Dynamic compression experiments on deuterium and their implications for first-principles theory

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Recently a so-called shock-ramp platform has been developed on the Sandia Z Accelerator to access off-Hugoniot states in liquids. The accelerator delivers a two-step current pulse; the first accelerates the electrode to a reasonably constant velocity, which upon impact with the sample cell creates a well-defined shock, the subsequent current rise produces ramp compression from the initially shocked state. This technique generates relatively cool (~1-2 kK), high pressure (>300 GPa), high compression states (~10-15 fold compression), allowing experimental access to the region of phase space where hydrogen is predicted to undergo a first-order phase transition from an insulating molecular-like liquid to a conducting atomic-like liquid. In this talk we will discuss the experimental platform, survey the various theoretical predictions for the liquid-liquid, insulator-to-metal transition in hydrogen, and present the results of experiments that clearly show an abrupt transition to a metallic state. We will also present recent Hugoniot and reshock data for deuterium with unprecedented precision in the vicinity of the molecular-to-atomic transition. These data not only establish maximum compression along the Hugoniot at 4.5-fold, but also enable high-fidelity comparisons with first-principles theory. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.