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

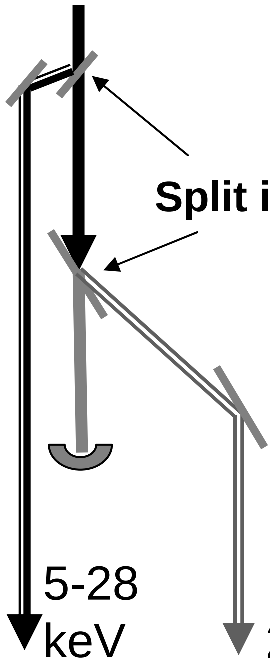
HP synchrotron techniques at HPCAT

- **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



Split in energy

5-28 keV

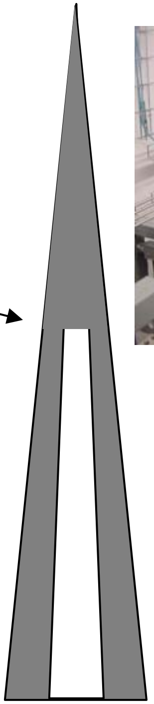
25-35 keV

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

IDB:
High-pressure
Micro-diffraction

Sector 16
Bending magnet beam

Split in space



6-70 keV

white

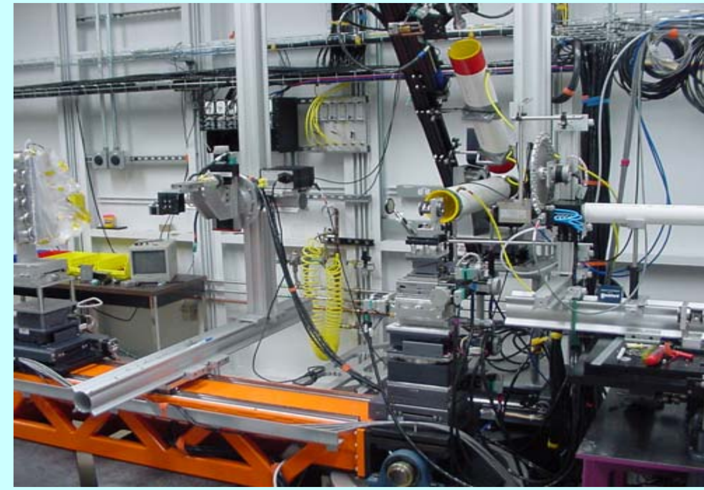
BMD-BMC:
Micro-diffraction
XAS

BMB:
EDXD
Micro-diffraction

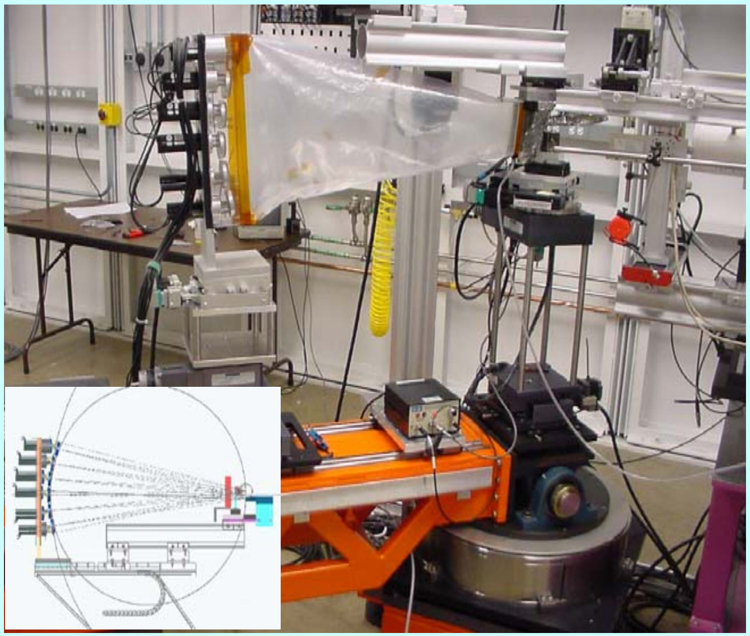
Characteristics of HPCAT beamlines

	16ID-D	16ID-B	16BM-D	16BM-B
Techniques	IXS/X-ray Raman NRIXS, NFS XES/RXES	Micro-diffraction High resolution	Micro-diffraction XAS Anomalous Single crystal	Micro-diffraction Single crystal Dispersive XAS
Energy range (keV)	5-28	25-35	6-70 White beam to 80 keV	White beam to 110 keV
Beam size (μm^2)	25(v)x55(h) 13(v)x15(h)	3(v)x4(h)	9(v)x5(h)	5-50 In diameter
Flux at sample position (p/s)	2.4×10^{12} (eV) 2×10^{9} (meV)	5×10^{10} @ 30 keV	3×10^{9} @ 15 keV 8×10^{8} @ 35 keV	-
On-line equipments	Ruby/Raman Cryostat	Laser heating Ruby/Raman Cryostat	Ruby/Raman Cryostat	Ruby/Raman Cryostat

