July 2007 Progress Report on the Laboratory for Laser Energetics

Inertial Confinement Fusion Program Activities

Rapid Heating of Solid-Density Matter During High-Intensity-Laser Interactions: Small mass targets are of interest in high-intensity laser–solid interactions because of their unique fast-electron-transport properties.[1,2] Electron refluxing by the Debye sheath fields that are set up at the target surfaces provides a unique environment for studying the rapid heating of solid-density matter and determining the laser-to-electron energy conversion efficiency. Previous measurements of the absolute K_α yield from copper foils as a function of the laser intensity demonstrate excellent agreement with electron-refluxing models and laser-to-electron energy conversion efficiencies of ~20%.

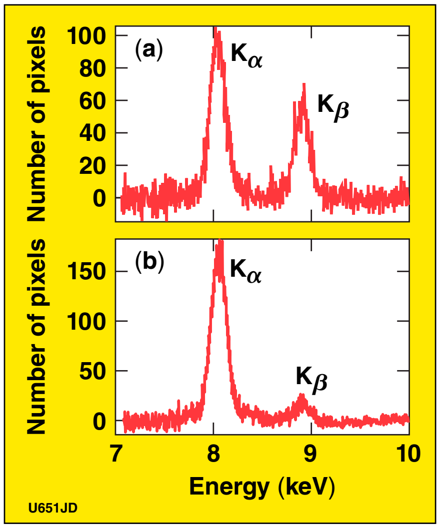

Figure 1. Copper K-shell spectra for (a) 500 × 500 × 20-μm and (b) 20 × 20 × 2-μm targets and a laser intensity of 2×10^{19} W/cm^2.

Ionization of the M-shell during volumetric heating within such small mass copper targets can cause a deviation in the ratio of the number of emitted K_β and K_α photons below the cold material limit. For sufficiently high energy densities, it is possible to impact both the K_α and K_β emission probabilities. This is a direct consequence of bulk target heating because of fast-electron energy loss. Such a deviation could provide a useful code benchmarking parameter on the energy content of the fast electrons and a consistency check on the laser–electron-conversion efficiency. To study this effect, copper foil targets ranging in size between 500 × 500 × 20 μm and 20 × 20 × 2 μm were irradiated by LLE's Multiterawatt (MTW) laser system with 1-ps-duration pulses at intensities of 2×10^{19} W/cm^2. The nonthermal plasma K-shell line emission was measured approximately normal to the target surface with an x-ray CCD operating in the single-photon-counting mode.[3]

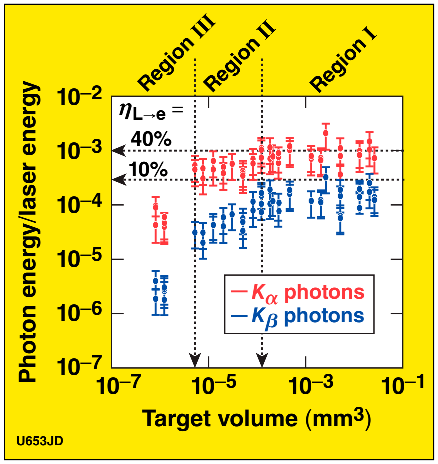

Figure 2. Variation in the K_α and K_β photon energies (normalized to the laser energy) as a function of target volume. The absolute K_α yield is compared to a semi-analytic model in the cold-material limit to infer the laser–electron conversion efficiency, $\eta_{L\to e}$.

Figure 1 shows example copper K-shell spectra from a 500 × 500 × 20-μm target (a) and a 20 × 20 × 3-μm target (b). M-shell depletion due to target heating in the 20 × 20 × 3-μm target and its impact on the emission of K_β photons is clearly observable. Figure 2 shows the ratio of the number of emitted K_β and K_α photons (NK_β/NK_α—normalized to the cold material limit) as a function of the target volume. Three distinct regions are accessible experimentally: from the cold material limit in Region I, to the onset of M-shell depletion in Region II, to the highest energy-density environment observed in Region III, where both the K_α and K_β emission are significantly affected. The absolute K_α yield is compared to a semi-analytic model of K_α production to infer the laser–electron conversion efficiency, $\eta_{L\to e}$. A value of 20% to 30% is in good agreement with previous measurements to within the experimental errors and indicates the achievement of an electron temperature of ~200 eV at a solid density. Three-dimensional numerical calculations are currently underway using the implicit-hybrid particle-in-cell code *LSP*, coupled with a collisional-radiative code and a K-shell emission postprocessor, to infer the energy content of the fast electrons that will enable a direct comparison against the predictions of the absolute K_α yield semi-analytic model.

OMEGA Operations Summary: During July 2007, 103 OMEGA target shots were conducted (with an overall shot effectiveness of 99%) for experiments led by LLE (68), LLNL (29), and NLUF (6). The NIC IDI program accounted for 23 of these shots; 50 target shots were provided to the NIC DDI campaign, and the remaining 30 shots were for various non-NIC programs. The ASBO off-axis telescope was qualified for use on the P6/P7 axis during this month.

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1. W. Theobald *et al.*, Phys. Plasmas **13**, 043102 (2006).
2. J. Myatt *et al.*, Phys. Plasmas **14**, 056301 (2007).
3. C. Stoeckl *et al.*, Rev. Sci. Instrum. **75**, 3702 (2004).

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