1. Introduction

The University of Rochester's Laboratory for Laser Energetics (LLE) operates the Omega Laser Facility for the National Nuclear Security Administration (NNSA) of the Department of Energy (DOE), for the Inertial Confinement Fusion (ICF) and the High-Energy-Density (HED) Campaigns in support of the Stockpile Stewardship Program, and for fundamental science programs. This facility includes two of the most powerful lasers in the world: OMEGA—a 60-beam ultraviolet (UV) neodymium:glass laser, completed in 1995, capable of producing laser pulses with total peak power of approximately 30 trillion watts, and OMEGA EP—a four-beam Nd:glass laser, completed in 2008, capable of producing infrared (IR) laser pulses with peak power in excess of 1000 trillion watts (petawatts) or ultraviolet pulses with energy in the range of 10,000 to 30,000 joules. For comparison, the peak electric-power-generating capacity of the United States is less than a trillion watts. The Omega Laser Facility can be readily reconfigured, typically overnight between shot days, for a wide variety of target and beam configurations. This includes the possibility of joint OMEGA/OMEGA EP shots where the petawatt OMEGA EP beam is propagated into the OMEGA target chamber.

Omega Facility Users include the ICF laboratories; i.e., Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), LLE, the Naval Research Laboratory (NRL), and Sandia National Laboratories (SNL); and university and business users. More than 60% of the Omega facility shots are conducted by external users of the facility. In recent years, the Ignition Campaign has been allocated ~35% to 40% of the shot time, the HED program ~30% to 35%, and the Fundamental Science program ~25% to 30%. The Fundamental Science allocation is divided between two programs: The Laboratory Basic Science (LBS) peer-reviewed program that provides target shots for LANL, LLNL, NRL, SNL, and LLE scientists and the National Laser Users' Facility (NLUF), a peer-reviewed program for scientists from academia or industry to conduct fundamental science experiments at the Omega Laser Facility. Approximately 5% of the available facility shot time is kept unallocated as a contingency at the start of each fiscal year.

When focused laser light from such powerful lasers irradiate small targets, pressures of tens of billions of atmospheres can be produced with temperatures of many millions of degrees. These HED conditions provide a unique capability for a broad range of fundamental and applied scientific research, including laser-driven fusion, measurements of the equation of state (EOS) of matter under extreme loading, unstable hydrodynamics of highly energetic fluids and plasmas, studies of the x-ray opacity of plasmas, warm-dense matter physics, fundamental nuclear processes, and other HED physics phenomena. Significant contributions to NNSA's mission are made through experiments at the Omega Laser Facility.

Many of the techniques, platforms, and diagnostics that are being used for the ICF campaigns at the National Ignition Facility (NIF) were developed at the Omega Facility. This includes the suite of nuclear diagnostics (yield and ion-temperature detectors, neutron imaging, and the magnetic recoil spectrometer to measure areal density). The platform to measure shock timing on the NIF was developed on ~200 shots on OMEGA. Other techniques such as re-emission spheres were demonstrated on OMEGA. Indirect-drive experiments provide support for the physics that underpins the ICF effort. This effort included an understanding of laser–plasma interactions in NIF-scale hohlraums, such as cross-beam energy transfer (CBET), the effects of two-plasmon decay in hohlraum windows, and measurement of the properties of NIF ablator materials (EOS and burnthrough).

The Omega Facility is used to develop the direct-drive ICF concept, providing an alternative to the mainline indirect-drive–ignition concept, and validates an understanding of the properties of deuterium–tritium (DT) at high compression. Cryogenic targets (thin spherical ablator surrounding a DT-ice shell) are routinely imploded with direct drive on OMEGA. These were the only ignition-relevant cryogenic target implosions before the NIF ignition campaign. The OMEGA cryogenic implosions produce areal densities up to 300 mg/cm^2, neutron yields above 2×10^{13} (~20% of that predicted by 1-D simulations), and ion temperatures up to 3 keV. Warm target exploding-pusher implosions on OMEGA have produced 14-MeV neutron yields in excess of 10^{14} neutrons. Such implosions are used to develop ignition diagnostics for the NIF. LLE is validating the polar-drive ICF concept that will allow for direct-drive–ignition experiments on the NIF while it is configured for indirect drive.

The Omega Laser Facility is routinely used to measure properties of HED materials and to develop platforms for HED experiments on the NIF. The EOS of materials has been measured with both shock and ramp compression. Several x-ray diffraction platforms have been developed and are routinely used for a variety of material studies. X-ray Thomson scattering was demonstrated on OMEGA several years ago and is a routine diagnostic for many studies of warm-dense-matter physics. An extended x-ray absorption fine structure (EXAFS) platform that relies on backlighting from a spherical target implosion has been developed and will be transferred to the NIF; Rayleigh–Taylor experiments that measure material strength have been performed; and x-ray sources for radiation effects and radiography have been developed.