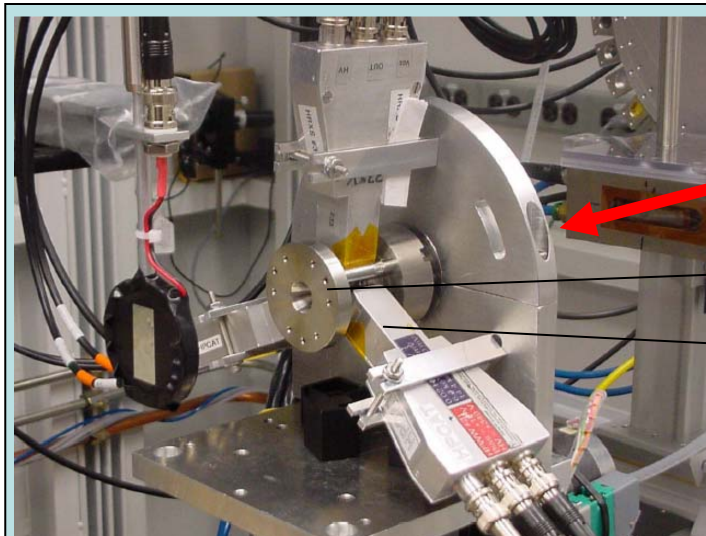
IDD: X-ray Spectroscopy Station



A dedicated XES/RXES setup coupled to the main 2.7 m spectrometer



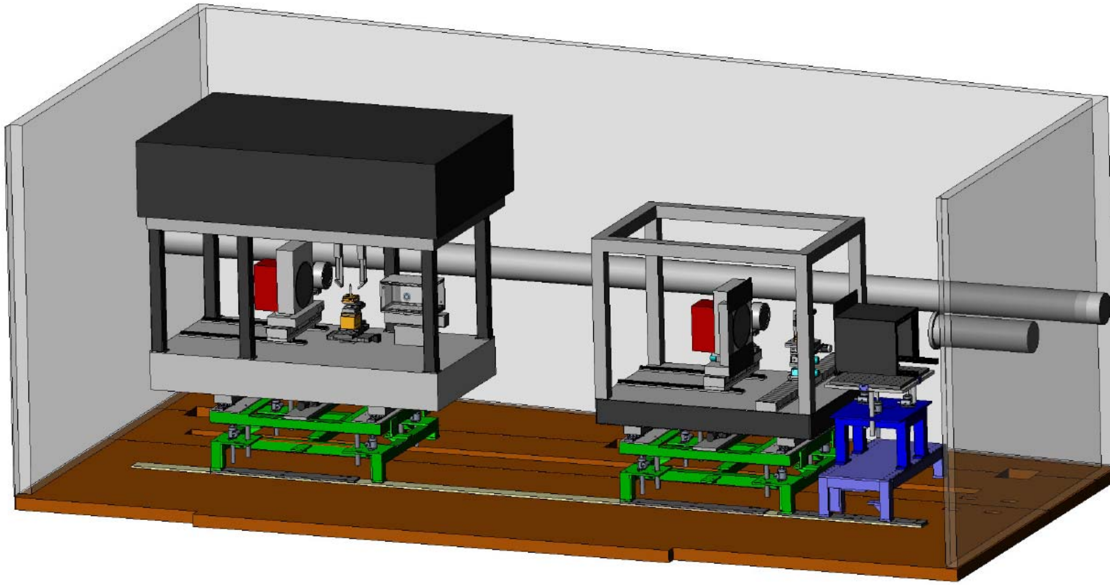
X-ray inelastic scattering/x-ray Raman setup using multi-element analyzer

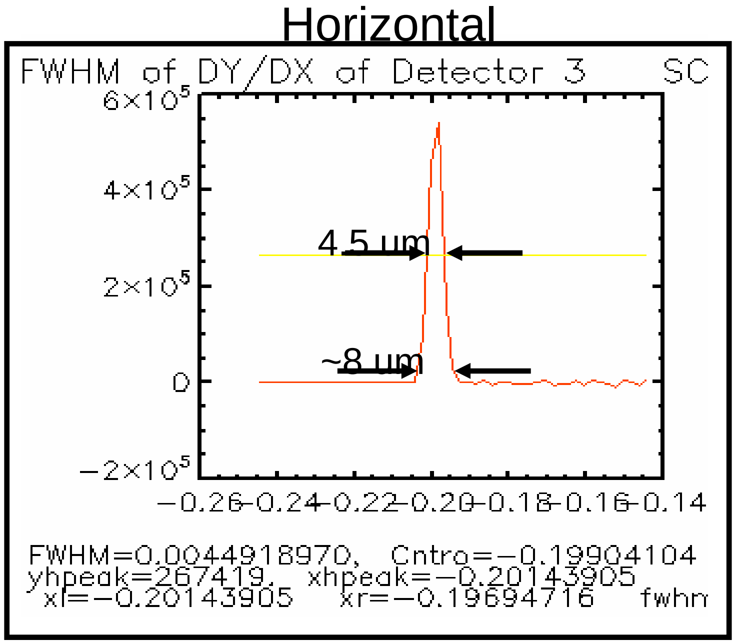


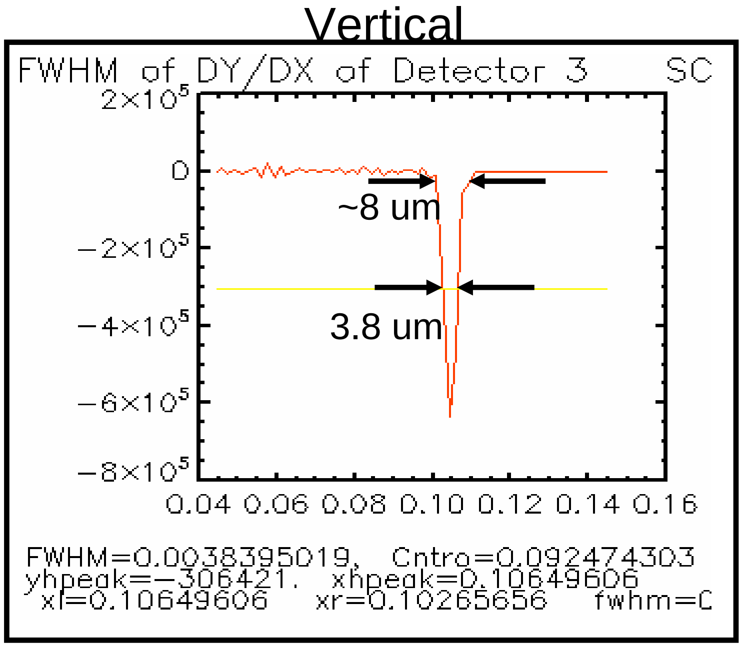
NFS/NRIXS setup using APD detectors

16ID-B:

