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Developing x-ray fluorescence spectroscopy as a temperature diagnostic for high-energy-density physics experiments[1]

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Electron temperature is a fundamental parameter used to characterize plasmas of all types. Yet, in the case of HED plasmas, there are very few temperature diagnostics, and many have limited utility. Here we present a technique using x-ray fluorescence (XRF) spectroscopy, which enables temperature measurements in HED experiments where other temperature diagnostics are not currently available. XRF interrogates the plasma with an external energy source (typically x-rays or electrons) to fluoresce specific ions in a plasma to determine the ion distribution, and in turn the plasma temperature. By optimizing the fluorescing element and emission lines for the expected plasma conditions, excellent temperature sensitivity can be achieved over a broad range of plasma conditions. XRF measurements have several advantages over other diagnostics. For example, XRF can probe a specific spatial region of the plasma either by localizing the fluoreser element to the region of interest, by exposing only a limited region of the plasma to the probe source, or a combination of both. XRF is also sensitive to much lower temperatures than traditional x-ray emission spectroscopy for a given photon energy, owing to the fact that the fluorescer ions are at a lower charge state. In addition, the signal is much brighter than similar scattering measurements due to the fact that XRF uses the photoelectric absorption cross section, which is several orders of magnitude larger than scattering cross sections for photon energies of typical x-ray backlighters in HED experiments. We present experimental results using XRF spectroscopy to infer temperatures in shocked foams at the Trident laser facility [1] and ongoing experiments at the Omega laser facility to improve atomic models required to interpret XRF data to extract plasma temperatures. This talk will explore how to optimize XRF measurements for various plasma conditions and how the technique could be applied to HED hydrodynamics experiments where there is a significant need for reliable temperature measurements. [1] M. J. MacDonald et al. J. Appl. Phys. 120, 125901 (2016).

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