September 2006 Progress Report on the Laboratory for Laser Energetics
Inertial Confinement Fusion Program Activities

X-Ray Absorption Measurements of Areal Density in Cryogenic DT Implosions: In the implosion of fusion targets with cryogenic fuel (solid deuterium or deuterium–tritium mixture) a low-density hot spot is formed at the target center, surrounded by a colder layer of significantly higher density (ρ) and areal density ($\rho\Delta R$). The achievement of high $\rho\Delta R$ of the cold layer is required for ignition as this layer stops the charged fusion products, boosting the temperature and leading to ignition. Methods for measuring $\rho\Delta R$ based on nuclear particles (e.g., slowing down of secondary protons) are deployed on OMEGA. The $\rho\Delta R$ can also be determined from the absorption by the colder shell of continuum x rays emitted by the central hot spot.[1,2] The resulting x-ray continuum spectrum is measured by a pinhole-array spectrometer[3] that records several hundred images, each at a slightly different photon energy. An example of the data is shown in Fig. 1. The pinhole-array spectrometer is suitable for this measurement because of its ability to separate the core emission from that of outer layers. Because of the low x-ray absorption in the hydrogenic fuel, the absorption can only be observed at low photon energies (≤2 keV), where filters (or blast shields) compromise the measurement; the pinhole-array can be configured without any such filters and still avoid damage.

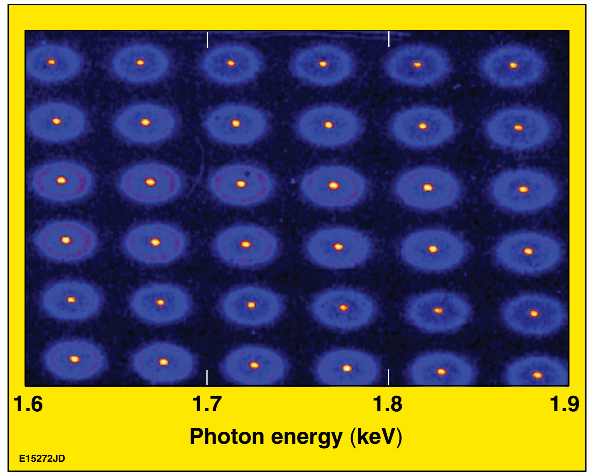

Figure 1. Data from pinhole (~50-μm-diam pinholes) array spectrometer for shot 44948: a cryogenic capsule containing deuterium (95-μm-thick layer) and irradiated with a low-adiabat ($\alpha \sim 1.3$) pulse with a total energy of 12.6 kJ. The array tilt spreads the images of each column along the energy axis. Each recording produces ~200 monochromatic images.

Figure 2 shows an example of the emitted spectrum from the implosion of a cryogenic–deuterium target using a low-adiabat ($\alpha \sim 1.3$) laser pulse. The spectrum calculated by the 1-D code *LILAC* is also shown, as well as the calculated spectrum that would have been emitted in the absence of absorption ("zero" opacity). The difference between the two curves is due to absorption by the cold shell and can be used to infer its areal density. The 1-D code was adjusted to account for 2-D effects to reproduce the observed spectrum. The information on the cold-shell $\rho\Delta R$ derives principally from the observed difference between the measured intensity at low photon energies (~1.5 keV) and the intensity obtained by extending the exponential high-energy spectrum to the lower energies. The slope of the measured spectrum at the higher photon energies yields the temperature of the emitting hot spot. Analysis of such spectra and comparison to particle-based measurement results are underway and promise to enhance our understanding of high-density cryogenic implosions.

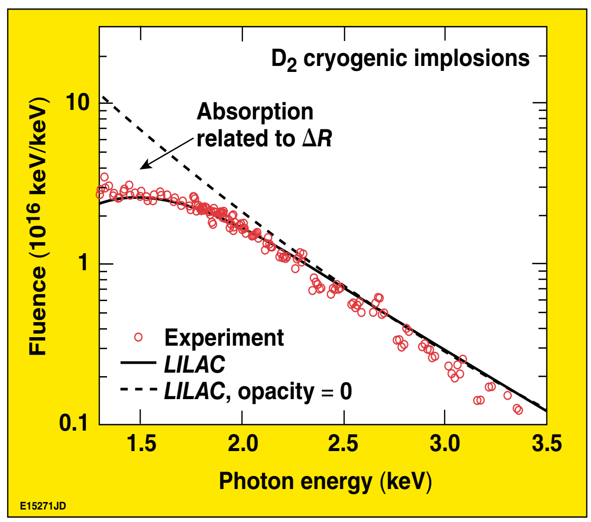

Figure 2. X-ray spectrum from shot 44948. Red circles correspond to the experimental measurement. The solid green line corresponds to the *LILAC*-predicted spectrum with 2-D corrections normalized to the experiment. The predicted areal density at peak x-ray emission for this shot is 180 mg/cm^2. The dashed line shows the predicted spectrum in the case of a zero-opacity plasma.

OMEGA Operations Summary: A total of 81 target shots were taken in September on OMEGA for experiments led by LLE (58), LLNL (16), and SNL (7). Of these shots, 67 were for the National Ignition Campaign.

1. B. Yaakobi, R. Epstein, and F. J. Marshall, Phys. Rev. A **44**, 8429 (1991).
2. F. J. Marshall *et al.*, Phys. Rev. E **49**, 4381 (1994).
3. B. Yaakobi, F. J. Marshall, and D. K. Bradley, Appl. Opt. **37**, 8074 (1998).

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