FRONTIER SYNCHROTRON INFRARED SPECTROSCOPY BEAMLINE UNDER EXTREME CONDITIONS (FIS)

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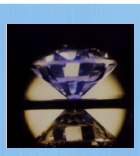
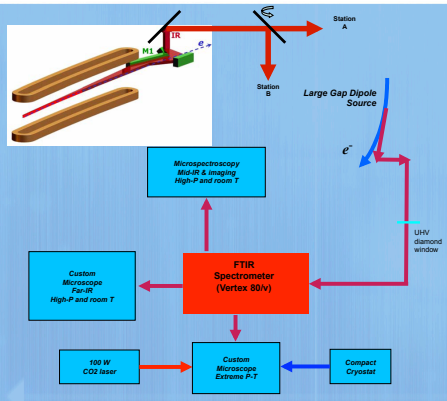
BROOKHAVEN NATIONAL LABORATORY

NATIONAL SYNCHROTRON LIGHT SOURCE II planned by Photon Sciences Directorate

TECHNIQUES AND CAPABILITIES



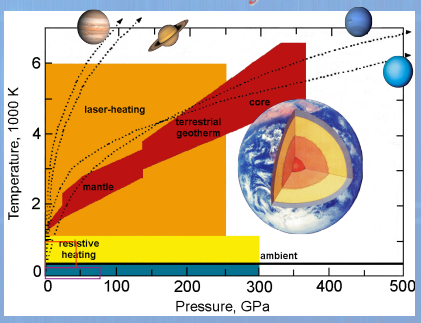
- **TECHNIQUE(S):**
  Fourier transform infrared spectroscopy;
  Raman and visible spectroscopy;
  Diamond anvil cell techniques for static high pressure;
  Gas-gun launchers for dynamic compression;
  Cryogenic techniques combined with DACs;
  Laser heating techniques combined with DACs.
- **SOURCE:** Large-gap (90 mm) dipole magnets
- **ENERGY RANGE / RESOLUTION:** 50-10000 cm^{-1} / 1 cm^{-1}
- **SPATIAL RESOLUTION:** Diffraction limited resolution in the entire energy range



Approved FIS large-gap IR beamline at NSLS-II: Beam extraction and endstations. Station A will be an integrated and dedicated infrared beamline for experiments at simultaneous high pressure and variable temperature with the following capabilities:
Infrared spectroscopy at high-pressure and ambient temperature
In-situ laser heating infrared spectroscopy at high P-T conditions
In-situ spectroscopy at high pressure and low temperature
Station B will be a multi-purpose station for measurements under dynamic compression.

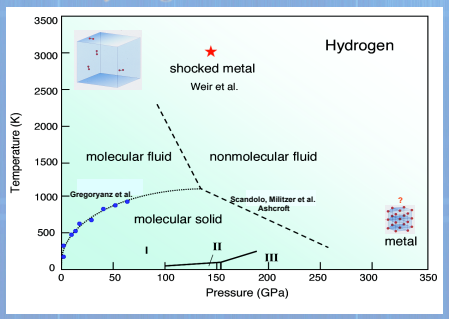
APPLICATIONS

Earth and Planetary Sciences



- Mimic the mantle extreme conditions and study the Earth's deep water cycle;
- Deep Carbon Cycle Research: study behavior of carbon-bearing materials in Earth's deep interior conditions.

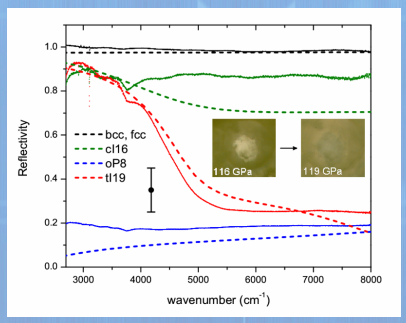
Hydrogen Metallization



Hydrogen phase diagram

FIS will enable *in-situ* optical studies of hydrogen metallization at multi-megabar pressure and low-T conditions due to the brighter and exceptionally stable infrared source at NSLS-II.

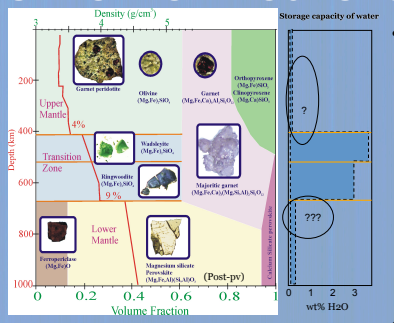
Material Sciences and Chemistry under Extreme Conditions



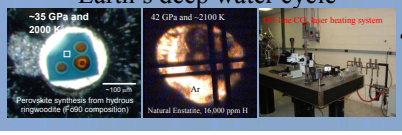
Anomalous properties of dense sodium

Synchrotron infrared spectroscopy on sodium shows a transition from a high reflectivity, nearly free-electron metal to a low reflectivity, poor metal in an orthorhombic phase at 118 GPa. An image of a sample across the cl16 → oP8 transition is shown.

SPECIFIC PROJECTS / ADDITIONAL INFORMATION



Earth's deep water cycle



- Infrared spectroscopy provides a key and often unique experimental approach with exceptional sensitivity to the O-H and C-O bonds and serves as an invaluable tool for studying Earth's deep water and carbon cycles. However, it is essential to extend diamond anvil cell techniques to higher temperatures and pressures with either external heating or laser heating techniques in order to directly probe thermodynamics, chemical diffusion, and molecular coordination under high *P-T* conditions. This requires brighter sources with diffraction-limited performance in the infrared range and superior stability. The capacity of the large-gap dipole at NSLS-II will provide an ideal infrared source for such studies to couple the high *P-T* DAC techniques with the FTIR spectroscopic measurements and to address these scientific questions and challenges related to Earth and Planetary Sciences;
- Metallization of hydrogen and hydrogen-rich materials such as methane, silane, and germane under extreme high pressure and low temperature;
- Optical studies of nano-crystalline materials and porous materials including BN nanotubes and zeolites/natrolites under extreme conditions for applications in energy efficiency, production, and storage.