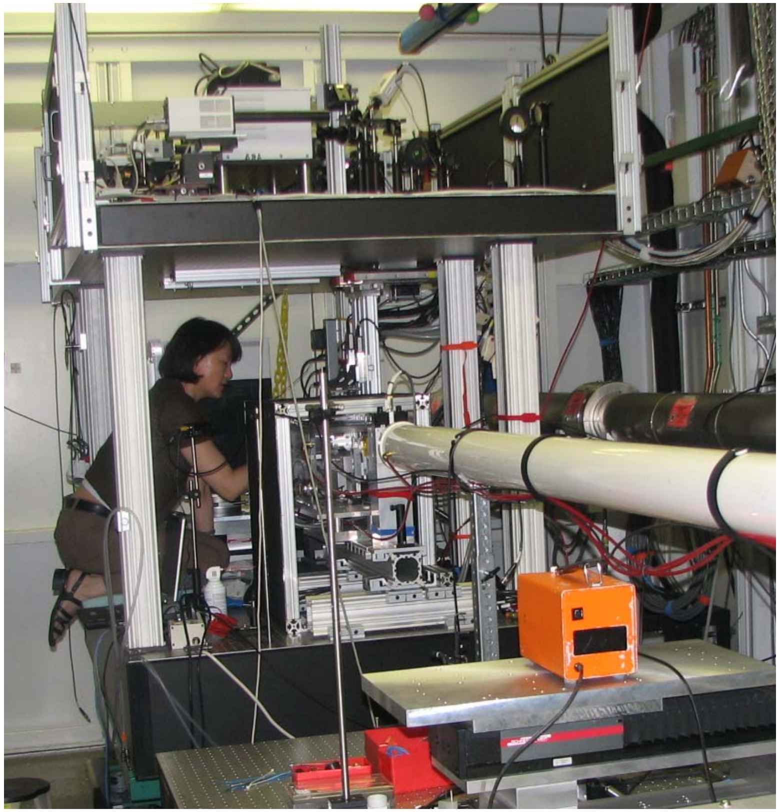
Micro-diffraction



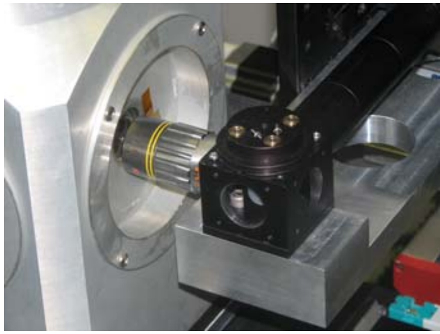


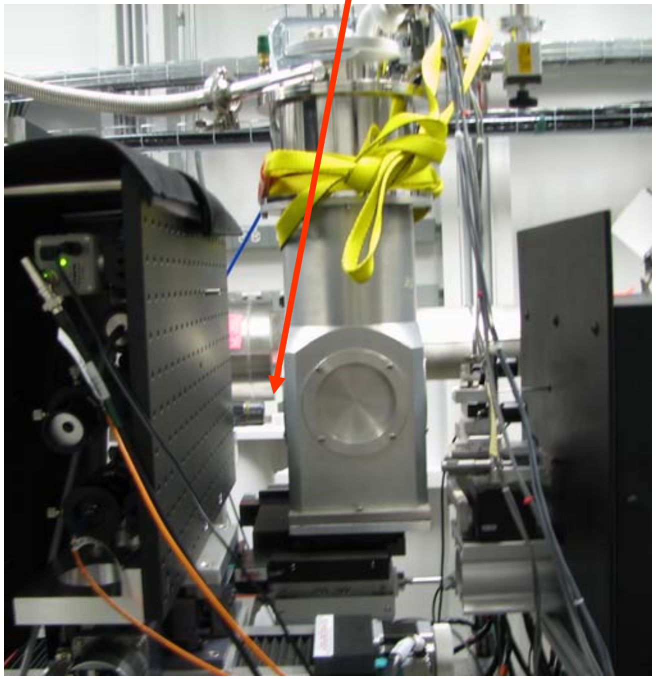


16ID-B Instruments



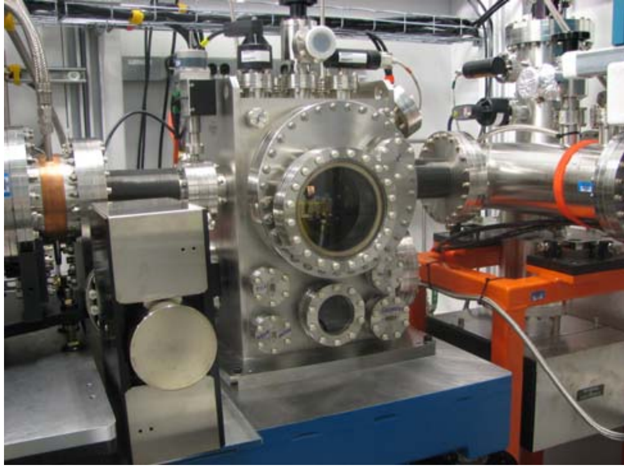
Laser heating table



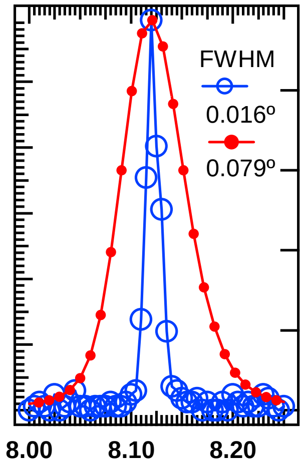


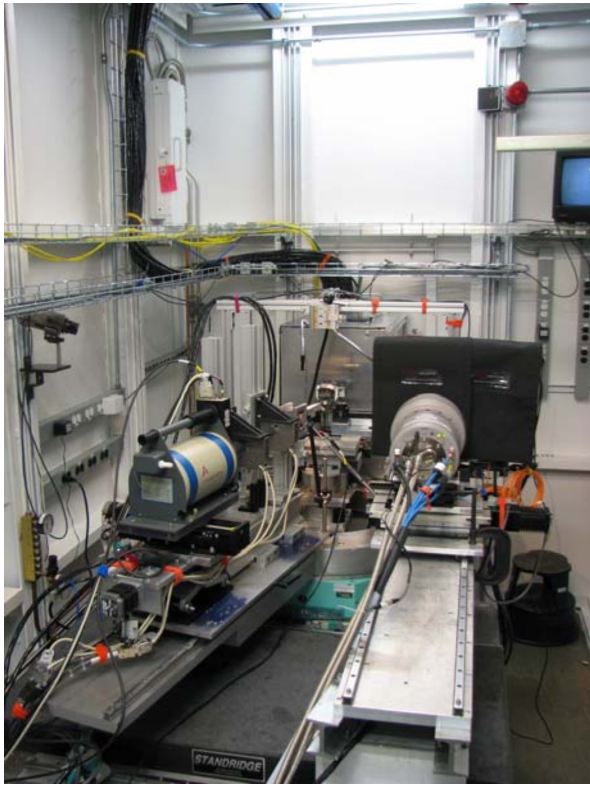
Cryostat experiment

16BM-D Characteristics

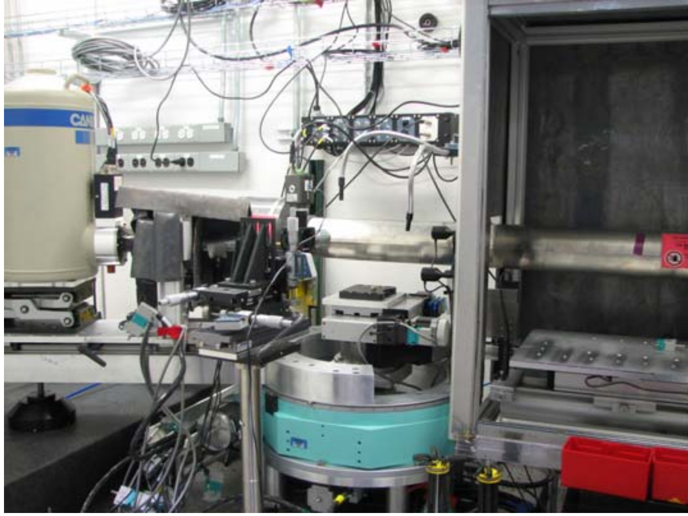


- **A unique station with both monochromatic and white beam available**
- **No beam position change with E-scan**



