Executive Summary

The fiscal year ending September 2016 (FY16) concluded the first 42 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 FY16, a record 2193 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 72% of the facility's FY16 target shots were designated for ICF or HED campaigns. 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 direct-drive ignition. 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 Confinement 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 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 FY16

The Laboratory for Laser Energetics' (LLE's) investigations of direct-drive implosions at the National Ignition Facility to validate models related to implosion velocities and the magnitude of hot-electron preheat are addressed beginning on p. 1. Implosion experiments indicate that the energetics are well modeled when cross-beam energy transfer (CBET) is included in the simulation. Trajectories from backlit images are also well predicted, although with lower velocities than theory, with discrepancies likely caused by nonuniformity growth seeded by laser imprint.

Experiments on the OMEGA Laser System to evaluate cryogenic implosions that are hydrodynamically equivalent to spherical ignition designs for the NIF are described (p. 30). Current cryogenic implosions on OMEGA have reached 56 Gbar, and implosions with a shell convergence (CR) < 17 and a fuel adiabat (α) > 3.5 perform close to one-dimensional (1-D) predictions. Demonstrating hydrodynamic equivalence on OMEGA will require reduced coupling losses caused by CBET and minimized long-wavelength nonuniformity. Ignition in a direct-drive cryogenic implosion on the NIF will require central stagnation pressures in excess of 100 Gbar.

During FY16 LLE researchers performed polar-direct-drive experiments (p. 57) on the NIF to quantify CBET. The polar-direct-drive laser configuration was used to limit CBET at the target poles while maintaining its influence at the equator. This combination of low- and high-CBET conditions in a single implosion made it possible to determine the effects of CBET on the ablation rate and ablation pressure. Hydrodynamic simulations performed without CBET agree with the measured ablation rate and ablation-front trajectory at the target pole, confirming that the CBET effects at the pole are small. CBET simulations incorporating a gain multiplier lead to excellent agreement with both polar and equatorial measurements.

A unique approach for filling nonpermeable ICF target capsules with deuterium–tritium (DT) by permeation if presented beginning on p. 90. This process uses a permeable capsule coupled into the final target capsule with a tapered 0.1- or 0.08-mm-diam fill tube. Such an approach makes is possible to fill new target materials without requiring the design and construction of a fill-tube–based DT filling station. Permeation filling of glow-discharge polymerization (GDP) targets using this method as well as ice layering of the target, has been successfully demonstrated, yielding an inner ice surface roughness of <1-μm rms.

Measurements of the maximum in-flight shell thickness, which decreased from 75±2 nm to 60±2 nm in direct-drive implosions on OMEGA when the shell adiabat was reduced from 6 to 4.5, are presented (p. 109). When the adiabat was decreased farther (to $\alpha = 1.8$), the shell thickness increased to 75±2 nm. Two-dimensional (2-D) simulations that included laser imprint, nonlocal thermal transport, cross-beam energy transfer, and first-principles equation-of-state models reproduced the measured shell thickness, shell trajectories, minimum core radius, and neutron yield and showed that the increased shell thickness for $\alpha \leq 3$ was caused by laser imprint.

Optical smoothing of laser imprinting in planar-target experiments on OMEGA EP using 1-D multi-FM smoothing by spectral dispersion (SSD) has been demonstrated (p. 115). Direct-drive ignition on the NIF requires single-beam smoothing to minimize imprinting of laser nonuniformities that can negatively affect implosion performance. One-dimensional, multi-FM SSD has been proposed to provide the required smoothing. A prototype multi-FM SSD system has been integrated into the NIF-like beamline of the OMEGA EP Laser System. Experiments have been performed to verify the smoothing performance by measuring Rayleigh–Taylor growth rates in planar targets of laser-imprinted and preimposed surface modulations. One-dimensional, multi-FM SSD has been observed to reduce imprint levels by +50% compared to the nominal OMEGA EP SSD system. The experimental results are in agreement with 2-D *DRACO* simulations using realistic, time-dependent, far-field spot-intensity calculations that emulate the effect of SSD.

