October 2007 Progress Report on the Laboratory for Laser Energetics

Inertial Confinement Fusion Program Activities

Experimental Studies of the Shock-Ignition ICF Concept: Shock ignition is a concept for direct-drive laser inertial confinement fusion[1] that promises ~4 times lower driver energy for ignition than the conventional isobaric hot-spot-ignition concept. The fuel is first assembled to a high areal density (ρR) on a low adiabat with a sub-ignition implosion velocity by using shaped nanosecond laser pulses. A strong shock wave is then launched into the compressed core by a high-intensity laser pulse (spike) at the trailing edge of the drive pulse to trigger a burn wave that ignites the fuel.

Initial experiments to study the shock-ignition concept were performed[2] on the OMEGA Laser System using 40-μm-thick, 430-μm outer-radius plastic shells that were filled with D_2 gas at pressures ranging from 4 to 45 atm. A comparison of typical experimental pulse shapes with and without a spike for a calculated adiabat of $\alpha \sim 1.7$ (the ratio of pressure to the Fermi degenerate pressure) is shown in Fig. 1. Compressed capsule areal densities with average values exceeding ~0.2 g/cm^2, peak areal densities above 0.3 g/cm^2, and yield-over-clean (YOC) of 10% for hot-spot convergence ratios (CR) up to 30 were measured.[2]

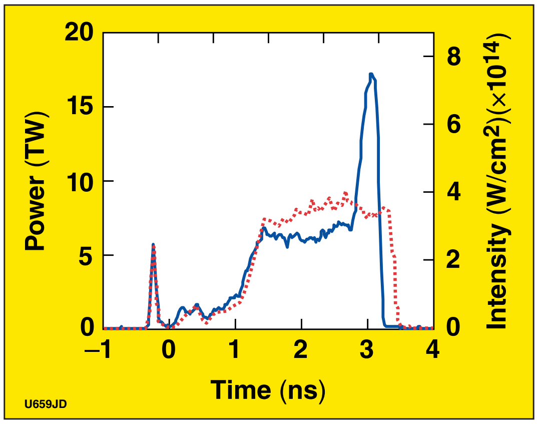

Figure 1. Pulse shapes with spike (solid curve, shot 46078, 18.6 kJ) and without spike (dashed, shot 46073, 19.4 kJ); neither pulse had SSD.

Neutron-yield measurements comparing the performance of a shock-ignition pulse shape to a similar pulse shape without the spike but the same total laser energy (see Fig. 1) reveal four times more neutrons with the spike pulse [$1.8\pm0.2 \times 10^9$ (without spike) to $8.0\pm0.8 \times 10^9$ (with spike)]. A 30% increase was also measured in the capsule fuel areal density with the spike pulse shape. Systematic studies of low-adiabat plastic-shell implosions were performed, varying the timing of the short picket and the high-intensity spike pulses to optimize the performance in terms of areal density and fusion product yield. The implosion performance was also studied for various shell-fill pressures between 4 and 45 atm (corresponding to a convergence ratio ranging from 30 to 10, respectively). Figure 2 plots the YOC versus CR for implosions with an optimized spike pulse shape (dots) and various pulse forms without spike (diamonds). The experiment demonstrates that YOC close to 10% has been obtained for plastic shell, $\alpha \approx 1.7$ low-adiabat implosions and CR of up to 30 indicating improved stability with shock-ignition pulse shapes. The typical YOC of similar implosions without spike is below 1% for CR > 23.

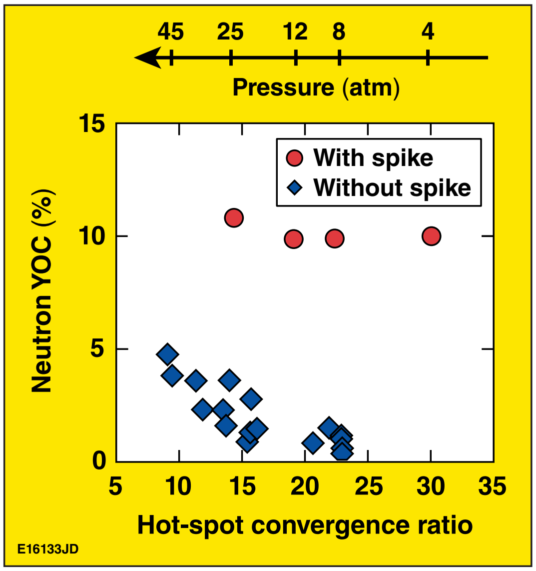

Figure 2. The neutron yield over clean versus hot-spot convergence ratio. The YOC is close to 10% for a hot-spot convergence of up to 30 with the spike pusle.

OMEGA Operations Summary: OMEGA conducted 138 target shots during October with an overall experimental effectiveness of 98.2%. The NIC accounted for 107 of these shots—they were conducted by teams from LLNL, LANL, and LLE. Several projects were completed in October including initial operations of MRS; successful integration of MIFEDS with OMEGA; activation of the OMEGA high-resolution velocimeter (OHRV); short-pulse, beam-tube integration; and the successful integration of the OMEGA EP timing system with the OMEGA timing system in preparation for future joint shots.

---

[1] R. Betti *et al*., Phys. Rev. Lett. **98**, 155001 (2007).

[2] W. Theobald, presented at the 49th Annual Meeting of the APS Division of Plasma Physics, Orlando FL, 12–16 November 2007 (invited paper).

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