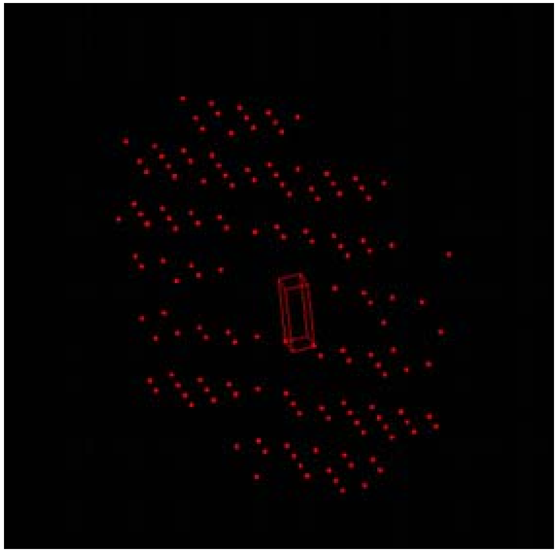


16BM-B White beam station



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

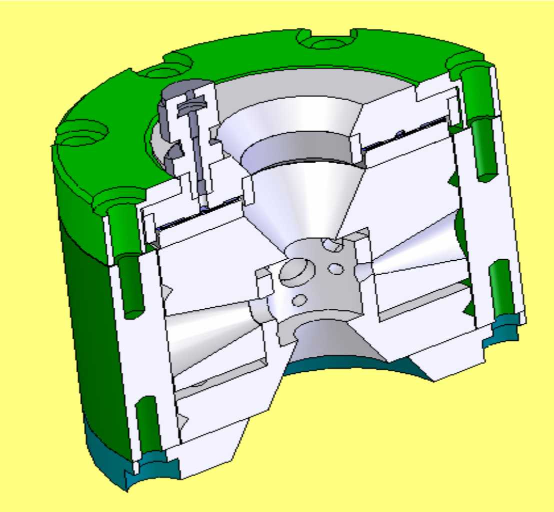
Paris-Edinburgh cell
EDXD single crystal diffraction
Liquids and amorphous materials (large Q coverage by scanning angle EDXD)
Dispersive XAS

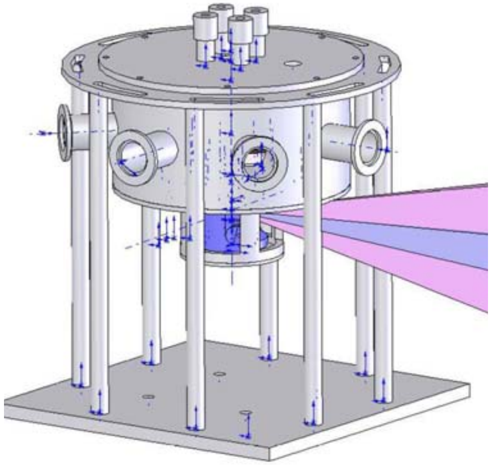


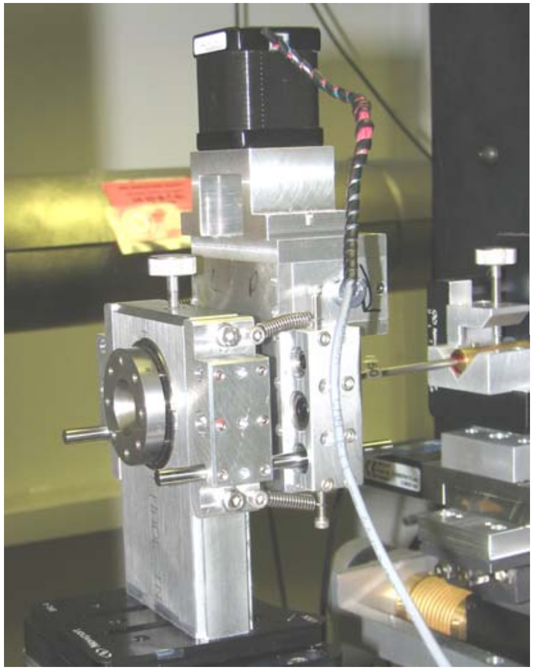
Supporting facilities

P-T conditions

- Laser heating
- Resistive heating
- Cryostat
- Motor driven DAC
- Membrane driven DAC