We report on plasma characterization using ultraviolet Thomson scattering from ion-acoustic and electron plasma waves (p. 125). Collective Thomson scattering is a technique that measures the plasma conditions in laser-plasma experiments. Simultaneous measurements of ion-acoustic and electron plasma wave spectra were obtained using a 263.25-nm Thomson-scattering probe beam. A fully reflective collection system was used to record light scattered from electron plasma waves at electron densities greater than 10^{21} cm^{-3}, which produced scattering peaks near 200 nm. An accurate analysis of the experimental Thomson-scattering spectra required accounting for plasma gradients, instrument sensitivity, optical effects, and background radiation. Practical techniques for including these effects when fitting Thomson-scattering spectra are presented and applied to the measured spectra to show the improvement in plasma characterization.

Measurements of hot-electron temperature in laser-irradiated plasmas are discussed beginning on p. 134. The total energy of hot electrons produced by the interaction of OMEGA nanosecond wide pulses with planar CH-coated molybdenum targets, using Mo K_α emission, was reported in 2012. The temperature of the hot electrons in that work was determined by the high-energy bremsstrahlung spectrum measured by a three-channel fluorescence-photomultiplier hard x-ray detector (HXRD). In the 2016 work, the HXRD was replaced with a nine-channel image-plate–based detector. For the same conditions (irradiance of the order of 10^{14} W/cm^2; 2-ns pulses), the measured temperatures were consistently lower than those measured by the HXRD (by a factor ~1.5 to 1.7). This measurement was supplemented with three experiments that measured the hot-electron temperature using K_α emission from high-Z target layers, independent of the hard x-ray emission. These experiments yielded temperatures that were consistent with those measured by the bremsstrahlung. For a given x-ray emission in ICF compression experiments, this result would lead to a higher total energy in hot electrons, but to a lower preheat of the compressed fuel, because of the reduced hot-electron range.

Beginning on p. 150, the influence of surface modifications on the adsorption and absorption of tritium into stainless-steel 316 is discussed. Tritium dissolution within the adsorbed water layers on stainless-steel surfaces can contribute a significant fraction to the total quantity of tritium absorbed during an exposure to tritium-containing gas. Additionally, these water layers govern the migration of tritium from the stainless-steel lattice to the metal surface after the surface is cleaned. The adsorbed water layers are sensitive to the conditions of the metal surface; different pretreatments can lead to different surface concentrations of water. In the reported work, the effect of altering the metal surface by mechanical polishing, electropolishing, Fe or Cr oxidation, gold plating, and nitric-acid treatments was studied using linear thermal desorption and plasma-induced ion sputtering. The results demonstrate that altering the metal surface can reduce tritium absorption by ≥35%. Finally, a quantitative migration model accurately describes the migration of tritium out of the stainless-steel lattice after the surface is cleaned.

The following advantages of the laser direct-drive (DD) approach to ignition are discussed (p. 172): the increased fraction of laser drive energy coupled to the hot spot and relaxed hot-spot requirements for the peak pressure and convergence ratios relative to the indirect-drive approach at equivalent laser energy. With the goal of successfully demonstrating ignition by using direct drive, the recently established national strategy has several elements and involves multiple national and international institutions. These elements include the experimental demonstration on OMEGA cryogenic implosions of hot-spot conditions relevant for ignition at MJ-scale energies available on the NIF and developing an understanding of laser–plasma interactions and laser coupling using DD experiments on the NIF. Direct-drive designs require reaching central stagnation pressures in excess of 100 Gbar. The current experiments on OMEGA have achieved inferred peak pressures of 56 Gbar. Extensive analysis of the cryogenic target experiments and in addition to 2-D and 3-D simulations suggests that power balance, target offset, and target quality are the main limiting factors in target performance. In addition, CBET has been identified as the main mechanism for reducing laser coupling. Reaching the goal of demonstrating hydrodynamic equivalence on OMEGA includes improving laser power balance, target position, and target quality at shot time. CBET must also be significantly reduced and several strategies have been identified to address this issue.

