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Full Equation of State Measurements of Warm Dense Carbon Using a Novel Technique of Shock and Release

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The equation of state of light elements at high densities and moderate temperatures falling in to the warm dense matter (WDM) regime is essential to understanding the structure of Jovian planets as well as inertial confinement fusion (ICF). In these systems quantum degeneracy and strong inter-particle forces are significant making the theoretical description of WDM extremely challenging. Here we present results from a combination of experimental techniques used to characterize thermodynamic properties of warm dense carbon at different conditions. The Omega laser was used to create WDM conditions at solid density and temperature $\sim 1 - 10$ eV, using the novel technique of laser driven shock and release. The graphite or diamond targets are first strongly shocked by a direct laser drive in planar geometry and then let undergo a large pressure release into the well-characterized low density pressure standard (SiO_2 aerogel foam) [1] creating conditions significantly different from the Hugoniot states typically studied on high power laser facilities. Direct measurement of electron temperature and density/ionization of warm dense carbon was obtained by spatially resolved x-ray Thomson scattering (XRTS). The Imaging X-ray Thomson Spectrometer [2], recently developed for Omega by LANL and the University of Michigan, provided the spatial resolution crucial to isolating the signal from the release wave avoiding contamination of the XRTS signal. VISAR and SOP were used to determine the shock velocity in the pressure standard which provided the pressure in the released carbon. X-ray radiography was employed to obtain an independent measurement of the mass density by transmission through the warm dense carbon. Various equation of state models are compared to the experimental results.

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[2] E. J. Gamboa, D. S. Montogomery, I. M. Hall, and R. P. Drake, JINST 6, P04004 (2011); E. J. Gamboa et al., Rev. Sci. Instrum. 83, 10E108 (2012).