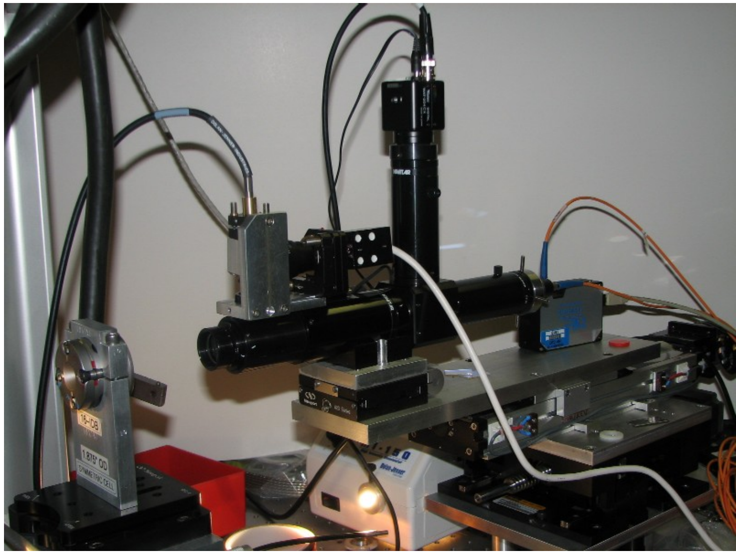


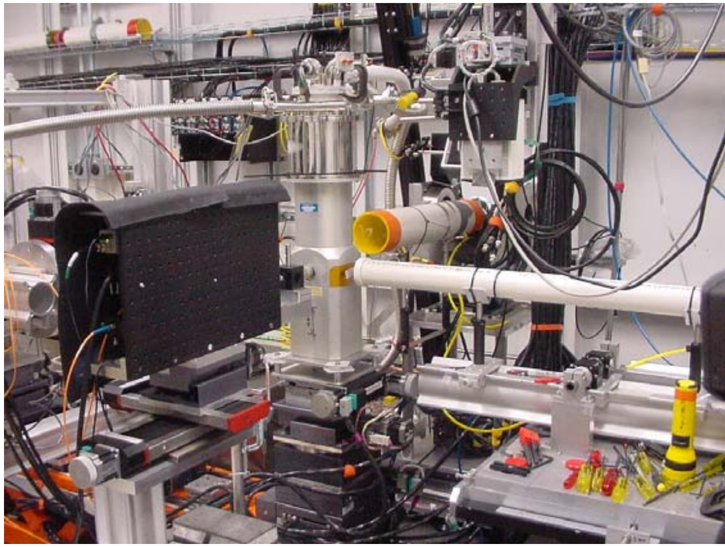




P-T measurements and sample characterization

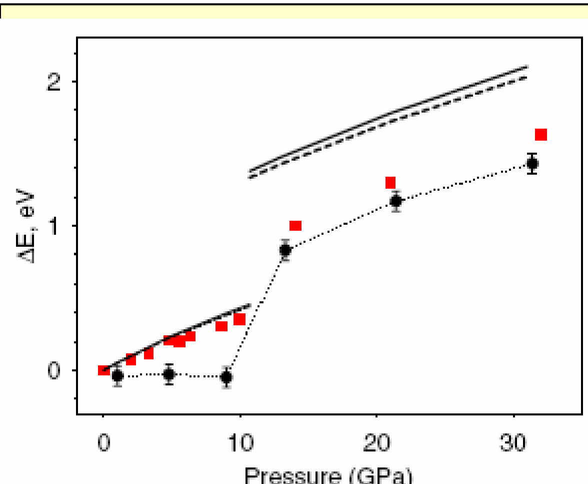
- **On-line and off-line ruby system**
- **On-line and off-line Raman system**

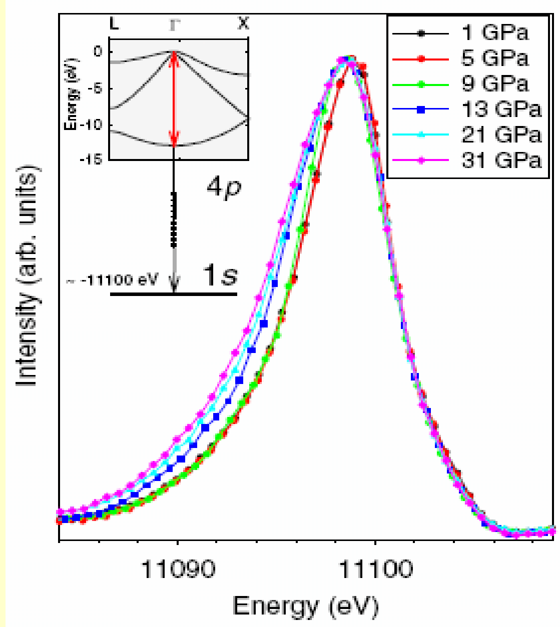




Science Highlights

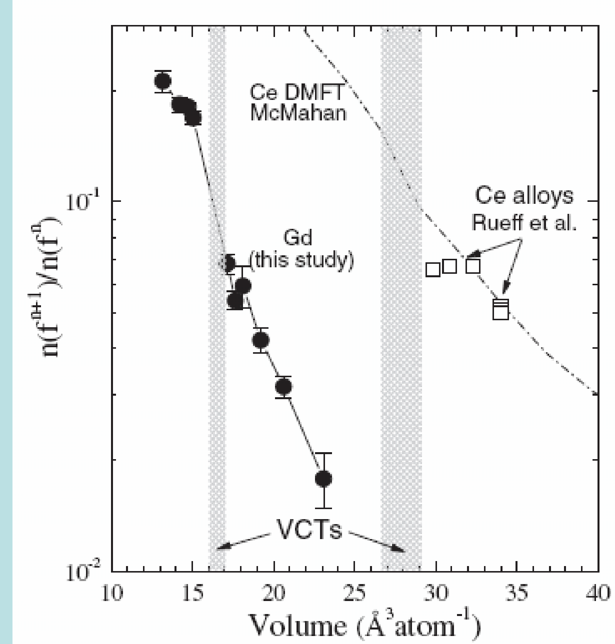
Fundamental Physics

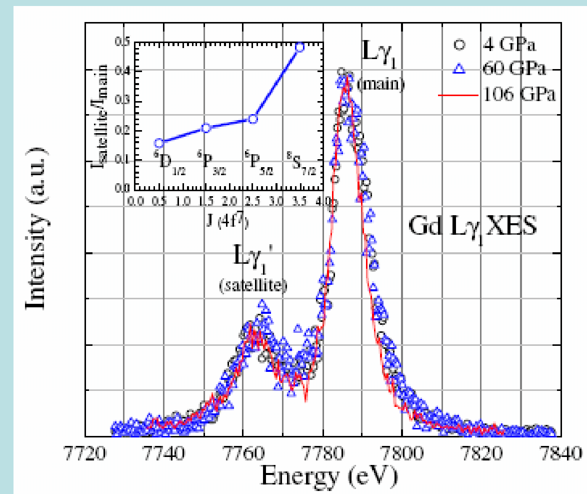




Metallization of Ge - valence band width

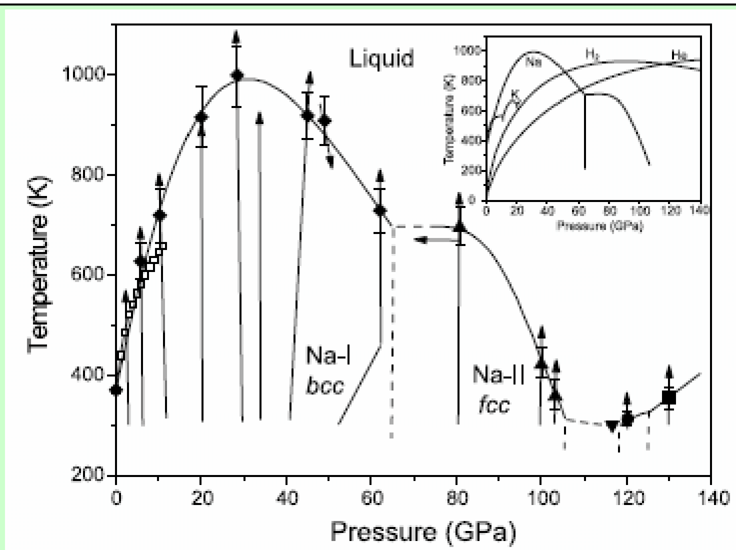
Struzhkin et al, PRL (2006)