2. Theoretical Design and Analysis

Hydrodynamic simulations to design a new experimental platform to investigate two-plasmon decay and other laser–plasma instabilities are presented (p. 15). Proposed experiments will use planar plastic targets with an embedded Mo layer to characterize the generation of hot electrons through Mo K_α fluorescence and hard x-ray emission, approximating conditions near both the equator and the pole of a polar-direct-drive implosion.

First-principles investigations of the ionization and thermal conductivity of polystyrene (CH) over a wide range of plasma conditions ($t = 0.5$ to 100 g/cm^3 and $T = 15{,}625$ to 500,000 K) are being conducted (p. 19). Hydrodynamic simulations of cryogenic deuterium–tritium targets with CH ablators on OMEGA and the NIF predict an ~20% variation in target performance in terms of hot-spot pressure and neutron yield (gain) relative to traditional model simulations.

3. Diagnostics

A next-generation neutron temporal diagnostic (NTD) that will determine the hot-spot pressure achieved in ICF experiments and will assess the implosion quality has been installed at the Omega Laser Facility (p. 36). This NTD is based on a fast-rise-time plastic scintillator, which converts the neutron kinetic energy to 350- to 450-nm-wavelength light that is relayed to a streak camera. An ~200-fold reduction in neutron background was observed during the first high-yield DT cryogenic implosions compared to the current NTD installation on OMEGA. An impulse response of ~40±10 ps was measured in a dedicated experiment with a 10-ps pulse from the OMEGA EP laser.

A newly designed pulse-front-tilt–compensated streaked optical spectrometer with high throughput and picosecond time resolution is described (p. 143). A high-throughput, broadband optical spectrometer coupled to the Rochester Optical Streak System equipped with a Photonis P820 streak tube has been designed to record time-resolved spectra with 1-ps time resolution. Spectral resolution of 0.8 nm was achieved over a wavelength coverage range of 480 to 580 nm, using a 300-groove/mm diffraction grating in conjunction with a pair of 225-mm-focal-length doublets operating at an *f*/2.9 aperture. Overall pulse-front tilt across the beam diameter generated by the diffraction grating can be reduced by preferentially delaying discrete segments of the collimated input beam using a 34-element reflective echelon optic. The introduced delay temporally aligns the beam segments and the net pulse-front tilt is limited to the accumulation across an individual sub-element. The resulting spectrometer design balances resolving power and pulse-front tilt while maintaining high throughput.

The design of an extreme ultraviolet spectrometer suite to characterize rapidly heated solid matter is reported (p. 146). An ultrafast, streaked, extreme-ultraviolet (XUV) spectrometer (5 to 20 nm) has been developed to measure the temperature dynamics in rapidly heated samples. Rapid heating makes it possible to create exotic states of matter that can be probed during their inertial confinement time—tens of picoseconds in the case of micron-sized targets. In contrast to other forms of pyrometry, where the temperature is inferred from bulk x-ray emission, XUV emission is restricted to the sample surface, allowing one to measure temperature at the material–vacuum interface. Measuring the surface temperature constrains models for the release of high-energy-density material. Coupling the XUV spectrometer to an ultrafast (<2-ps) streak camera provided an evolution in the picosecond time scale of the surface-layer emission. Two high-throughput XUV spectrometers have been designed to simultaneously measure the time-resolved and absolute XUV emission.

An x-ray detection system (XDS) has been developed and commissioned at LLE with the intent of nondestructively extrapolating the pressure of tritium-filled targets from their measured activity (p. 186). The x-ray emission from silica (SiO_2) and plastic (CH and CD) targets have been measured in the helium environment of the XDS in OMEGA and ICF implosions. The T_2 permeation half-lives were measured for three plastic targets, allowing for the actual initial-fill pressures of those targets to be calculated based on the slope of the pressure versus activity. The half-lives measured by the XDS are compared with values reported by the target manufacturer, differing with a range of up to 2.3×.

High-Energy-Density Science

We report on measurements of the equation of state of carbon at extreme pressures (p. 159). These measurements are of interest to studies of planetary ice giants and white dwarfs and to ICF. Knowledge of the high-pressure shock-and-release responses of diamond is necessary to accurately model an ICF implosion and design ignition targets. The article presents Hugoniot and release data for both single-crystal diamond and high-density carbon (HDC), comprised of nanometer-scale grains, used as a NIF ablator. Diamond was shock compressed to multimegabar pressures and then released into reference materials with known Hugoniots at the Omega Laser Facility. Hugoniot results indicate that HDC, which is ultrananocrystalline and ~4% less dense than single-crystal diamond, has a stiffer response than single-crystal diamond.

