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X-ray Scattering as a Microscopic Probe for Solid Density Plasmas

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X-ray scattering has been used extensively for 75 years to obtain information on the microscopic structure of cold solid matter. Similarly, visible and UV light scattering using intense lasers has been used for 30 years to characterize low density short-lived plasmas in the laboratory. We have combined the two techniques to directly characterize for the first time the microscopic state of solid density plasmas that is inaccessible to visible light. Such characterization will allow for improved understanding of macroscopic dense plasma properties such as x-ray transmission, heat capacity, and thermal and electrical conductivity. The first proof-of-principle x-ray scattering experiments and analysis were performed by plasma physicists from Lawrence Livermore National Laboratory using the Laboratory for Laser Energetics OMEGA laser facility in Rochester, NY (Siegfried H. Glenzer, 925-422-7409, **glenzer1@llnl.gov**, Gianluca Gregori, 925-42 **ggregori1@llnl.gov**.) The original idea appeared in 2000 in the Journal of Quantitative Spectroscopy and Radiative Transfer, and two papers reporting on the results and analysis been submitted recently.

In the proof-of-principle experiment, a mm-sized sample of solid beryllium was heated uniformly at up to 600,000° K using x-rays from a laser-initiated hot plasma produced at the surface of the beryllium. One nanosecond later, before the hot beryllium plasma had a chance to explode and drop in density, a second set of laser beams were focussed on a titanium foil to produce a narrowband source of probe x-rays at ≈ 2.6 Å. Those 2.6 Å x-rays that scatter from the free electrons in the beryllium are Doppler-shifted in wavelength by an amount that depends on the speed (and hence temperature) of the electrons in the plasma. The scattered x-rays are spectrally resolved by an efficient diffractive crystal and x-ray detector. The data below show the expected broadening of the spectra to longer wavelengths when comparing unheated to heated beryllium. We will also describe at the APS DPP meeting a theoretical model combining scattering theory with dense plasma theory for fitting the data and hence extracting the temperature (600,000° K in the example below), density and degree of ionization of the plasma.

Such direct access to microscopic parameters of solid density and super-solid density plasmas is of great interest in inertial confinement fusion, laboratory astrophysics, and warm dense matter research. For example, x-ray scattering should be able to diagnose conditions of the 1000x compressed fuel in inertial confinement fusion plasmas.

Figure Caption: X-ray scattered spectra from heated beryllium, cold beryllium and original unscattered spectrum