SHOCK13-2013-020111

Abstract for an Invited Paper
for the SHOCK13 Meeting of
the American Physical Society

Isochoric heating using proton beams and shock compression generated by UHI lasers

MARKUS ROTH, Technische Universität Darmstadt

Material conditions in the Warm Dense Matter (WDM) regime are of great interest for high energy density physics, the development of controlled thermonuclear fusion and astrophysics. Each experiment involving high energy deposition will be strongly affected by the sample's changed behavior in the WDM regime. In particular, carbon is an interesting material for warm dense matter studies, as it is accessible experimentally since carbon samples can easily be manufactured and handled in the laboratory. Due to its low number of electrons, a number of theoretical and numerical techniques, including ab-initio simulations, allow for the description of its properties within the computational resources available today. Additionally, the solid-liquid phase transition of carbon is in the warm dense matter regime and may play a major role in the physics of ice giants like Neptune and Uranus [1, 2] and white dwarfs [3]. This transition is poorly understood so far and further investigation is needed [4]. In fact, the solid-liquid phase transition on the graphite Hugoniot has never been measured reliably so far. A recent new option is the use of x-rays which are able to access the processes inside the sample. In comparison to radiography x-ray scattering cannot only measure the propagation of a shock but also the microscopic structure inside the sample [5, 6, 7]. Thus, strong changes in the structure due to the phase transitions induced by shock or isochoric heating can be measured directly. The creation of fluid carbon requires a rapid energy input, preferably into a large volume. Ion beams are a unique tool for that task as they deposit their energy deep in the target resulting in a uniform heating profile. Ultra-short proton bursts generated by high-intensity laser beams match both the high particle number and the short pulse length required to create fluid carbon without noticeable expansion. In this talk we present the measurement of the microscopic structure change of graphite in a heated sample and in a laser driven shock with x-ray scattering. This method was first applied for the carbon solid-liquid phase transition at lower pressure in a proof-of-principle experiment where the isochoric heating was realized by laser-accelerated protons [8]. However, in this first experiment only the relative increase of the total scattering signal was measured. It was not possible to distinguish between the elastic and inelastic features. In the experiment presented in this talk, we have obtained frequency-resolved scattering spectra, which allow to study the evolution of both the elastic and the inelastic features separately.

[1] W. B. Hubbard et al., Science 253, 648 (1991) [2] S. Stanley and J. Bloxham, Nature 428, 151 (2004) [3] P. Dufour et al. Nature 450, 522 (2007) [4] A. A. Correa, S. A. Bonev and G. Galli, Proc. Natl. Acad. Sci. USA 103, 1204 (2006) [5] S. H. Glenzer and R. Redmer, Rev. Mod. Phys. 81, 1625 (2009) [6] E. Garcia Saiz et al., Nature Physics 4, 940 (2008). [7] K. Wünsch, J. Vorberger, and D.O. Gericke, Phys. Rev. E 79, 010201(R) (2009). [8] A. Pelka, G. Gregori, D. O. Gericke et al., Phys. Rev. Lett. 105, 265701 (2010) .