Measuring the Hugoniot and material properties of plastic to Gbar pressures

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Experiments are being done at the National Ignition Facility to measure the Hugoniot of materials such as plastic at extreme pressures. In these experiments, a strong spherically converging shock is launched through a solid ball of material using a hohlraum radiation drive. The shock front conditions are characterized using X-ray radiography which enables a measurement of the Hugoniot up to pressures near a Gbar. By tracking the temporal history of the shock wave a locus of Hugoniot points is measured in a single experiment. For CH a single low drive NIF experiment measured Hugoniot points from 25 – 120 Mbar while a high drive NIF shot measured the Hugoniot from 120 - 720 Mbar. These experimental results are compared with theoretical results. At the higher pressures shell effects from K-shell ionization start to affect the compressibility. Eventually the background from shock coalescence overtakes the signal from the 9-keV backlighter and limits the pressure that can be measured.

As the shocks coalescence at the center the pressure reaches tens of Gbars and can be further characterized by measuring the X-ray self-emission from the shock flash region. In one experiment the standard plastic sphere was replaced with a deuterated polyethylene sphere that reached sufficiently high densities and temperatures in the central hot spot to produce neutrons from DD fusion reactions that can be measured by a neutron time of flight spectrometer (nTOF) and act as a temperature diagnostic. From the nTOF spectral width an average ion temperature of 1.06 keV is measured in the central hot spot with a measured neutron yield of 7.0 x 10^9 DD neutrons. The experimental data is compared to simulations that predict mean temperatures of 1 keV in the central hot spot with mean densities of 33 g/cc and mean pressures of 25 Gbar.

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