June 2001 Progress Report on the Laboratory for Laser Energetics
Inertial Confinement Fusion Program Activities

UR LLE

Shell Mix in Compressed Core of Spherical Implosions: The amount of CH shell material in the compressed core of spherical implosions has been estimated by comparing time-resolved spectroscopic measurements with nuclear measurements of fuel areal density (ρR) and core x-ray images on OMEGA. The deuterium fuel of a plastic capsule was doped with trace amounts of Ar, and the core electron density was determined by measuring the time-dependent, Stark-broadened Ar K-shell emissions. Figure 1(a) shows the spectrum recorded at the estimated time of peak neutron emission for shot 22507, along with the modeled spectrum, which includes the contribution from the background bremsstrahlung emission. The electron temperature and density at this time are inferred to be $T_e = 2.0(\pm 0.2)$ keV and $n_e = 2.2(\pm 0.5) \times 10^{24}$ cm^{-3}, respectively. As the implosion proceeds to peak compression, the inferred electron density continues to increase to $3.1(\pm 0.6) \times 10^{24}$ cm^{-3}, while the electron temperature decreases to $1.7(\pm 0.17)$ keV. The spectrum measured at peak compression is shown in Fig. 1(b) along with the modeled results. The measured core n_e has a contribution from the deuterium fuel, the Ar dopant, and the CH shell material that is mixed into the core [i.e., $n_e = n_e(\mathrm{D}) + n_e(\mathrm{Ar}) + n_e(\mathrm{CH})$]. Nuclear measurements of fuel ρR are combined with x-ray core images to estimate the fuel density. The estimated fuel density, $4.4(\pm 1.3)$ g/cm^3, accounts for ~60% of the neutron-burn-averaged electron density. The small contribution from the Ar dopant known from target metrology is $n_e(\mathrm{Ar}) = 4.0(\pm 0.8) \times 10^{22}$ cm^{-3}. Plastic shell material that has mixed into the core contributes the remaining electrons, resulting in an estimated density of $2.6(\pm 0.8)$ g/cm^3.

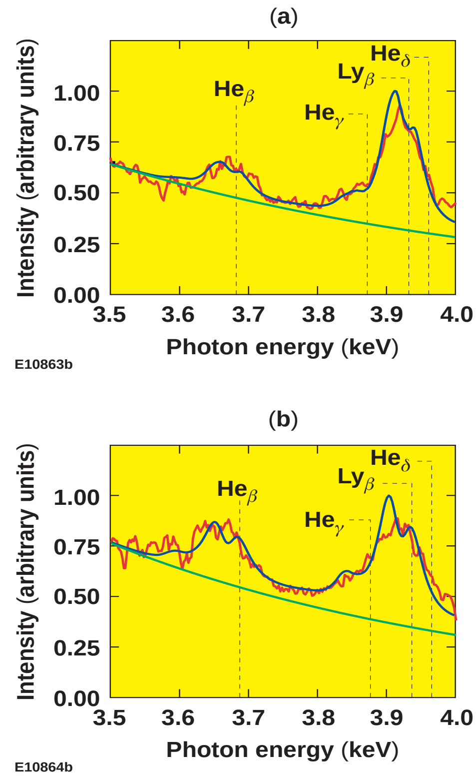

Figure 1. The measured spectra (red curves) and modeled spectra (blue curves) in the 3.5- to 4.0-keV range at (a) $t = 1.93$ ns corresponding to the time of peak neutron emission (inferred $T_e \sim 2.0\pm 0.2$ keV, $n_e \sim 2.2\pm 0.5 \times 10^{24}$ cm^{-3}) and (b) $t = 2.01$ ns, corresponding to the time of peak x-ray emission (inferred $T_e \sim 1.7\pm 0.17$ keV, $n_e \sim 3.1\pm 0.6 \times 10^{24}$ cm^{-3}). The green curve represents the background bremsstrahlung emission spectrum, and the vertical dotted lines represent the unshifted line centers of the Ar K-shell resonance lines.

Tertiary Neutron Diagnostic: Measurement of tertiary neutron yield (15 to 30 MeV) has been proposed as a method to determine the ρR of high-density DT capsules. A carbon activation [^{12}C (n, 2n) ^{11}C] reaction with a threshold of 18.7 MeV is a possible means of measuring these neutrons. The isotope ^{11}C decays with a half-life of 20.3 min and emits a positron, resulting in the production of two 511-keV gamma rays upon annihilation. The carbon activation diagnostic requires very pure carbon samples, free from any positron-emitting contamination. In recent years LLE, together with SUNY Geneseo, has developed carbon purification, packaging, and handling procedures that minimize the contamination signal level. Experiments were performed recently to determine the combined signal level produced by cosmic ray background and contamination of the carbon activation system. For a capsule with a DT neutron yield of 4.7×10^{13} and no significant expected tertiary signal, a combined background and contamination signal of 40 counts per hour was obtained. In comparison, 1-D simulations of OMEGA cryogenic DT capsule implosions indicate that the same carbon sample would detect 2000 to 3000 counts per shot from tertiary neutrons. This signal would be well above the background/contamination level and should yield reliable estimates of fuel ρR for cryogenic DT capsules.

OMEGA Operations Summary: OMEGA was operated for four full shot weeks during the month of June. The system availability was excellent and resulted in 126 shots over the 12 shot days. LLE used one week for spherical targets (33 shots). LLNL campaigns (44 shots) were spread over a dedicated week and a split week that included shots for CEA (12 shots) and the NLUF (9 shots). LANL users used a full week for three campaigns that included a high-neutron-yield day for neutron diagnostic development (28 shots).

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