6. Target Production

Constructing and delivering targets for experiments on OMEGA and OMEGA EP are the responsibility of General Atomics (GA). Funding for targets is provided by the NNSA directly to GA to cover the costs for manufacture. It is the responsibility of prospective Principal Investigators (PI's) to provide an adequate description of the targets' construction to allow GA to estimate a cost for manufacture. Specific target requests are to be sent to Michael Farrell (farrell@fusion.gat.com) at GA, who coordinates constructing and creating Target Request Forms (TRF's). This web-based database documents target characteristics (specifications, quantities, delivery dates, and other relevant data) for a campaign shot date that is related to the OMEGA schedule (see Target Fabrication, PI Portal, and OMEGA Schedule). A GA technician, based at LLE, is responsible for coordinating the delivery of targets to LLE, allowing for any further target construction or characterization that must be performed at LLE to be interfaced with other target tasks within the LLE Target Group. This technician is also responsible for performing those tasks and delivering the targets to the OMEGA Experimental Operation Group for implosions; assistance in these tasks is provided by the LLE Target Group as resources and expertise allow.

A wide range of targets with different features and unique complexities are manufactured for experiments on OMEGA. Examples range from targets comprised of multiple flat foils oriented at precise angles relative to each other to plastic shells filled with DT ice with precise specifications on the uniformity and smoothness of all the surfaces. The different types of target that are produced are described as an example of our capabilities and may be used as a basis for future requests.

6.1 Targets for OMEGA and OMEGA EP Experiments

Targets that are imploded at room temperature are the most common types of targets provided for experiments. They include flat-foil assemblies and shells (both glass and plastic) that typically contain gas mixtures, as defined by the experiments. These targets are used for experiments on OMEGA, OMEGA EP, and the Multi-Terawatt Laser. Figure 6.1 shows a capsule supported by a low-*Z*, low-mass support. The silicon carbide fiber supporting the shell has a diameter of 17 μm, and less than 50 pg of glue is used to attach the shell to the fiber.

6.1.1 Thin-Walled Glass Shells

These targets, typically 400 and 860 μm in diameter with a wall thickness of 2 to 4 μm, are used for diagnostic-development experiments and for neutron-detector-calibration implosions. They may also be used as a proton source for proton-radiography applications. These targets typically contain deuterium (D), deuterium–tritium (DT), pure tritium (T), or deuterium-^{3}helium (D^{3}He) gases. A benefit of this type of target is the long deuterium-gas retention time in the target, which simplifies their production. Experimental campaigns using this target are related to the MIFEDS (magneto-inertial fusion electrical discharge system) diagnostic and proton-probe NLUF experiments.

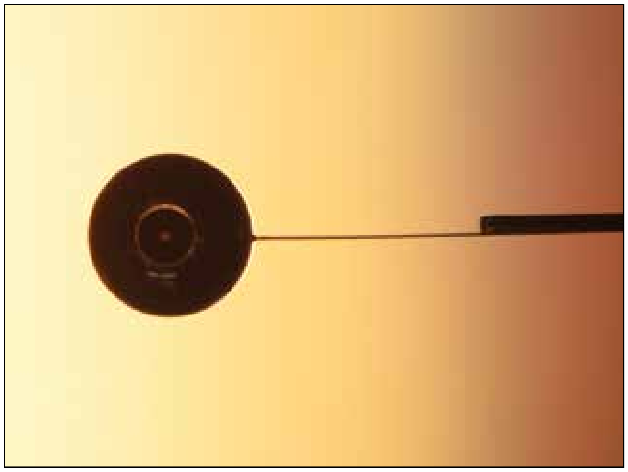
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Figure 6.1
Typical spherical target mounted on a silicon carbide fiber.

6.1.2 Thick Plastic Shells

These targets typically possess a wall thickness of 15 to 34 μm with diameters of 860 μm. These are high-quality, cost-effective shells produced by GA. Typically the specifications on the target's smoothness and roundness are relaxed compared to those targets for cryogenic experiments. Examples of experimental campaigns that use these targets are Diagnostic Development, Polar-Drive High Convergence, and Shock Ignition. The targets typically contain D, DT, T, or D^3He gases. Dopant gases such as argon are available. The maximum pressure achievable is usually limited by the wall thickness of the plastic shell; however, in the event that a particularly thick shell is selected, the maximum pressure rating of the gas manifold is 25 atm. Plastic shells require a thin barrier layer (typically aluminum) be deposited on them to provide an acceptable permeation half-life. Applying these thin films (typically by sputter coating and typically 1000-Å thick) adds several weeks to the production cycle. Once the targets are filled to the desired pressure, they are sealed in individual pressure cylinders with the same gas mixture until shot time to ensure an accurate gas fill.

