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Free-electron laser measurements of plasmons in warm dense matter

ELISEO GAMBOA, SLAC National Accelerator Laboratory

Strong plasmon resonances characteristic of electron density fluctuations in warm dense matter (WDM) plasmas have recently been observed for the first time at the Linac Coherent Light Source (LCLS). These experiments record forward scattering from ultrabright 8 keV x-ray pulses to probe dynamically compressed solids driven by shaped ns laser pulses at the Matter in Extreme Conditions (MEC) instrument. From the x-ray scattering spectra we observe well-pronounced plasmon peaks that directly access the electron densities and temperatures. We can access densities >5 g/cm^3 and pressures approaching 5 Mbar that are important for planetary and material science as well as inertial confinement fusion research. In this talk we characterize the plasmon loss against wavenumber-resolved x-ray scattering that provides an independent density measurement through shifted Bragg and ion-ion correlation scattering features. We will compare ideal plasma states achieved in heated aluminum with those measured from uncompressed and compressed CVD diamond. The latter shows plasmon energies strongly affected by the band structure up to the highest experimental pressures of several Mbar. This method is presently being applied in numerous experiments to characterize the physical properties of dense plasmas. We will describe the first demonstration of this technique at LCLS, present applications to characterize shocks in dense plasmas, and discuss novel ideas for measuring the properties of high-pressure materials.