Thermodynamic properties and time-resolved spectrum of warm dense helium plasmas

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Abstract: Warm dense matter has important application in astrophysics, thermonuclear fusion, and new energy development under extreme pressure and temperature conditions, prompting the need for thermodynamic properties of helium under shock compression. Multi-shock experiments on dense gaseous helium in the 150 GPa pressure range are presented. By means of a multi-channels pyrometer and a Doppler- pins-system, the time-resolved optical radiation histories and interface particle velocity profile history were measured. Compared with liquid helium, dense helium with higher dynamic compression ($\rho_{\text{H}}/\rho_0=4–48$) and number density have been obtained due to the increase of electronic excitations and ionizations, which leads to a large drop of thermal pressure and softening of Hugoniot. The time-resolved transience radiance spectrum was performed to analyze the temperature (1–3eV) of helium under multi-compression and ionization. Experimental data have efficiently validated the self-consistent fluid variational theory (SFVT) considering partially ionized plasma. Current techniques and results can serve the designs of fusion experiments and astrophysics physics.

Keywords: warm dense helium; multi-shock compression; equation of state; time-resolved spectrum