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Experimental observation of elevated heating in dynamically compressed CH foam

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Abstract

We present an experimental result of significantly increased heating in a laser-driven blastwave experiment carried out at the OMEGA laser facility. Abnormally high temperatures were observed in warm dense CH compared to older experiments and theoretical predictions. The higher temperatures in compressed CH were linked to an improved smoothness of the laser intensity profile, which resulted in better efficiency of the drive and coupling of more energy into the system compared to previous similar experiments. Fifteen beams with combined intensity of $\sim 7\times 10^{14}$ W cm^{-2} and a square intensity profile with 2 ns duration were used to drive a strong shock, which subsequently developed to a blastwave travelling through low density CH foam creating warm dense matter. Multiple diagnostics were used to examine the thermodynamic conditions in the warm dense CH foam. Velocity interferometry (VISAR) and streaked pyrometry (SOP) observed increased blastwave velocities, while x-ray Thomson scattering (XRTS) measured elevated temperatures of $17.5 - 35$ eV in compressed CH foam. The experimental results were compared to hydrodynamic simulations and a potential contribution from x-rays to the elevated temperatures in the dense material was considered.

Keywords: warm dense matter, heat transport, laser plasmas, dynamic compression, shock physics

(Some figures may appear in colour only in the online journal)

1. Introduction

The understanding of thermodynamic properties and dynamic behavior of materials at extreme conditions of high energy density (HED) states is crucial for research in laboratory astrophysics, specifically the cores of Jovian planets, white and brown dwarfs [1–3], and Inertial Confinement Fusion (ICF) [4]. This Warm Dense Matter (WDM) regime is characteristic for moderately high temperatures of 0.1–100 eV, solid densities, and often exists at pressures above 1 Mbar. Under such extreme conditions, ions are strongly correlated and the electron population is partially or fully degenerate, which results in increased challenge for any theoretical model as well as standard experimental diagnostic systems. Specifically, transport of radiation and particles through WDM influences the layer structure and convection of astrophysical objects, and electrical conductivity strongly affects magnetic fields generated by planetary core dynamos [5]. The efficient design of