Direct measurement of ion temperature and electron-ion equilibration in warm dense matter

Bob Nagler

SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, CA 94025, USA

To understand or model the behavior of a dense plasma or Warm Dense Matter, accurate knowledge of the temperature is crucial. Nevertheless, such measurements remain elusive. While some methods exist to determine the electron temperature, directly measuring the ion temperature in rapidly evolving (and potentially out-of-thermal-equilibrium) samples has eluded scientists. In this presentation, we will introduce a method to directly and model-independently measure the ion temperature of a gold sample with temperatures up to a few eV. Using a high-resolution (50 meV) x-ray scattering platform developed at the LCLS x-ray free-electron laser, we can measure the width of a quasi-elastic Rayleigh peak. In the back-scattering geometry, the width of this peak directly reveals the velocity distribution of the ions and their corresponding temperature, due to the Doppler shift of the scattered photons. We use this diagnostic to track the ion temperature evolution in thin gold samples after irradiation by a short-pulse laser. In this way, we unambiguously determine the electron-ion relaxation dynamics in Warm Dense Gold. Furthermore, in combination with x-ray diffraction, we can determine the Debye temperature when the heated gold remains crystalline, resolving a decades-old controversy regarding changes in bond strength in laser-excited gold.