High-Resolution X-Ray Line-Shape Spectroscopy of Hot Dense Matter: Experiments investigating the transition from solid to hot dense plasma conditions at temperatures approaching several million Kelvin are being carried out on the OMEGA EP laser to evaluate the effects of hot dense plasma environments on atomic structure and interaction rates. The goal is to measure detailed x-ray line shapes from plasmas in extreme thermodynamic conditions and test the predictions of different heating and atomic physics models. For the experiments, Cu foils with different thicknesses and aspect ratios were irradiated with up to 650-J, 10-ps pulses focused to intensities above 10^{18} W/cm^2. Figure 1(a) shows the laser–target interaction geometry. The high-power laser–matter interaction generates a hot-electron population with MeV energies that transports energy away from the laser-focal region and into the target. Collisional and collective (electromagnetic) processes couple energy to the target over 10 to 20 ps or less.

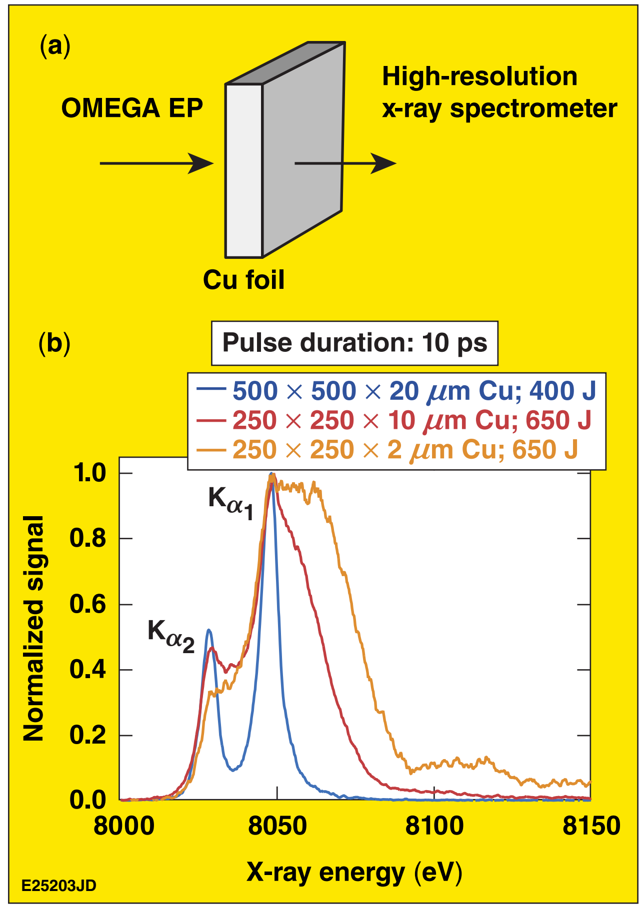

Figure 1. (a) The experimental setup for x-ray line-shape spectroscopy on the OMEGA EP Laser System. (b) Time-integrated $K_{\alpha 1,2}$ emission spectra from 500- × 500- × 20-μm (blue), 250- × 250- × 10 μm (red), and 250- × 250- × 2-μm (orange) Cu foils irradiated with 400-J or 650-J, 10-ps pulses from OMEGA EP.

Figure 1(b) shows example time-integrated K-shell emission spectra from three different target interactions. The target dimensions were 500 × 500 × 20 μm (blue), 250 × 250 × 10 μm (red), and 250 × 250 × 2 μm (orange). The data were measured using the time-integrated channel of the high-resolution x-ray spectrometer (HiResSpec) recently developed at the Laboratory for Laser Energetics in collaboration with scientists from the Princeton Plasma Physics Laboratory.[1] Highly resolved Cu $K_{\alpha 1,2}$ emissions is observed from the 500 × 500 × 20 μm target (blue). The radiation is generated by hot electrons colliding with Cu ions in the bulk-target material. Increasing the laser energy and decreasing the target volume accesses higher-energy-density conditions, shifting and broadening the K_α emission spectrum to higher photon energies (red and orange). These detailed line-shape measurements will be used to test the predictions of different target heating and collisional-radiative model predictions that account for changes in the hot-electron population and the ionization distribution of the emitting material over the heating period. The data provide a firm foundation for future experiments that will explore the time-dependent nature of x-ray line shifting and broadening from metals in the hot-dense-matter regime.

Omega Facility Operations Summary: The Omega Laser Facility conducted 289 target shots with an average experimental effectiveness (EE) of 92.9% in August 2017. The OMEGA laser accounted for 171 shots (with EE = 91.8%) while OMEGA EP carried out 118 shots (with EE = 94.5%). The ICF program accounted for 76 of these target shots for experiments led by principal investigators (PI's) from LANL, LLNL, and LLE. The HED program had 94 shots for LANL, LLNL, and LLE. Ten target shots were taken for an LLE ARPA-E funded experiment. The LBS program conducted 24 target shots for experiments led by LLNL and LLE; and the NLUF program carried out 73 shots for experiments led by PI's from the University of Michigan, MIT, Princeton University, and General Atomics. Finally, 12 target shots were taken for a CEA experiment.

1. P. M. Nilson *et al*., Rev. Sci. Instrum. **87**, 11D504 (2016).