June 2005 Progress Report on the Laboratory for Laser Energetics

Inertial Confinement Fusion Program Activities

Spectrally Resolved X-Ray Scattering Experiments: Initial x-ray scattering (XRTS) experiments were performed on the OMEGA laser system in collaboration with scientists from the Lawrence Livermore National Laboratory.[1] Their main goal is to measure the electron temperature T_e and average ionization Z in shock-heated, direct-drive targets.

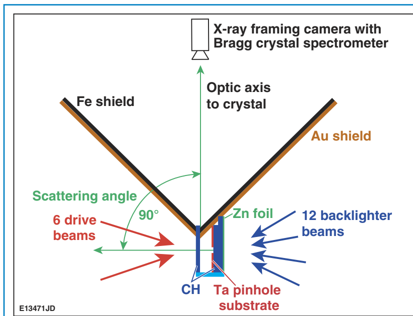

Figure 1. Schematic of the XRTS experimental configuration.

Figure 2. An XRTS target (right) compared in size to a penny.

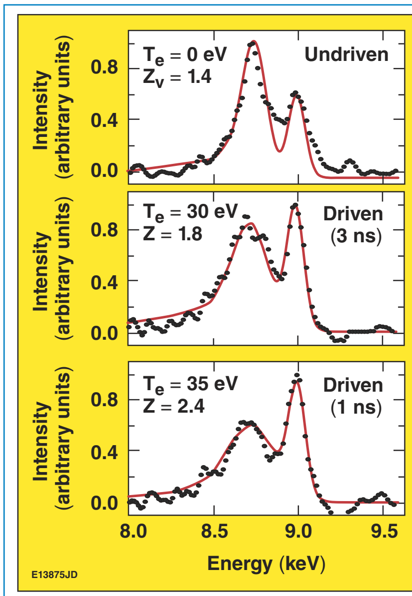

Figure 3. Scattered x-ray spectra for undriven (top), 3-ns driven (center), and 1-ns driven (bottom) targets. The measured spectra are represented by black dots. The solid red curves represent the calculated spectra. The spectral feature at 9.0 keV is the Rayleigh component of the scattered x rays; the feature at 8.7 keV is the Compton component.

The layout of the x-ray scattering experiment is illustrated in Fig. 1; a photograph of an XRTS target is shown in Fig. 2. A plastic, planar foil (125 μm thick) was irradiated with six overlapped beams with distributed phase plates (SG8 DPP's), which provide uniform drive intensity within the central 0.5 mm of the 1-mm laser spot. The 1-D hydrocode *LILAC* predicts that the shock-heated targets will have peak plasma conditions in the range $n_e \sim 1$ to 6×10^{23} cm^{-3}, $T_e \sim 10$ to 30 eV, and $Z \sim 0.5$ to 1.6. A 1-ns square laser pulse having a peak intensity of 5×10^{14} W/cm^2 generated a 50-Mbar shock in the plastic. A second set of experiments was carried out with a weaker 15-Mbar shock that was generated by a 3-ns square laser pulse with a peak intensity of 1×10^{14} W/cm^2. Around the time of shock breakout, the uniformly compressed region of the target was irradiated with 9-keV, He$_\alpha$ K-shell x rays from a Zn backlighter generated by 12 tightly focused beams. The x rays scattered at either 90° or 120° were dispersed with a Bragg crystal and recorded with an x-ray framing camera. The large Au/Fe shields block unwanted signals from direct lines of sight to the CH and Zn plasmas, which would overwhelm the scattered x-ray spectrum. A Ta pinhole substrate with a 400-μm aperture assures that the measured x rays are only scattered from the region of interest. The scattering angle is defined by the relative placement of the backlighter beams and the pinhole location.

The measured spectra from an undriven target (i.e., cold CH target), a 3-ns driven target, and a 1-ns driven target are shown in Fig. 3 (black dots), along with the modeled spectra (red curves). The spatially averaged plasma electron temperature (T_e) and average ionization (Z) are inferred from the spectral line shapes of the elastic Rayleigh and the inelastic Compton components. These two components correspond to scattering from tightly bound electrons (Rayleigh) and valence and free electrons (Compton). For the undriven targets, we find $T_e = 0$ eV and $Z_v = 1.4$, where Z_v is the average number of valence electrons. For the shock-driven targets, we find $T_e = 30$ (35) eV and $Z = 1.8$ (2.4) for the 3-ns (1-ns) laser pulses. The inferred T_e and Z for the driven targets are higher than the 1-D predictions and will be investigated in follow-up experiments using x-ray absorption spectroscopy.

OMEGA Operations Summary: During the month of June 2005, OMEGA conducted a total of 102 target shots for LLNL (22 shots), NLUF (8), CEA (22), SNL (11) and LLE (39). The two NLUF teams carrying out experiments in June were led by scientists from the University of Washington and the University of California, Berkeley, respectively. Scheduled maintenance activity was carried out in the last week of the month.

1. O. L. Landen *et al*., J. Quant. Spectrosc. Radiat. Transf. **71**, 465 (2001); S. H. Glenzer *et al*., Phys. Rev. Lett. **90**, 175002 (2003); G. Gregori *et al*., Phys. Rev. E **67**, 026412 (2003).

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