Lasers, Optical Materials, and Advanced Technology

The contribution of thin-film interfaces to the near-ultraviolet absorption and pulsed-laser–induced damage for ion-beam–sputtered and electron-beam–evaporated coatings is discussed beginning on p. 43. Film characterization shows a small contribution to total absorption from the interfaces relative to that of the HfO_2 film material, with a higher damage resistance in the seven-layer coating compared to the single-layer HfO_2 film. The results indicate a similarity of interfacial film structure with that formed during the co-deposition of HfO_2 and SiO_2 materials.

A simple diagnostic to characterize 1-D chromatic aberrations in a broadband beam is discussed (p. 52). A Ronchi grating is placed in front of a spectrometer entrance slit to provide spatially coupled spectral phase information. The phase-offset variation in the interferogram along the wavelength axis contains the information on chromatic aberrations that can be extracted using Fourier analysis. The radial-group delay of a refractive system and the pulse-front delay of a wedged glass plate have been accurately characterized in a demonstration.

A description of an eight-channel, time-multiplexed pulse-shaping system that generates, demultiplexes, and retimes optical waveforms from a single pulse-shaping unit begins on p. 68. This system can provide pulses to multiple optical systems with low relative jitter and lower cost. Losses of less than 5 dB and extinction ratios of the order of 50 dB for an eight-channel system were measured for the system. By operating with only four channels, this system can provide a contrast of the order of 70 dB by using the final stage of the demultiplexer to enhance the contrast in the output.

A new design approach to continuous distributed phase plates (DPP's) using the code *Zhizhoo*' has been developed (p. 74). *Zhizhoo*' produces DPP designs with exceptional control of the envelope shape, spectral and gradient control, and robustness from near-field phase aberrations. This code leads to rapid DPP design optimization, with achieved focal-spot shapes having high fidelity relative to the design objective. Using a personal computer, phase-dislocation–free DPP designs with low near-field modulation can be achieved with a less-than-1%-to-2% weighted $\sigma_{\rm rms}$ error of the far-field spot shape in a few minutes.

Experimental efforts were made to correlate the mechanical properties of multilayer diffraction gratings to laser-induced–damage thresholds (LIDT's) (p. 78). Nanoindentation of holographic diffraction gratings etched into silica provides the penetration depth, brittleness, and yield strength of the structure; lower LIDT's are strongly correlated with greater measured yield stresses and lower penetration depths for the evaluated samples. This work indicates that mechanical testing may provide guidance on grating cleanliness and damage thresholds for use in high-intensity laser systems.

The first complete set of measurements of a laser–plasma optical system's refractive index, as seen by an independent probe laser beam, as a function of the relative wavelength shift between the two laser beams have been made (p. 181). Both the imaginary and real refractive-index components have been found to be in good agreement with linear theory using plasma parameters measured by optical Thomson scattering and interferometry; the former is in contrast to previous work and has implications for cross-beam energy transfer in indirect-drive inertial confinement fusion, and the latter is measured for the first time. The data include the first demonstration of a laser-plasma polarizer with 85% to 87% extinction for the particular laser and plasma parameters used in this experiment, complementing the existing suite of high-power, tunable, and ultrafast plasma-based photonic devices.

Omega Laser Facility Users Group (OLUG)

The Eighth Omega Laser Facility Users Group (OLUG) Workshop, held on 27–29 April 2016, attracted more than 110 scientists, postdoctoral fellows (postdocs), and students from institutions in the U.S. and abroad. OLUG consists of over 430 members from 55 universities and 35 research centers and national laboratories from 21 nations covering 4 continents. As has been the case in previous workshops, postdocs and students received travel support for the workshop from DOE's National Nuclear Security Administration (NNSA).

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.