A wide variety of fundamental HED science experiments have been performed at the Omega Laser Facility. The propagation of astrophysically relevant shock waves has been studied by multiple groups, including one experiment that led to a further round of Hubble Space telescope observational time and another that focused on understanding the evolution of Super Novas. EOS and other materials' properties relevant to planetary interiors is an active area of research. Magnetized HED plasmas are a new field of study that are likely to provide many exciting results over the next few years. The OMEGA EP high-intensity petawatt beams are the highest-energy short-pulse beams operating routinely worldwide. OMEGA EP has been used in the studies of fast ignition, isochoric heating of materials, the generation and use of high-energy proton beams, and studies of positron beam generation and electron–positron plasmas. In addition, OMEGA EP is now being routinely used for many of the long-pulse UV-beam HED experiments, enhancing the capability that until now was available only on the OMEGA laser.

This users' guide was created to help users of the Omega Laser Facility propose and carry out experiments at the facility. All potential and approved users of this Omega facility are expected to be familiar with the contents of this guide and the relevant references to which it points. Understanding the general information, policies, and procedures contained herein is necessary to formulate, submit, and implement a user proposal. Additional information is provided on the procedures to follow once a proposal is conditionally approved but before system shots are carried out. Finally, introductory and orientation information is included to assist a user during visits to LLE.

Conducting experiments on the OMEGA and OMEGA EP Lasers is a collaborative effort between the Principal Investigator (PI), the Omega Facility, the Omega Experiments group, and the Experimental Support group. The governance of the Facility is described in Chap. 7. The allocation of system time is coordinated by a Facility Advisory and Scheduling Committee (FASC). System time is allocated to the PI so that the PI has decision authority to optimize the scope (complexity) versus shot-rate trade-off. The minimum block of time that is scheduled on OMEGA is a half day (6 h). OMEGA EP is scheduled in full 12-h day increments. This typically results in five to six shots.

Upon approval and allocation of time at the facility, there are four key steps used to communicate the experimental requirements for a campaign:

1. A "three-page" viewgraph description is used initially to determine the placement of an experiment in the annual facility schedule. This document is required by the FASC in advance of the annual facility scheduling meeting that takes places in mid-June of each year for the fiscal year starting in October of that year.

2. The PI is expected to initiate a Target Request Form (TRF) at least four months in advance of the scheduled date.

3. Three months prior to the shot day the PI submits a detailed "Proposal" using an online proposal template that describes the configuration(s) required for the experiment. The FASC reviews the proposal in detail for compatibility with Facility capabilities and either approves or rejects with required changes. To successfully complete this task the campaign proposal must include a reference Shot Request Form (SRF) for each configuration planned for shot day. All laser-pointing and beam-smoothing configurations, all target configurations, and all diagnostics needed for the campaign must be specified on at least one reference SRF to ensure compatibility.

4. Two weeks prior to the campaign, the PI must complete the diagnostic set-up sheets and prepare a tentative sequence of shots for each of the reference SRF's. The PI and LLE stakeholders review these detailed requirements and work to optimize the shot-day plan at a "PI Brief" meeting. Between the two-week PI Brief and the one-week PI Brief the remainder of the SRF's are completed and the shot plan is then reviewed again. The SRF's are used by the Facility managers to conduct detailed planning such as weekend, morning, and evening alignment operations, phase-plate exchanges, and diagnostic configuration and assembly operations. The SRF's are "locked" for this reason, one week prior to the shot day, since these database files are the agreed upon configuration for the campaign.

PI training is required for effective completion of the above tasks. PI training occurs throughout the year on an as-needed basis. During PI training the points of contact within the facility are communicated and the details regarding preparing the "three-page" presentations, "Proposals," and SRF's are described by Facility managers. A PI trainee then "shadows" a PI through a campaign for final qualification to run an experiment at the Facility.

Chapters 2 and 3 of this guide provide descriptions of OMEGA and OMEGA EP lasers and their capabilities, respectively; Chap. 4 is an overview of the experimental systems used on these two lasers; Chap. 5 provides descriptions of the diagnostic capabilities of the facility. Target-fabrication requirements, capabilities, and procedures are presented in Chap. 6; the Omega Facility governance plan and shot allocation process is presented in Chap. 7; the proposal submission process for basic science experiments (NLUF and LBS programs) is discussed in Chap. 8. Chapter 9 includes a discussion of the Omega Laser Facility Users Group (OLUG). Laboratory Policies that may be relevant to users of the facility are included in Chap. 10. Travel and Housing information is provided in Chap. 11. Several appendices are included to complete the guide.