High Pressure Collaborative Access Team (HPCAT)

Recent Progresses

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Outline

• HP synchrotron techniques at HPCAT
• Beamlines: characteristics
• Supporting equipments
• Science highlights
• HPSynC
Optimized for high pressure research

- Fundamental Physics
  *Novel states of matters, transitions, processes*
- Fundamental Chemistry
  *New bonding, HP periodic table*
- Materials Science
  *New materials, properties, mechanism*
- Earth and Planetary Sciences
  *Mineral physics, geophysics, geochemistry*
HP synchrotron techniques at HPCAT

• X-ray scattering
  – *Inelastic scattering, x-ray Raman* (bonding, charge dynamics)
  – *Nuclear resonant inelastic scattering* (phonon dynamics)
  – *Nuclear forward scattering* (spin, valence state)

• X-ray spectroscopy
  – *(Resonant) Emission spectroscopy* (spin, electronic structure)
  – *Absorption spectroscopy* (bonding, local structure)

• X-ray diffraction
  – *Micro ADXD* ($\Delta d/d \sim 10^{-3}$)
  – *Micro EDXD* ($\Delta d/d \sim 10^{-2}$)
  – *High resolution* ($\Delta d/d \sim 10^{-4}$)
  – *Single crystal diffraction* (EDXD)
  – *Anomalous diffraction/scattering* (element specific information)

• HP techniques
  – *Double sided laser heating*
  – *Resistive heated DAC with membrane*
  – *Cryostat*
HPCAT Beamlines
Four Independent Beamlines

Sector 16
Undulator beam

 IDC – IDD - IDE:
High-pressure
Spectroscopy
(Shockwave)

IDB:
High-pressure
Micro-diffraction

Split in energy

5-28 keV

25-35 keV

Sector 16
Bending magnet beam

BMB:
EDXD
Micro-diffraction

BMD-BMC:
Micro-diffraction
XAS

6-70 keV

white

Split in space
## Characteristics of HPCAT beamlines

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<th>16ID-D</th>
<th>16ID-B</th>
<th>16BM-D</th>
<th>16BM-B</th>
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<tr>
<td><strong>Techniques</strong></td>
<td>IXS/X-ray Raman NRIXS, NFS XES/RXES</td>
<td>Micro-diffraction High resolution</td>
<td>Micro-diffraction XAS Anomalous Single crystal</td>
<td>Micro-diffraction Single crystal Dispersive XAS</td>
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<tr>
<td><strong>Energy range (keV)</strong></td>
<td>5-28</td>
<td>25-35</td>
<td>6-70 White beam to 80 keV</td>
<td>White beam to 110 keV</td>
</tr>
<tr>
<td><strong>Beam size (μm²)</strong></td>
<td>25(v)x55(h) 13(v)x15(h)</td>
<td>3(v)x4(h)</td>
<td>9(v)x5(h)</td>
<td>5-50 In diameter</td>
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<tr>
<td><strong>Flux at sample position (p/s)</strong></td>
<td>2.4x10¹² (eV) 2x10⁹ (meV)</td>
<td>5x10¹⁰ @ 30 keV 8x10⁸ @ 35 keV</td>
<td>3x10⁹ @ 15 keV</td>
<td>-</td>
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<tr>
<td><strong>On-line equipments</strong></td>
<td>Ruby/Raman Cryostat</td>
<td>Laser heating Ruby/Raman Cryostat</td>
<td>Ruby/Raman Cryostat</td>
<td>Ruby/Raman Cryostat</td>
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IDD: X-ray Spectroscopy Station

- X-ray inelastic scattering/x-ray Raman setup using multi-element analyzer
- NFS/NRIXS setup using APD detectors

A dedicated XES/RXES setup coupled to the main 2.7 m spectrometer
16ID-B: Micro-diffraction

**Horizontal**

FWHM of DY/DX of Detector 3

- SC
- FWHM = 0.004418970, Cntro = -0.19904104
- yhpeak = 2674.19, xhpeak = -0.20143905
- xl = -0.20143905, xr = -0.19694718

- ~8 um

**Vertical**

FWHM of DY/DX of Detector 3

- SC
- FWHM = 0.003635019, Cntro = 0.092474303
- yhpeak = -306421, xhpeak = 0.10649608
- xl = 0.10649608, xr = 0.09265656

- ~8 um
- 3.8 um

16ID-B Instruments

Laser heating table

Cryostat experiment

16BM-D Characteristics

• A unique station with both monochromatic and white beam available
• No beam position change with E-scan
16BM-B White beam station

- Tunable beam size (5-50 μm)
- White beam energies to 110 keV
- Two-theta sphere-of-confusion <5 μm

Paris-Edinburgh cell
EDXD single crystal diffraction
Liquids and amorphous materials (large Q coverage by scanning angle EDXD)
Dispersive XAS
Supporting facilities
**P-T conditions**

- Laser heating
- Resistive heating
- Cryostat
- Motor driven DAC
- Membrane driven DAC
P-T measurements and sample characterization

- On-line and off-line ruby system
- On-line and off-line Raman system
Science Highlights
Metallization of Ge - valence band width
Struzhkin et al, PRL (2006)

Kondo-like delocalization in Gd
Maddox et al, PRL (2006)

Alkali metal – meltdown
Greygoryanz et al, PRL (2005)
Fundamental Chemistry

Structure and bonding of CO$_2$

Thermal densification of GeO$_2$ glass
Shen et al, PNAS (2007)

Formation of a molecular compound (H$_2$)$_2$O$_2$
Materials science

Novel, superhard Os and Ir Nitrides
Young et al, PRL (2006)

Volume collapse in bulk metallic glass
Earth and Planetary Sciences

Giant planet may host superionic ice

Deformation of post-perovskite
HPSynC – High Pressure Synergetic Center at APS

- An infrastructure team
- A gateway for users

HPSynC – Near Future Goals

- Develop novel HP synchrotron techniques and make them available to the user community
- Construct various portable systems for HP experiments at different beamlines
- Establish a sample preparation laboratory with the state-of-art technology
- Make synergetic effort in coordinating with the resources at APS and beyond
- Function as a gateway for users to access APS beamlines
- Organize summer schools and workshops