Kondo-like delocalization in Gd

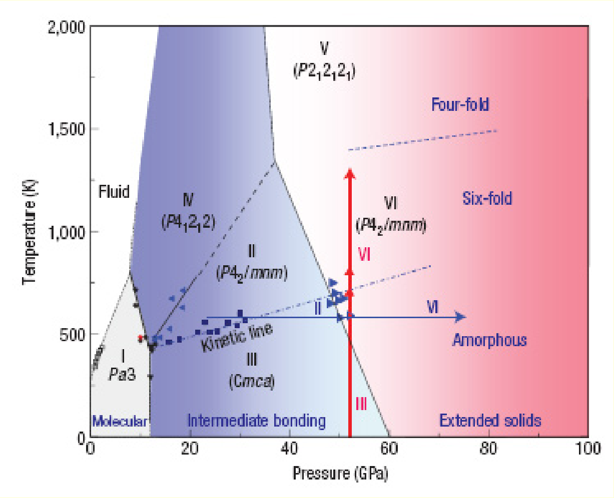
Maddox et al, PRL (2006)

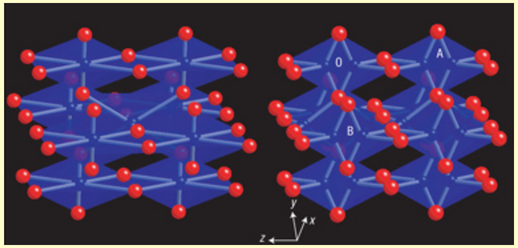


Alkali metal – meltdown

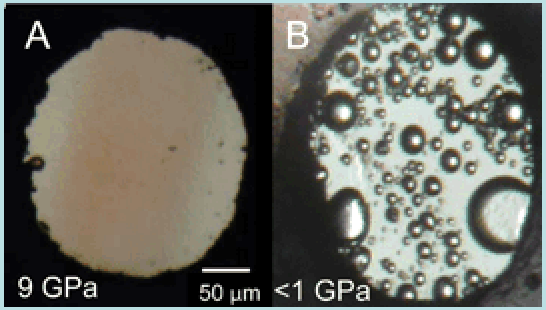
Greygoryanz et al, PRL (2005)

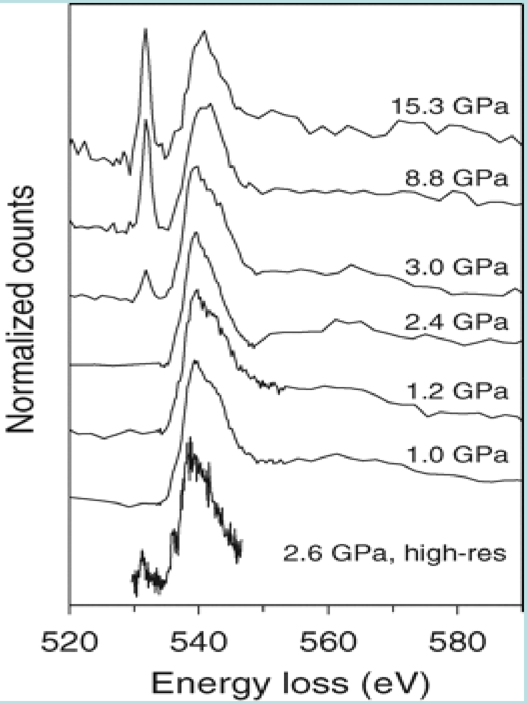
Fundamental Chemistry



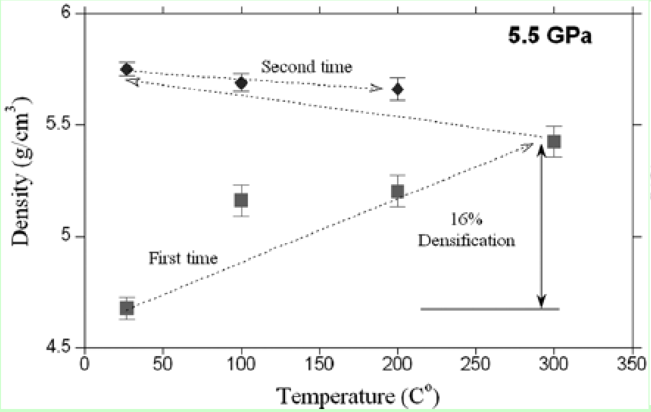


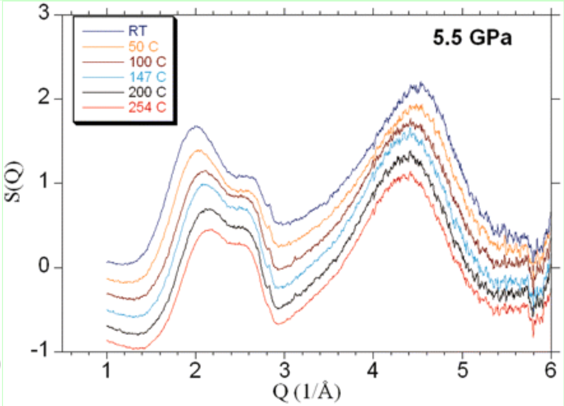
Structure and bonding of CO_2
Iota et al, Nature Mat. (2007)





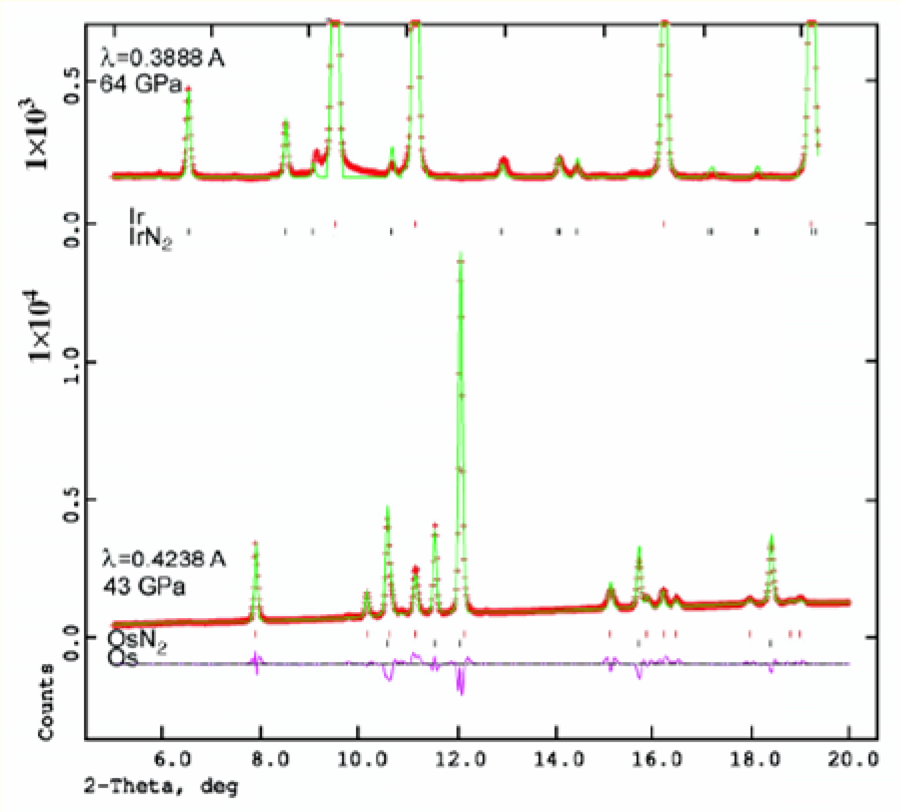
Formation of a molecular compound $(H_2)_2O_2$
Mao et al, Science (2006)



