In Search of the Plasma Phase Transition in Hot Dense Hydrogen

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There are at least two pathways to metallic hydrogen at static pressures:

- Isothermal compression to multi-megabar pressures
- Heating above the melt line to the plasma phase transition (PPT) of liquid atomic metallic hydrogen
Our research project is to make and study in a DAC

**Isothermal:** Solid or Liquid Metallic Hydrogen

<table>
<thead>
<tr>
<th>Density:</th>
<th>Pressure</th>
<th>300-400 GPa?</th>
<th>400-600 GPa?</th>
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Quasi Isothermal and Plasma Phase Transition:
Putative phase diagram of a few years ago.
Our current region of study

Heating: melt line and the PPT
Summary phase diagram showing our data on the melting line and data for the transition that coincides with predictions of the PPT—2013 Pt absorber Dzyabura, Zaghoo, & Silvera, PNAS 110, 8040 (2013)
What are the problems setting the limit on pressure and temperature?

Diamonds or gaskets fail before highest pressures are achieved. In particular at high temperature, hydrogen diffusion embrittles diamonds and they fail.

**Solutions**

- We etch our diamonds and coat them with a layer of alumina to act as a hydrogen diffusion barrier;

- We use pulsed laser heating to minimize heating, chemical reactions, and diffusion.
50 microns
WE make a 1.5 micron diameter hole in the Pt absorber (FIB) to measure the transmission of the hot hydrogen:
BUT AT MEGABAR PRESSURES THE HOLE CLOSED UP IN TWO RUNS.
We measure heating curves: temperature vs pulsed laser power. A kink or plateau represents a phase change such as melting or the PPT. This was for Platinum absorber, 2013.
Recent heating curve on Tungsten (W) absorber
Plateau does not depend on absorber—thus property of hydrogen
Current Effort:
Show that the transition is to a metallic phase by measuring the optical properties of hot dense hydrogen
- Pulsed laser heating of Hydrogen
- Temperature measurement from spectral irradiance
- Optical Transmission & reflectivity by fast detectors
Goal:
measure transmission of hot hydrogen at and above the plateau.

How?
Thin semi-transparent film of W on diamond.
Virgin Diamond

Diamond with W coating
What we expect to see to establish metallic behavior at the plateau.
Transmitted CW laser Power during heating pulse for temperatures below the plateau

Complications: thermo-transmittance of W.

Microsecond time scale
Thank you