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(I) Homogeneous, Micron-scale High Energy Density Matter Generated by Relativistic Laser-solid Interactions

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Short-pulse, laser-solid interactions provide a unique platform for studying complex high-energy-density (HED) matter. HED matter exists in extreme states of temperature and density, producing conditions comparable to those found within astrophysical environments. Elucidating the relationship between temperature, pressure, and density in HED environments is critical for understanding the physics of stellar interiors and the achievement of inertial confinement fusion. However, developing an accurate description of HED conditions in this regime remains an experimental and theoretical challenge rapidly evolving conditions and spatial inhomogeneities present in laboratory plasmas.

In this talk, I will discuss our recent work performing high-resolution X-ray spectroscopy of copper K-shell emission from high-intensity (I ~ 10^{21} W/cm^2) laser experiments using the ALEPH laser at Colorado State University. The fielding of two X-ray spectrometers, including a newly developed high-resolution hard X-ray spectrometer, enabled the study of K-shell absorption effects to determine the plasma heating profile. Numerical modeling using collisional-radiative and 3D particle-in-cell codes reveals that solid-density plasmas were produced with electron densities exceeding 10^{24} cm^{-3} and temperatures exceeding 3 keV. This micron-scale homogeneity, not observed when using the laser fundamental wavelength of 800 nm, is attributed to the trapping and refluxing of the few MeV electrons within the target sheath fields. The capability of generating such hot, homogeneous, solid-density plasmas over large length-scales using mid-scale, short-pulse laser facilities provides novel and highly accessible experimental platforms that may be used for a wide range of HED applications.

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