Filling either plastic or glass shells with tritium is a resource that is available through the Operations Division at LLE. Shells are delivered from GA to the GA technician at LLE. If the shells are to be filled with any gas other than DT (or T_2) then all the gas-permeation work is performed by the LLE Target Group. If they are to be filled with DT (or T_2) the shells are characterized, loaded into specific target holders, and delivered to the Cryogenic Tritium Facility. As an alternative, targets may be first sent to LLNL to be filled with DT or pure T_2. The targets are then to be sent to the UR Radiation Safety Office with an explanation that they contain tritium, and the GA technician at LLE is defined as the point-of-contact. These targets are then to be delivered directly to the Cryogenic Tritium Facility (Room 157) to be processed, stored, and delivered for experiments. This sequence ensures the safe handling and minimizes the contamination of tritium throughout the laboratory space.

A sub-category of the plastic shells, which are more exotic and considerably more complicated to produce, are shells with specific dopants embedded in the plastic wall at well-prescribed depths and concentrations. Examples of these dopants are titanium, copper, and silicon. Experimental campaigns that use these targets are selective targets for cryogenic implosions where a 6-at. % silicon dopant is present in the outer 5 μm of the shell wall, and NLUF targets that have the first 0.5 μm of the plastic shell be doped with titanium (3% and 6 at%).

6.1.3 Fast-Ignition Targets

These are shells with an embedded gold cone to shield a portion of the target from the plasma that develops with the implosion [see Figs. 6.2(a) and 6.2(b)] The apex of the gold cone is precisely positioned within 50±5 μm of the center of the target. Early experiments with these targets do not require the cone/shell assembly to be gas tight; however, future experiments and experiments concurrently being performed to shape a solid deuterium ice layer have the added requirement that the assembly be capable of maintaining a gas fill.

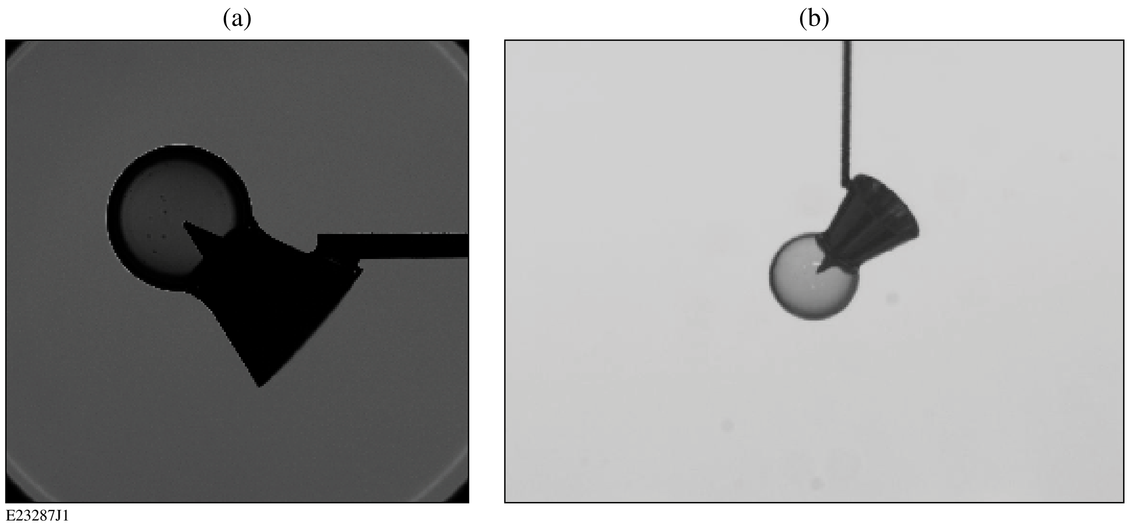

Figure 6.2
(a),(b) Fast-ignition, cone-in-shell targets.

6.1.4 Hohlraum and Cylindrical Targets

Most indirect-drive targets are fabricated off-site (LLNL), given the specialization of tools and familiarity of assemblies. However, GA personnel at LLE have been trained to build, test, and characterize this class of targets at LLE. LLE possesses the infrastructure to add different gases to these targets—the following gases are generally in stock and approved for use on OMEGA: helium, argon, krypton, xenon, methane, and neopentane. These assemblies may contain individual pressure transducers that accompany the target into the Target Chamber to confirm the gas retention at the moment of the implosion. Gases containing halogens, such as sulfur-hexaflouride or chlorine, that can poison tritium-gettering systems require prior approval from the Laser Facility to be used (Fig. 3).