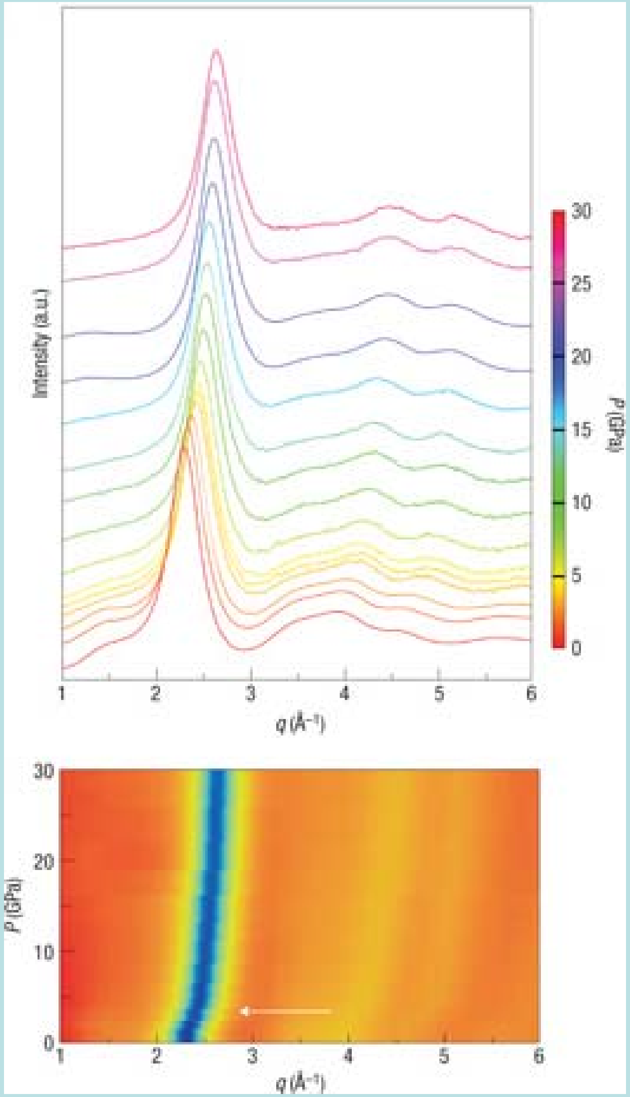


Thermal densification of GeO_2 glass
Shen et al, PNAS (2007)

Materials science

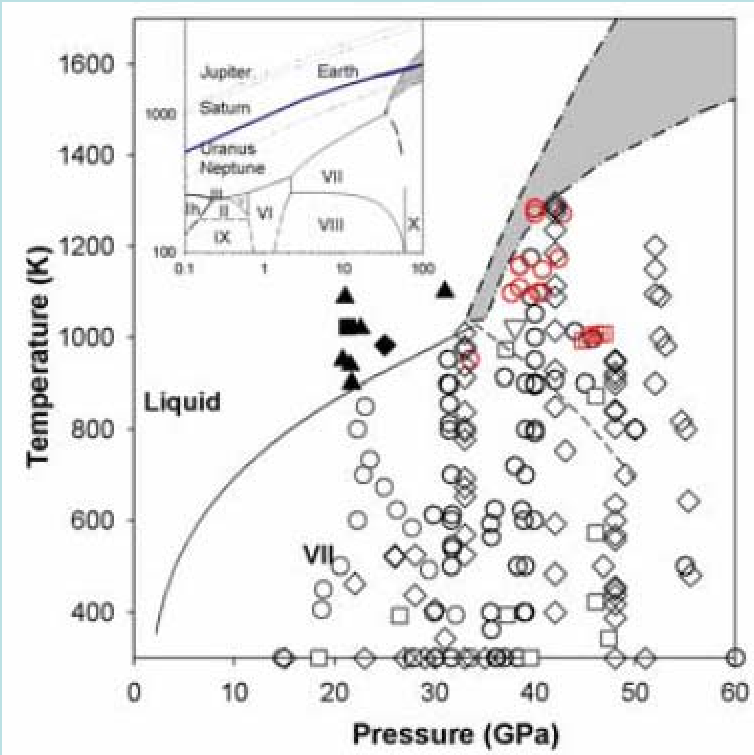


Novel, superhard Os and Ir Nitrides
Young et al, PRL (2006)



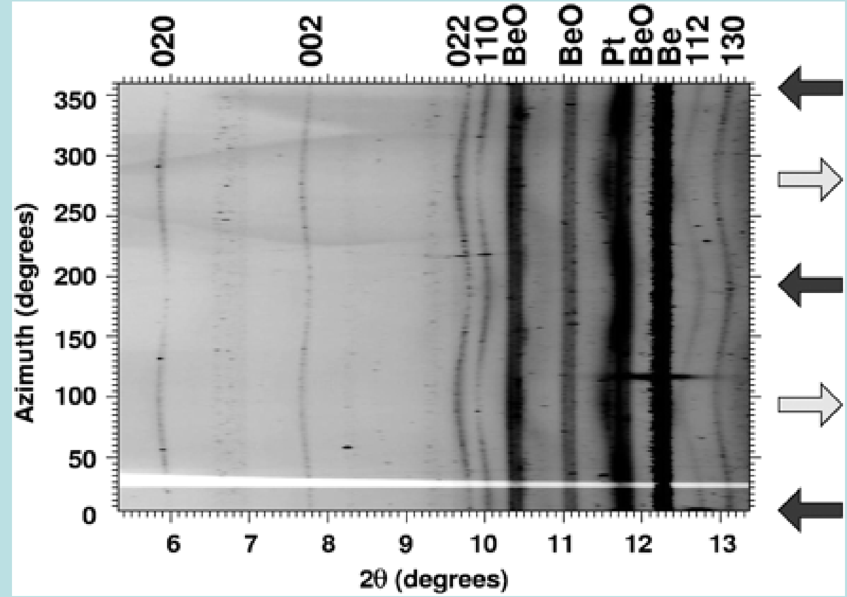
Volume collapse in bulk metallic glass
Sheng et al, Nature Mat. (2007)

