic implementation on port P11

- Activation of OMEGA EP streaked optical pyrometer (SOP)
- Implementation of precision timing system
- LLNL/LLE study (using OMEGA EP) of multi-FM pulse propagation for the NIF
- OMEGA EP infrared transmission study
- Ultrafast temporal diagnostics study
- Implementation of an arbitrary waveform generator on the OMEGA backlighter driver
- Upgrade of FTS#1 target inserter
- Upgrade of the cryogenic cart viewing system

National Laser Users' Facility and External Users' Programs

Under the facility governance plan 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 of the FY15 target shots were allocated to the ICF Campaign conducted by integrated teams from Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Naval Research Laboratory (NRL), and LLE and the HED Campaigns conducted by teams led by scientists from the national laboratories, some with support from LLE.

The Fundamental Science Campaigns accounted for ~24% of the Omega Facility target shots taken in FY15 (Fig. 1). Nearly half of these were dedicated to university fundamental science under the NLUF Program, and the remaining shots were allotted to the LBS Program, comprising peer-reviewed fundamental science experiments conducted by the national laboratories and by LLE, including the Fusion Science Center (FSC).

The Omega Laser Facility was also used for several campaigns by teams from the Commissariat à l'énergie atomique et aux énergies (CEA) of France. These programs are conducted at the facility on the basis of special agreements put in place by DOE/NNSA and participating institutions.

The facility users during this year included 13 collaborative teams participating in the NLUF Program; 14 teams led by LLNL and LLE scientists participating in the LBS Program; many collaborative teams from the national laboratories conducting ICF experiments; investigators from LLNL and LANL conducting experiments for high-energy-density–physics programs; and scientists and engineers from CEA.

In an article beginning on p. 215 we review all the external user activity on OMEGA during FY15.

1. FY15 NLUF Program

FY15 was the first of a two-year period of performance for the NLUF projects approved for FY15–FY16 funding and Omega Laser Facility shot allocation. Thirteen NLUF projects (see Table 144.XIV, p. 216) were allotted Omega Laser Facility shot time and conducted a total of 234 target shots at the facility. The FY15 NLUF experiments are summarized in the section beginning on p. 215.

2. FY15 LBS Studies

In FY15, LLE issued a solicitation for LBS proposals to be conducted in FY16. A total of 23 proposals were submitted. An independent review committee reviewed and ranked the proposals; on the basis of these scores, 14 proposals were allocated 20 shot days at the Omega Laser Facility in FY16. The FY15 LBS experiments are summarized in the section beginning on p. 230. Table 144.XV (p. 231) lists the approved FY16 LBS proposals.

Fourteen approved LBS projects were allotted Omega Facility shot time and conducted a total of 235 target shots at the facility in FY15 (see Table 144.XVI, p. 232).

3. FY15 LLNL Experimental Programs at the Omega Laser Facility

In FY15, LLNL's HED Physics and Indirect-Drive Inertial Confinement Fusion (ICF-ID) Programs 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, these LLNL programs led 468 target shots in FY15, with 315 shots using only the OMEGA Laser System, 145 shots using only the OMEGA EP Laser System, and eight shots using OMEGA and OMEGA EP jointly. Approximately 25% of the total number of shots (56 OMEGA shots and 67 OMEGA EP shots, including the eight joint shots) supported the ICF-ID Campaign. The remaining 75% (267 OMEGA shots and 86 OMEGA EP shots) were dedicated to experiments for HED physics. Highlights of the various HED and ICF Campaigns are summarized in this section, p. 245.

In addition to these experiments, LLNL Principal Investigators (PI's) led a variety of Laboratory Basic Science

Campaigns using OMEGA and OMEGA EP, including 90 target shots using only OMEGA and 61 shots using only OMEGA EP.

LLNL led a total of 619 shots at LLE in FY15. LLNL PI's also supported 39 NLUF shots on OMEGA and 35 NLUF shots on OMEGA EP in collaboration with the academic community.

4. FY15 LANL Experimental Campaigns at the Omega Laser Facility

LANL conducted a total of 258 target shots on the OMEGA Facility in FY15 (58 for ICF and 200 for the HED programs). A summary of these experiments is contained in a section beginning on p. 266.

5. FY15 SNL Program

Sandia National Laboratories (SNL) conducted 17 target shots on OMEGA EP for the MagLIFEP experiment (p. 276). SNL also participated in the MagLIF experiment on the OMEGA laser in FY15.

6. FY15 NRL Program

The Naval Research Laboratory (NRL) conducted seven target shots on OMEGA EP in FY15 on high-Z coatings of targets described in a section beginning on p. 277.

7. FY15 CEA Experiments at the Omega Laser Facility.

CEA conducted 25 target shots on the OMEGA laser in FY15 for the campaigns discussed in a section beginning on p. 278.

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