November 2002 Progress Report on the Laboratory for Laser Energetics Inertial Confinement Fusion Program Activities

Direct-Drive Fast-Ignition Research at LLE: The LLE direct-drive research program includes the investigation of the direct-drive fast-ignition (FI) concept.[1] FI involves the assembly of a dense fuel core using a conventional high-energy-density system and the subsequent heating of the core to ignition conditions by the rapid deposition of energy from an ultrahigh-power, short-pulse, 1-μm laser. In collaboration with General Atomics, Lawrence Livermore National Laboratory, and the Institute of Laser Engineering of the University of Osaka, Japan, LLE has initiated experiments to study direct-drive fuel core assembly for FI using the "cone-in-shell" concept[2] with the specific objective of validating this approach for ultimate implementation on the NIF. Recent OMEGA experiments used the target shown in Fig. 1 to demonstrate that cone-in-shell targets could be imploded in a direct-drive mode on OMEGA (see Fig. 2). In future experiments, gas-filled capsules will be imploded, and ultimately the experiments will be extended to cryogenic targets and to the heating of the compressed core using ultrahigh-intensity laser beams from the OMEGA EP system currently in design.

Figure 1. Photograph of a direct-drive cone-in-shell target used in recent OMEGA experiments. The target consists of an unfilled CH shell with an attached Au-coated cone. The attached foil is used for x-ray backlighting.

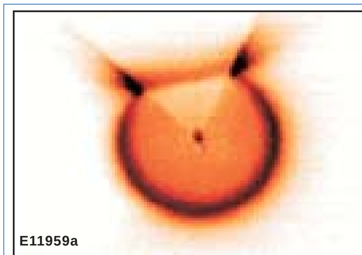

Figure 2. X-ray pinhole camera photograph of a direct-drive cone-in-shell target implosion from the recent OMEGA experiments. Note the opaque area corresponding to the cone inside the shell and the core emission at the center of the shell.

2-D Performance of a Low-Adiabat Cryogenic Implosion: A new low-adiabat drive pulse ($\alpha \sim 4$) has been developed specifically for the 5-μm-CH, 100-μm-thick cryogenic D_2 capsules routinely imploded on OMEGA. The shell stability[3] with this pulse is considerably improved compared to the nominal $\alpha \sim 3$ design that is, in turn, scaled from the baseline direct-drive-ignition pulse shape for the NIF. Therefore, these implosions are less sensitive to the current levels of laser system nonuniformity on OMEGA. Shot 28969 was the first cryogenic implosion with little or no target alignment offset using this new pulse shape. A shadowgraph of the capsule (Fig. 3) shows a relatively large $\ell = 1$ mode on the ice layer ($\ell = 1$ amplitude ~8 μm). The measured neutron yield was only 11% of the 1-D prediction but very close to the calculated 2-D *DRACO* yield (Table I). Although the low-mode, D_2-ice nonuniformity most likely dominated the implosion performance, the 2-D *DRACO* simulation was able to correctly account for the degradation in performance; the 2-D predictions agree well with the experimental quantities listed in Table I.

Figure 3. A shadowgraph of the capsule imploded on shot 28969. The asymmetry in the ice thickness is apparent.

Table I: A comparison of the 1-D *LILAC* and 2-D *DRACO* predictions for shot 28969 shows that the 2-D simulation agrees well with the experimental measurement of primary (Y_{1n}) and secondary neutron yield (Y_{2n}), average areal density (ρR in mg/cm^2), and ion temperature (T_{ion} in keV).

	1-D Simulation	2-D Simulation	Experiment
Y_{1n}	5.60×10^{10}	5.32×10^9	5.95×10^9
Y_{2n}	6.94×10^8	6.31×10^7	6.75×10^7
$\langle\rho R\rangle$	80	58	67
T_{ion}	1.7	2.0	2.5

OMEGA Operations Summary: A total of 107 target shots were taken on OMEGA during November. The LLE campaigns (34 shots) included stockpile stewardship and Rayleigh–Taylor (RT) instability experiments. LLNL campaigns (69 target shots) included RT, NIF hohlraum symmetry, x-ray Thomson scattering, gas-bag long-scale-length plasma physics, and x-ray conversion experiments. Four target shots were taken for long-scale-length plasma physics experiments by Commissariat à l'Énergie Atomique. In addition, 16 laser development shots were taken on OMEGA to explore the system energy performance limits with low-adiabat pulses.

1. M. Tabak *et al.*, "Ignition and High Gain with Ultrapowerful Lasers," Phys. Plasmas **1**, 1626 (1994).
2. P. A. Norreys *et al.*, "Experimental Studies of the Advanced Fast Ignitor Scheme," Phys. Plasmas **7**, 3721 (2000).
3. V. N. Goncharov *et al.*, "Modeling Hydrodynamic Instabilities in Inertial Confinement Fusion Targets," Phys. Plasmas **7**, 5118 (2000).

Contact: Wolf Seka (585) 275-3815; fax: (585) 275-5960; e-mail: seka@lle.rochester.edu
John M. Soures (585) 275-3866; fax: (585) 256-2586; e-mail: jsou@lle.rochester.edu
http://www.lle.rochester.edu/