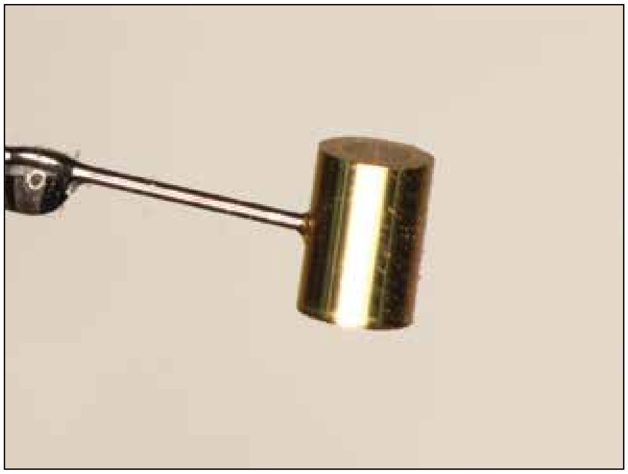

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Figure 6.3
A gas-filled hohlraum target mounted on a 250-μm-diam stainless steel tube.

Consideration and limitations for different types of targets

1. Any targets containing beryllium or a radioactive material must be identified well before construction begins, and such materials must be explicitly identified in the shipping documentation. Targets containing radioactive materials must be shipped to the Radiation Safety Office.

2. Target design should attempt to minimize the target's mass to reduce damage to optics in the Target Chamber. The target design must be reviewed by the Laser Facility Managers ahead of construction to identify any features that may be unacceptable to the Facility.

3. The choice of materials for target construction should attempt to minimize outgassing into the chamber (see OMEGA EP requirements document).

6.1.5 Planar Cryogenic Targets

Two cryogenic platforms are available to provide frozen or liquid deuterium for equation-of-state or shock-timing experiments. Any interest in performing these types of experiments requires a more-detailed discussion with the NLUF Manager, who can direct the questions to the personnel responsible for the different aspects of fielding these more complex experiments [Figs. 4(a) and 4(b)].

6.1.6 Flat-Foil Targets

These targets are the most common and diverse targets used at LLE. They can consist of a single-drive foil orientated at specific (θ,ϕ) angles and possibly additional debris shields that are x-ray transparent or completely blocking light-of-sight shields. These targets are assembled using machined fixtures to align the components to tight tolerances (typically to $\pm 1°$ and <10 μm). The as-built dimensions are measured using an inspection and metrology station (Powellscope). All target designs are configured using Visrad™ software to properly align the targets relative to different beam ports [Figs. 5(a) and 5(b)].

The equipment available for use at LLE is listed below. Scheduling time to use the equipment is coordinated by Mark Bonino (mbon@lle.rochester.edu).

(a) (b)

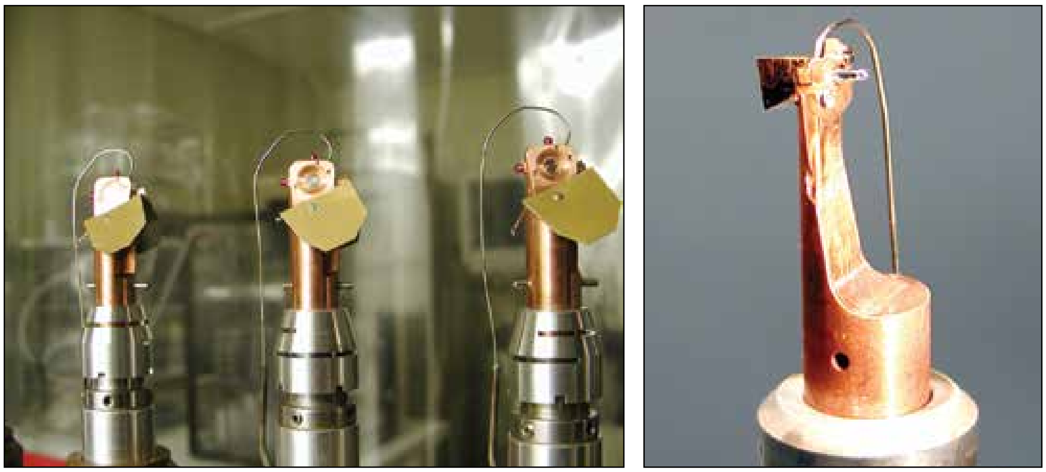

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Figure 6.4
(a) Planar cryogenic targets for x-ray Thomson scattering and (b) shock-timing experiments.

