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X-ray Scattering Measurements from Near-Degenerate Plasmas at Gbar pressure at the National Ignition Facility[1]

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Precise knowledge of ionization is required to accurately model compressibility, heat capacity, and the equation of state of materials at extreme conditions. This requires a good understanding of ionization potential depression in dense plasmas, which is an area of vigorous scientific debate, motivated by experiments that have found higher ionization than predicted by widely used theoretical models.[1,2] NIF enables near-degenerate plasmas to be probed at unprecedented densities and pressures. We have developed an experimental platform for x-ray Thomson scattering (XRTS) at NIF to characterize the plasma conditions in ICF capsule implosions near stagnation.[3,4] The electron density and temperature can be inferred from the inelastic Doppler-broadened Compton scattering signal. The ratio of elastic to inelastic scattering is a measure of ionization level.

I will present XRTS results from Be, carbon, and CH capsule implosions that reached mass densities up to 50 g/cm^3, accessing near- degenerate plasmas where the electron density exceeds 1e+25 cm^{-3}, the Fermi energy approaches 200 eV, and the pressure exceeds 1 Gbar. These experiments find higher ionization than predicted by widely-used ionization models, and we see evidence for pressure ionization of the Be K-shell. At mass densities greater than 20 g/cm^3, the results show an additional reduction of elastic scattering associated with the delocalization of bound K-shell electrons, which eventually leads to a fully ionized plasma at sufficiently high densities, and affects the compressibility of matter, which can be measured by radiography.[5]

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[2] D. Kraus, T. Döppner et al., Phys. Rev. E **94**, 011202(R) (2016).
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[4] D. Kraus, T. Döppner et al., J. Phys. Conf. Ser. **717**, 012067 (2016).
[5] T. Döppner, Phys. Rev. Lett. **121**, 025001 (2018).

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