A Scattered-Light Uniformity Imager for Diagnosing Laser-Absorption Asymmetries on OMEGA

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Successful implosions require efficient and highly uniform deposition of laser energy. Simulations suggest that the nonuniformity must be below the 1% rms level to achieve ignition.[1] Accurate measurement of the laser absorption is essential to evaluate implosion performance, including various schemes to mitigate laser–plasma instability losses. Laser light scattered from a target is the most direct measurement for diagnosing laser absorption in a direct-drive implosion. Observations from OMEGA implosions have shown much larger scattered-light asymmetries than standard predictions.[2,3] To address the insufficiencies of the existing scattered-light instruments, a new diagnostic, the scattered-light uniformity imager (SLUI), has been designed and deployed on OMEGA to absolutely measure the scattered-light intensity and nonuniformity for the purpose of diagnosing the asymmetry and determining its effect on laser drive uniformity. SLUI's collect a much larger portion of the scattered light around the target than other diagnostics.

SLUI measures the angularly discriminated scattered-light intensity distribution over a collection cone area by imaging a translucent transmission diffuser plate using a charge-coupled–device (CCD)/lens assembly There are two major assemblies in each SLUI: the diffuser plate front-end ten-inch manipulator (TIM)-based payload and a rear-end imaging assembly [Fig. 1(a)]. The main component of the front end is the 0.5-mm-thick translucent white spectralon diffuser plate. A stray light baffle, debris shield, and antireflection absorbing filter are also incorporated into the diagnostic payload inserted into the target chamber. The imaging part of the diagnostic (light baffle, vacuum window, filters, lens, and CCD camera) is located outside the target chamber. A sample diffuser image is shown in Fig. 1(b). Fine-scale structures, such as highlighted by the inset, are believed to be caused by structure in the diffuser plate. Some large-scale variances over the image may also be caused by the diffuser plate nonuniformity. The fine- and large-scale diffuser effects will be clarified by upcoming flat-fielding measurements. Each SLUI instrument sensitivity is absolutely calibrated offline using a National Institute of Standards and Technology traceable photodiode.

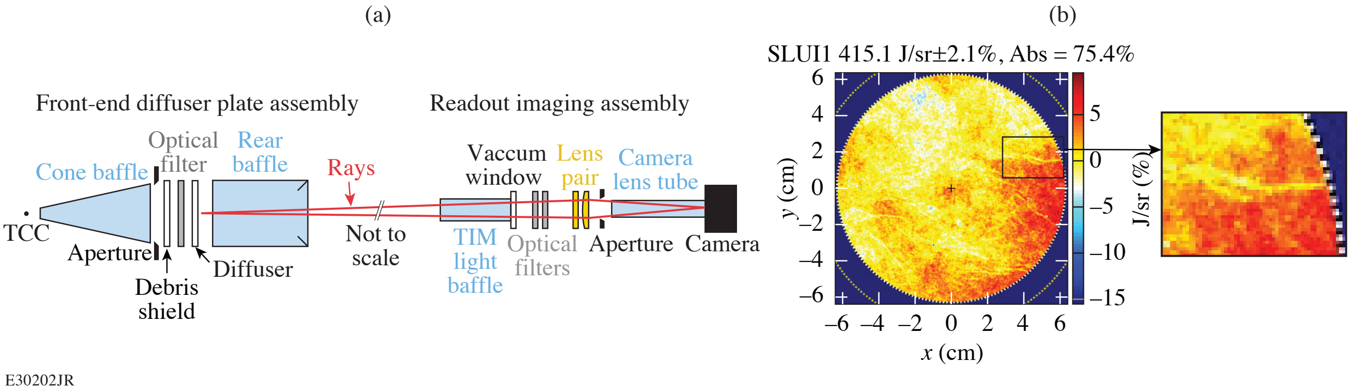

Figure 1
(a) The SLUI diagnostic. (b) Sample SLUI image of the diffuser plate for an OMEGA implosion. The inset highlights one of the small-scale features that are caused by the interior structure of the diffuser plate. TCC: target chamber center.

The standard operating position of the SLUI's places the diffuser plate standoff distance (SOD) at 31.5 cm from target chamber center (TCC) to avoid any chance of beam interference and helps reduce sputtering of baffle material on high-power shots. At this SOD, a SLUI has an effective *f* number of 2.5 and records the scattered light over a cone angle of 11.3° or ~0.97% of the total 4π emission area. Based on the measured point spread function, this effective area provides over 20K independent intensity measurements, enabling the study of the intensity and distribution of the scattered light over this area. Five SLUI's have been built and deployed in OMEGA's TIM diagnostic ports, covering almost 5% of the emission surface, enabling an absolute scattered-light measurement that according to modeling should be within a few percent of the global average. Five SLUI positions allowed resolution of the lowest modes (ℓ = 1,2) in the distribution. The large solid-angle image from each SLUI records the large local slopes in the distribution due to higher modes. Work is underway using these measured variations to evaluate the accuracy of the predicted scattered-light distributions and identify whether additional physics or other considerations need to be included.

The accuracy of the SLUI's measurements are sufficient to distinguish the effects of a 12-μm offset in target position. The green squares in Fig. 2 show the laser absorption inferred from each SLUI for an implosion that was centered at TCC within a couple of microns. The variation between the SLUI's is indicative of the scattered-light variation over the target chamber. The mean absorption for this shot is shown by the dotted black line. The blue diamonds are the laser absorptions inferred from SLUI from a similar implosion except that the target was intentionally offset 12 μm toward one of the SLUI's. The difference between the two implosions is illustrated by the red line. A consistent trend is found with a delta of about 5% absorption difference between the SLUI toward the offset and the SLUI away from the offset.

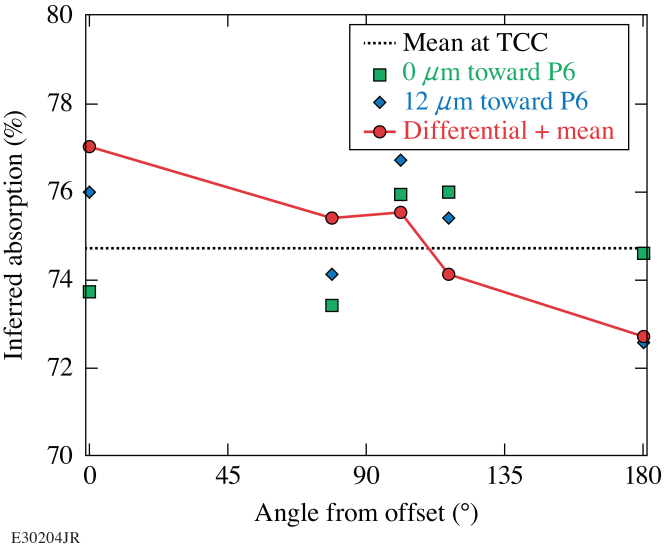

Figure 2
SLUI experimental measurements show the effect of a target offset. Shown is the laser absorption inferred for individual SLUI's for two similar implosions, one well centered at TCC (green squares) and the other intentionally offset ~12 μm toward one of the SLUI's (blue diamonds). The red line shows the difference between the two measurements centered on the mean overall absorption for the case at TCC (dotted black line).

The SLUI diagnostic is now available for deployment on OMEGA implosions, providing an absolutely calibrated platform to study the global laser absorption and sources of scattered-light and absorption asymmetries such as beam pointing, target offset, power balance, and polarization effects on cross-beam energy transfer.

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3. O. M. Mannion *et al.*, Phys. Plasmas **28**, 042701 (2021).