(a) (b)

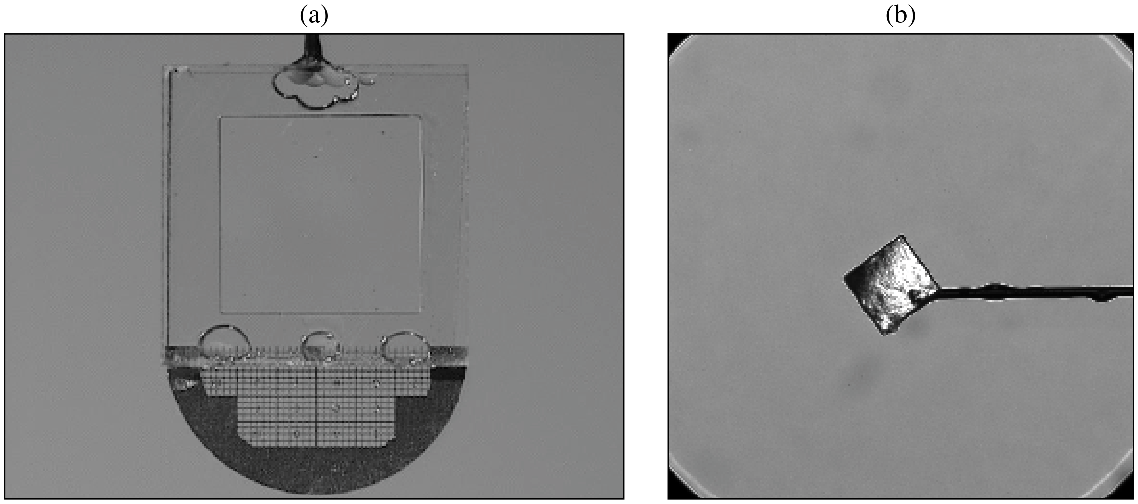

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Figure 6.5
Examples of planar targets. (a) Precision EOS LiF adhered to alpha quartz; the resolution grid is attached as a ficucial for the ASBO laser. (b) Small-scale copper foils (100 × 100 × 2 μm) illustrate the limit of capability in the Target Fabrication Group.

6.1.7 Equipment

The equipment used to build targets includes manipulators and microscopes to assemble submillimeter-scale components on precision-machined assembly fixtures. The Target Group has six target-assembly stations that use high-precision manipulators and stereomicroscopes (one Olympus, one Zeiss, three Wild, and one Nikon SMZ1500) to assemble targets. Once assembled, the targets are characterized using microscopes (Mitutoyo compound microscope) and the Powellscope inspection and metrology station to measure the target dimensions and angles. Target assembly work is done in a class-1000 clean room. An exception is those targets intended for cryogenic experiments; they are assembled and characterized in a class-100 clean room to reduce the chance of debris contaminating the capsules.

Three separate vacuum systems are available to make components for targets. One of the vacuum systems uses evaporation processes to deposit inorganic (primarily metallic) coatings on shells or to evaporate gold and salts (e.g., NaCl, KF, KI, and KBr) onto flat substrates to make components for flat-foil targets or diagnostic cathodes. A second vacuum system is used to sputter-coat thin metallic films. This LLE-built sputter coater (operating in dc or rf modes) provides a "bounce-coating" capability for depositing thin aluminum permeation-barrier films onto shells. This coater is equipped with a "bounce-pan" substrate that supports and randomizes the shells' orientation in the coating flux, making it possible to coat the shells with a uniformly thin aluminum layer. This sputter system is also used to coat metallic thin films to construct multilayered flat-foil targets. The third vacuum system deposits parylene (a carbon–hydrogen plastic) onto flat substrates at low pressure. This is the plastic-depositing analogue of the sputter coater and is used to construct flat-foil targets with well-defined lateral and thickness specifications.

Equipment is available to permeate different gas mixtures into spherical glass and plastic targets. Two gas manifolds are used for this purpose. The first manifold permeation fills capsules with gases such as D_2, H_2, He, N_2, and trace concentrations of Ne, Ar, Kr, or Xe. The second manifold is dedicated for filling only ^{3}He. This format has been chosen to eliminate the chance of residual gas species in the capsules. As was stated before, tritium fills are carried out through the Operations Division, through Samuel Morse (smor@lle.rochester.edu). Filled capsules are stored individually in pressure vessels until shot time. As a quality-assurance step, each vessel is measured for pressure prior to the gas fill being released.

A separate fill manifold is available for filling gas-filled hohlraums and other fill-tube-type assemblies. This manifold is the property of LLNL, but stationed at LLE for fill-tube specific experiments. The maximum allowable working pressure is 80 psia. Targets of this class use a pressure transducer attached downstream of the target. The electrical connection allows for a pressure to be read at shot time using a compatible readout in the OMEGA control room.

A Leica DCM 3-D confocal microscope evaluates surfaces of spherical and flat-foil targets. This new capability allows the outer and inner surfaces of cryogenic target assemblies to be mapped. It also scans planar surfaces to the tens of nanometer level for baseline surface features in Rayleigh–Taylor growth experiments. This equipment is under constant use; any requests for surface scans must be defined well in advance of campaign shot days. Other metrology equipment used for characterizing targets is as follows: Mach–Zehnder interferometer, precision microbalance (Mettler-Toledo, accuracy of 0.1 μg), and a thermal mechanical analyzer (TMA), for measuring material properties over a temperature range of –150°C to 300°C.