The workshop program included an overview on the National ICF Program presented by Keith LeChien from NNSA; four review and science talks by Craig Sangster (National ICF Direct-Drive Program), Carlo Graziani (Inferring Morphology and Strength of Magnetic Fields from Proton Radiographs), Philip Nilson (High-Resolving-Power, Ultrafast Streaked X-Ray Spectroscopy on OMEGA EP), and Jonathan Davies (An Overview on Laser-Driven Magnetized Liner Inertial Fusion on OMEGA); one Omega Laser Facility talk given Samuel Morse (Progress on Recommendations and Items of General Interest); three poster sessions including a total of 76 research posters and 15 Omega Laser Facility posters (the majority of the contributed posters were presented by postdocs and students); two mini-workshop sessions dedicated to streak cameras (organized by Charles Sorce) and magneto-inertial fusion electrical discharge system (MIFEDS) (organized by Gennady Fiksel); a students and postdocs panel discussion; a discussion and presentation of the Findings and Recommendations; and research and career opportunity talks by representatives from Lawrence Livermore National Laboratory (LLNL) (Robert Heeter), Los Alamos National Laboratory (LANL) (S. Batha), Sandia National Laboratories (SNL) (P. Knapp), and LLE (Michael Campbell).

Detailed reporting on the workshop and the Findings and Recommendations may be found in an article beginning on p. 193.

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. 200) to graduate education.

1. High School Program

During the summer of 2016, 13 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. Three hundred and fifty-three high school students have now participated in the program since it began in 1989. This year's students were selected from approximately 60 applicants.

2. Undergraduate Student Program

Thirty-nine 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 Program

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 FY16, 62 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 Massachusetts Institute of Technology (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, 170 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 FY16.

FY16 Omega Laser Facility Operations

During FY16, the Omega Laser Facility conducted 1414 target shots on OMEGA and 779 target shots on OMEGA EP for a total of 2193 target shots (see Tables 148.IX and 148.X, p. 202). OMEGA averaged 11.7 target shots per operating day with Availability and Experimental Effectiveness averages for FY16 of 95.6% and 96.6%, respectively. OMEGA EP was operated extensively in FY16 for a variety of internal and external users. A total of 718 target shots were taken in the OMEGA EP target chamber and 61 joint target shots were taken in the OMEGA target chamber. OMEGA EP averaged 7.9 target shots per operating day with Availability and Experimental Effectiveness averages for FY16 of 96.9% 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 the Commissariat à l'énergie atomique et aux energies (CEA) of France (see Fig. 1). In FY16, 72% of the target shots were taken for the ICF and HED programs.

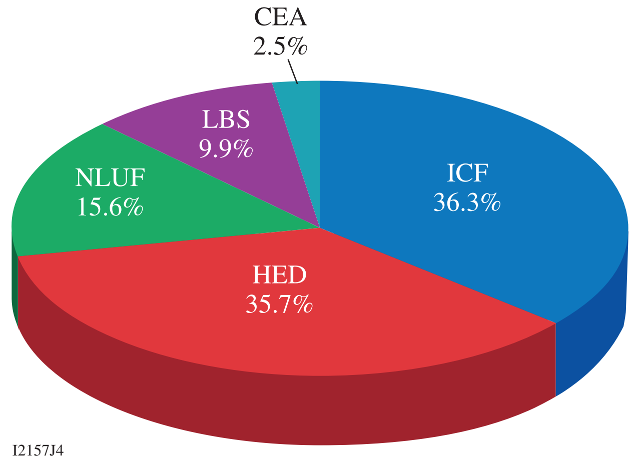

Figure 1
The distribution of non-maintenance Omega Laser Facility target shots by program in FY16.

Details of this work are contained in an article beginning on p. 202. Highlights of the Omega Laser Facility activities in FY16 included the following:

- Improved energy balance over 100-ps segments of the pulse shape
- Changed the equivalent-target-plane diagnostic from Beamline 46 to Beamline 56
- Synchronized the SSD modulators to the laser pulse shape
- Improved the beam-timing system
- Provided an alternative beam path for Beamline 35 to support magnetized liner inertial fusion experiments
- Augmented the lower-compressor diagnostic beam path on OMEGA EP
- Overhauled the OMEGA EP stimulated Brillouin scattering suppression system
- Improved the OMEGA EP short-pulse diagnostic package
- Added a low-yield neutron time of flight diagnostic on OMEGA

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 Laser Facility shots are allocated by campaign. The majority (71.9%) of the FY16 target shots were allocated to the ICF Campaign conducted by integrated teams from LLNL, LANL, NRL (Naval Research Laboratory), SNL, and LLE. The HED Campaigns were conducted by teams led by scientists from the national laboratories, some with support from LLE.

