December 2000 Progress Report on the Laboratory for Laser Energetics Inertial Confinement Fusion Program Activities

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Mix-Model Analysis of Direct-Drive Implosions: A static model of 20-μm-thick plastic shell implosions filled with 15 atm of DD or DT has been developed. A 1-ns square pulse with 23 kJ of energy, one-color-cycle 1-THz 2-D smoothing by spectral dispersion (SSD), and polarization smoothing (PS) was used to drive the capsules modeled by this analysis. The model produces a tightly constrained set of core properties (ranges shown in Fig. 1). Temperature and density profiles compare favorably with 1-D simulations of these implosions using *LILAC* (shown as the solid lines in Fig. 1). The optimal model requires about 1 μm of the initial shell material to be mixed into the fuel to produce results that are consistent with the experimentally observed primary yields, secondary neutron ratios (ratio of the secondary neutron yield to primary neutron yield), secondary proton ratios, neutron-averaged ion temperatures, and knock-on deuteron and triton ratios.

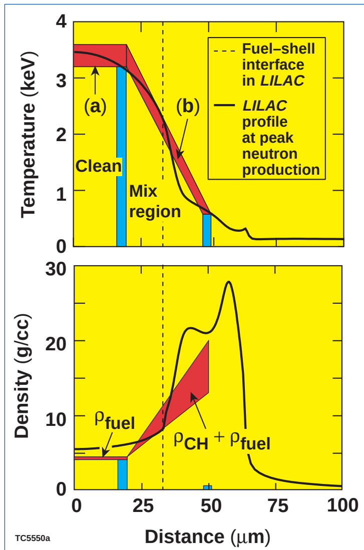

Figure 1. Core and fuel–shell mix profiles inferred from mix model. The range of the parameters, which is consistent with experimental observations, is shown by the width of the various parameter bands. The regions (a) and (b) refer to the temperature range of the clean fuel and CH in the mix region, respectively.

Characterization of Core Conditions: In a collaboration involving LLE, University of Wisconsin, and University of Florida scientists, direct-drive-implosion core conditions were characterized on OMEGA with time-resolved Ar *K*-shell spectroscopy. Plastic shells with an Ar-doped deuterium fill gas were driven with a 24-kJ, 1-ns square laser pulse smoothed with 1-THz SSD and PS. These targets are predicted to have a convergence ratio of ~16. The emissivity-averaged core electron temperature (T_e) and density (n_e) were inferred from the measured time-dependent Ar *K*-shell spectral line shapes. The Stark-broadened line profiles for the Ar He-β, -γ, and H-β resonant transitions and associated satellites were calculated using a second-order quantum mechanical relaxation theory. Significant changes in the Stark-broadened linewidths and the relative ratios of the Ar *K*-shell emissions occur during the course of the implosion. Comparisons were made between the modeled and measured spectra (Fig. 2) to infer a time history of the emissivity-averaged core T_e and n_e (Fig. 3). As shown in Fig. 3, a peak electron density of ~7 × 10^{24} cm^{-3} and an electron temperature of 2.5 keV are inferred from these observations. This represents the highest combination of electron density and temperature measured using x-ray spectroscopy in laser-driven implosions.

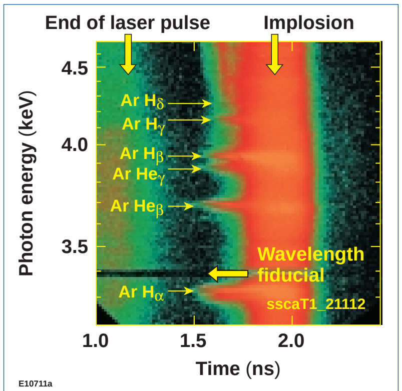

Figure 2. Time-resolved Ar *K*-shell spectral measurement for shot 21112. The x-ray streak camera was timed to capture the coronal plasma emission at the end of the laser pulse just after 1 ns and the implosion at 1.9 ns. The onset of the Ar *K*-shell line emission occurs during the shock heating beginning at ~1.5 ns, and the Stark-broadening increases as the implosion proceeds.

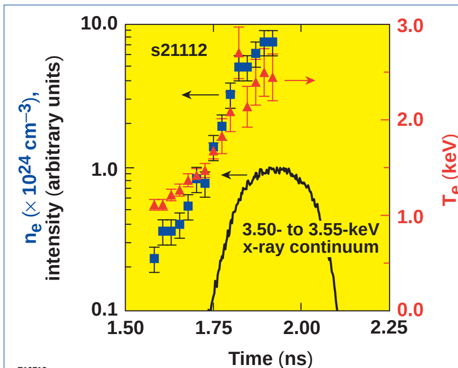

Figure 3. The time history of emissivity-averaged core electron temperature and density inferred from the time-resolved, Ar *K*-shell spectroscopy. The electron temperature and density rapidly rise from the beginning of the shock heating just after 1.5 ns to the implosion of the target at 1.9 ns. The x-ray continuum in the 3.50- to 3.55-keV range is shown for reference. As the imploding shell decelerates on its trajectory, the electron temperature increases from ~1 keV to ~2.5 keV and the electron density increases from ~0.2 × 10^{24} cm^{-3} to ~7 × 10^{24} cm^{-3}.

OMEGA Operations Summary: Over a period of nine shot days during December, 12 different experimental campaigns for a total of 82 target shots were conducted on OMEGA. National laboratory users from LLNL and SNL conducted 32 and 10 target shots, respectively, over a two-week span that also included 11 shots for an NLUF laboratory astrophysics experiment carried out by a team led by the University of Michigan. LLE continued the Rayleigh–Taylor instability (RTI) adiabat campaign with 29 target shots. Two days of laser power balance shots during the shortened holiday week were dedicated to tuning the laser for upcoming experiments.

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