October 2015 Progress Report on the Laboratory for Laser Energetics

Inertial Confinement Fusion Program Activities

Reduction of cross-beam energy transfer for direct-drive, layered deuterium–tritium implosions on OMEGA: Cross-beam energy transfer (CBET) has been shown[1] to reduce the target absorption and resulting ablation pressure of direct-drive inertial confinement fusion (ICF) targets. The first step of the direct-drive ICF CBET mitigation campaign[2] has demonstrated an increase in hydrodynamic efficiency (HE), which is defined as the kinetic energy of the imploding target divided by the incident laser energy. A proposed technique[1] to reduce CBET, by driving the spherical target with overlapping laser beams having individual focal spots smaller than the outside diameter of the target, was investigated with layered-DT implosions on OMEGA.[3] The targets had the following combinations of target diameter/DT ice-layer thickness: 800 μm/50 μm, 860 μm/50 μm, 900 μm/50 μm, 960 μm/65 μm, and 1000 μm/65 μm. The larger targets were driven with up to 29 kJ of laser energy with 2-D smoothing by spectral dispersion (SSD) applied only to the pickets. The peak laser power was kept constant for all shots, resulting in a peak intensity that ranged from 9×10^{14} W/cm^2 for the 860-μm targets to 7×10^{14} W/cm^2 for the 1000-μm targets. The lower intensity reduced the risk of preheat from two-plasmon decay, which occurs as the intensity at the quarter-critical surface rises following a reduction in CBET. The measured laser absorption increased from 54±6% to 75±2% as the target diameter was increased from 800 μm to 1000 μm. The simulated values including CBET changed from 52% to 77%, respectively, in good agreement with the experiments. If CBET were not included in the model the simulated values would be 71% to 92%. Comparing the simulated absorption values with and without CBET shows that the relative change in the absorption is 27% for the smaller target and 16% for the larger target, which indicates, as expected, that the effect of CBET is reduced for the larger target. Shell-trajectory measurements were recorded for targets having outside diameters of 860 μm, 900 μm, and 1000 μm using the coronal plasma x-ray imaging technique outlined in Ref. 4. The 1-D simulation matched the measured trajectories, scattered laser light, and neutron bang time, within experimental uncertainty. The HE inferred from comparing the measured results with the 1-D simulation is presented in Fig. 1(a). The HE increased from 3.4% to 7.4% as the target diameter was increased from 800 μm to 1000 μm, with a fixed beam size of 825 μm. The effect of increasing the density scale length and, therefore, inverse-bremsstrahlung absorption was estimated from 1-D simulations where the beam size matched the target size. As seen in Fig. 1(a), the HE has a maximum value of 5.2% from this increase in absorption. Consequently, the reduction in CBET caused an increase in the HE from 5.2% to 7.4% or a 40% increase. As can be seen in Fig. 1(b), the ratio of inferred P_{hs} from nuclear and x-ray measurements[3] to the 1-D prediction was ~50%, but decreased slightly with an increased target diameter caused by a reduction in beam overlap on target. The predicted hot-spot pressure stays fairly constant for the different shell sizes.

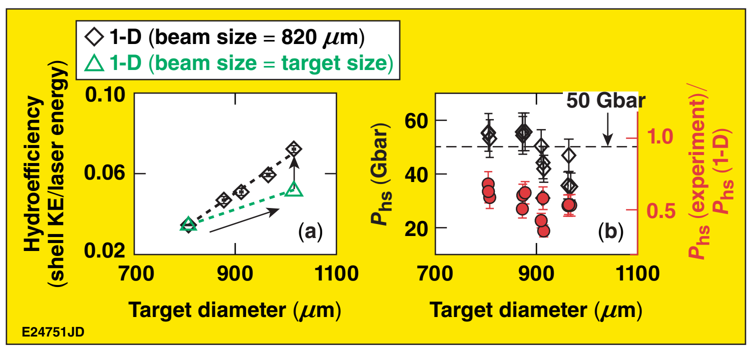

Figure 1. (a) The hydrodynamic efficiency as a function of the initial target diameter for a fixed beam size (diamonds) and a beam size equal to the target size (triangles). (b) The inferred hot-spot pressure (diamonds) and the comparison to the 1-D simulated values (circles) versus the initial target diameter.

Omega Facility Operations Summary: During October (FY16), the Omega Facility conducted 167 target shots with an average experimental effectiveness (EE) of 96.7% (116 on the OMEGA laser with EE of 96.1% and 51 on the OMEGA EP laser with EE of 98.0%). The ICF program accounted for 61 target shots for experiments led by LANL, SNL, and LLE. HED experiments led by LLNL, LANL, and LLE had 81 target shots and two NLUF experiments led by Rice University and MIT conducted 25 target shots.

1. I. V. Igumenshchev *et al*., Phys. Plasmas **17**, 122708 (2010);
I. V. Igumenshchev *et al*., Phys. Plasmas **19**, 056314 (2012);
D. H. Froula *et al*., Phys. Rev. Lett. **108**, 125003 (2012).
2. V. N. Goncharov *et al*., Phys. Plasmas **21**, 056315 (2014).
3. S. P. Regan *et al*., submitted to Physical Review Letters.
4. D. T. Michel *et al*., Phys. Rev. Lett. **114**, 155002 (2015).

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