The Fundamental Science Campaigns accounted for 25.5% of the Omega Laser Facility target shots taken in FY16. Over 61% of these shots were dedicated experiments 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.

The Omega Laser Facility was also used for several campaigns by teams from CEA. 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 and LLE conducting ICF experiments; investigators from LLNL, LANL, and LLE conducting experiments for high-energy-density–physics programs; and scientists and engineers from CEA.

FY16 NLUF Program

FY16 was the second 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 148.XI, p. 206) were allotted Omega Laser Facility shot time and conducted a total of 342 target shots at the facility. The FY16 NLUF experiments are summarized in the section beginning on p. 205.

FY16 Laboratory Basic Science Studies

In FY16, LLE issued a solicitation for LBS proposals to be conducted in FY17. A total of 23 proposals were submitted. An independent 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 FY17. Table 148.XII, p. 226, lists the approved FY17 LBS proposals.

Fourteen LBS projects previously approved for FY16 target shots were allotted Omega Laser Facility shot time and conducted a total of 218 target shots at the facility in FY16 (see Table 148.XIII, p. 227). The FY16 LBS experiments are summarized in a section beginning on p. 225.

1. FY16 LLNL Experimental Programs

In FY16, 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 430 target shots in FY16, with 304 shots using only OMEGA and 126 shots using only OMEGA EP. Approximately 21% of the total number of shots (77 OMEGA shots and 14 OMEGA EP shots) supported the ICF-ID Campaign. The remaining 79% (227 OMEGA shots and 112 OMEGA EP shots) were dedicated to experiments for the HED Physics Campaign. Highlights of the various HED and ICF campaigns are summarized beginning on p. 238.

In addition to these experiments, LLNL Principal Investigators (PI's) led a variety of Laboratory Basic Science Campaigns using OMEGA and OMEGA EP, including 81 target shots using only OMEGA and 42 shots using only OMEGA EP.

2. FY16 LANL Experimental Campaigns

In FY16, LANL scientists carried out 22 shot days on the OMEGA and OMEGA EP Laser Systems in the areas of HED science and ICF. The HED shots focused on the areas of radiation flow, hydrodynamic turbulent mix and burn, the equations of state of warm dense matter, and coupled Kelvin–Helmholtz/Richtmyer–Meshkov instability growth. The ICF campaigns focused on the priority research directions of implosion phase mix and stagnation and burn, specifically as they pertain to laser direct drive. Several of the shot days also focused on transport properties in the kinetic regime. LANL continues to develop advanced diagnostics such as neutron imaging, gamma reaction history, and gas Cherenkov detectors. The reports starting on p. 261 summarize the LANL campaigns, their motivation, and the main results from FY16.

FY16 NRL Experimental Campaigns

During FY16, NRL/LLE collaboration on laser imprint led to three successful shot days on OMEGA EP. A new method was devised to produce smooth preheating of the coating without installing a dedicated laser for preheating. It utilized soft x rays generated by a low-energy laser pulse on an auxiliary gold foil to heat and expand the coating on the main target. Streaked x-ray radiography shows that the x rays successfully expanded the coating in front of the plastic foil prior to the arrival of the main laser drive. Well-resolved measurements of Rayleigh–Taylor–amplified laser imprint (Fig. 148.136, p. 274) were obtained on OMEGA EP, showing significant reduction of the target perturbations with the gold overcoat. Initial analysis shows further reduction when the coating is pre-expanded by the prepulse (Fig. 148.137, p. 274).

FY16 CEA Experiments

CEA conducted 55 target shots on the OMEGA laser in FY16 for the campaigns discussed starting on p. 274.

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