X-ray Diffraction of Warm, Dense Fluids in the Laser-Heated Diamond Cell

Benedetti L.R., Sihachakr D. *, Dewaele A. *, Weck G. *, CrichtonW., Mezouar M., Loubeyre P.*

European Synchrotron Radiation Facility, BP 220, 38043 Grenoble Cedex, France
*SPMC/DPTA, Comissariat à l'Energie Atomique, 91680 Bruyères-le-Châtel, France
benedetti@esrf.fr

We are developing techniques to combine simultaneous laser-heating of high-pressure samples in the diamond cell with x-ray diffraction in order to determine the structures and densities of warm, dense fluids at pressures and temperatures greater than those available with either the large-volume press or the resistively-heated diamond cell. The laser-heated diamond cell, in contrast, can achieve pressures greater than 1 Mbar and temperatures greater than 5000 K, thus providing a static link to a wide range of dynamic experiments and also accurately simulating the deep interior conditions of planets. This represents a factor of ~5 increase in temperature over resistively heated diamond cells and in pressure over the large volume press.

We will present x-ray diffraction of fluid bromine melted by laser-heating in the diamond anvil cell. Our best data covers one laser-heating cycle at 6 gigapascals (GPa) with temperatures measured between 2000 and 5000 K. The sample was heated from both sides with a Nd:YAG (? = 1064 nm) laser. This is the first qualitatively usable diffraction of a fluid in a diamond cell heated by laser-heating from the ESRF.

Bromine itself likely undergoes two phase transitions with compression in the fluid that we hope to observe: the first, an insulator to conductor transition of the Br_2 molecule, and the second, a transition from molecular Br_2 to atomic Br that may be first order. [1-3] Both transitions should be in a P-T range readily accessed by laser heating (pressure less than 20 GPa; temperature between 1000 and 3000 K).

In addition, we will discuss candidly the challenges to quantitative measurements and our efforts to surmount them. Particularly, we will describe the tradeoffs of several sample geometries, and we will discuss the use of x-ray fluorescent materials as internal calibrants and alignment aids. Exploratory experiments to 40 GPa indicate that the x-ray phosphors Gd_2O_2S:Tb and Y_2O_3:Eu fluoresce brightly enough at high pressure to precisely locate the x-ray beam with respect to the YAG laser. In addition they may be useful as pressure calibrants.

References

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