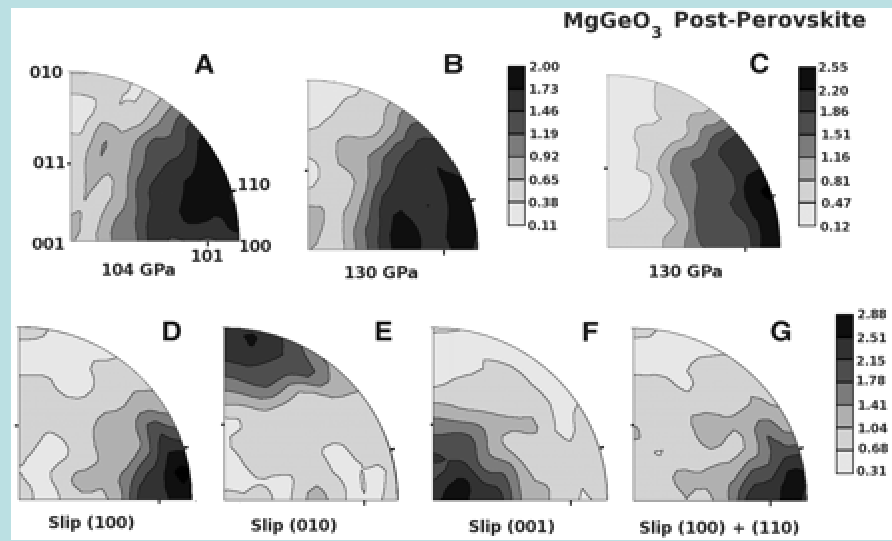
Earth and Planetary Sciences



Giant planet may host superionic ice

Lin et al, Geo. Phys. Lett (2005)

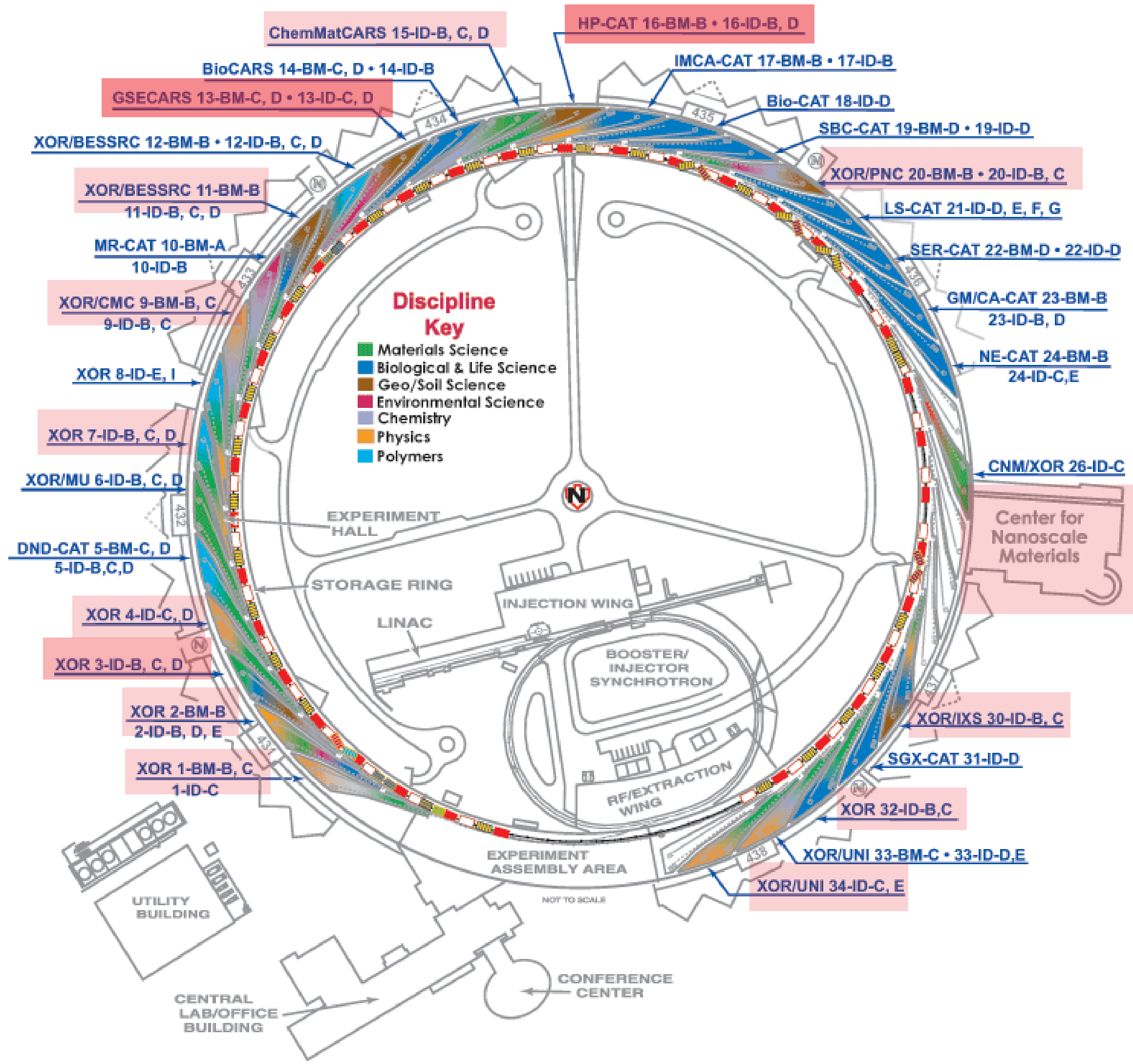




Deformation of post-perovskite

Merkel et al, Science (2006, 2007)

[HPSynC – High Pressure Synergetic Center at APS]



- **An infrastructure team**
- **A gateway for users**

http://www.aps.anl.gov/Users/Scientific_Interest_Groups/HPSynC/

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**