Laser-Shock Compression and Hugoniot Measurements of Liquid Hydrogen

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Hydrogen at high pressure in the fluid state is of great interest for understanding interiors of gas giant planets. Although it is difficult to generate high pressures in hydrogen because of its low shock impedance, it can be possible to generate an extreme condition comparable to the deep inside of Jupiter using shock waves excited by high-intensity lasers. Then we carried out laser-shock compression of liquid hydrogen and measured the thermodynamic properties of the shocked state. The experiment was performed on the Gekko-XII/HIPER laser facility at the Institute of Laser Engineering, Osaka University and successfully obtained the Hugoniot data up to 50 GPa. This pressure range is about 5 times higher than the earlier experiments done by a two-state gas gun.

The quartz was used as the reference standard for the impedance-matching measurement. Targets consisted of an aluminum ablator and liquid hydrogen layer which is sandwiched by 50 um-thick alpha-quartz plates. The hydrogen was cooled to 15 K and thus the initial density is 0.076 g/cc. A spatially smoothed laser beam (wavelength of 0.35 um) with an intensity of several times 1013 W/cm2 irradiated the target for 2.5 ns. Shock velocities in the quartz and liquid hydrogen were measured using a line-imaging velocity interferometer system for any reflector (VISAR). Two VISARs with different velocity sensitivities were run concurrently to resolve the phase shift ambiguities.

Velocities immediately before and after the shock crossed the quartz-hydrogen interface were used in the impedance-matching analysis. The shock velocities in quartz and hydrogen extracted from the VISAR trace are 21 km/s and 30 km/s, respectively. The shock pressure in the compressed hydrogen is then estimated to be 53 GPa. The shock compression is 4.5 and consistent with a stiffer EOS model.

In this presentation, we will also discuss about the temperature measurements and comparison of our data with theoretical EOS models and the deuterium results.