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Cutting-edge Upgrade of Diamond Anvil Cell Program at GSECARS

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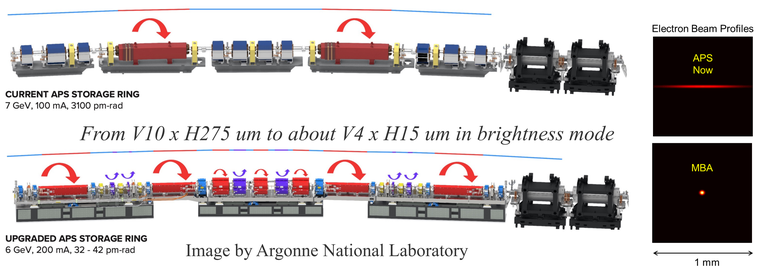
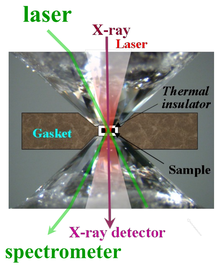


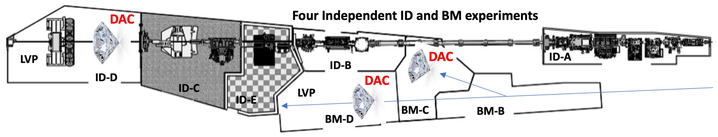
The Advanced Photon Source is undergoing a complex upgrade replacing its original electron storage ring with a new multi-bend achromat lattice to provide extremely enhanced coherent flux and increased hard X-ray brightness by a hundred times. To take full advantage of these improved capabilities we have started the process of comprehensive technical improvements and developments of multi-probe techniques across a suite of beamline stations at GSECARS



Multiple optical axes (x-ray, lasers, spectroscopy and imaging) should be aligned with sub-micron precision on sample inside the diamond anvil cell

We are anticipating significant advances in many fields of Earth science:

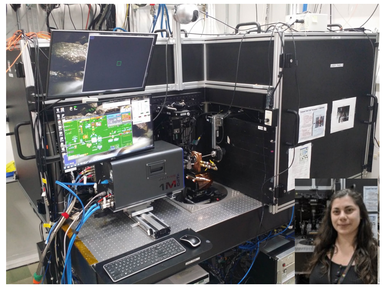
- *Melting studies and phase transition in multi-megabars pressure range*
- *Structure determination of complex metastable phases at high P-T*
- *Dynamic experiments in combination with CW and/or pulse laser heating*
- *Structure and phase stability of hydrogen bearing minerals and low-Z compounds*



13-IDD

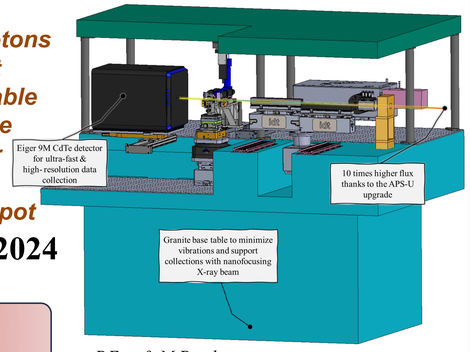
X-ray energy 5-80 keV, beam size 0.3 - 2 μm
XRD, sXRD, XES, on-line laser heating, Raman and VIS-IR spectroscopy

2024 beamline upgrade



- *10 -100 times more photons*
- *300 nm x-ray focal spot*
- *Vibration free granite table*
- *Air-bearing rotary stage*
- *9M Eiger CdTe detector*
- *Supercontinuum laser*
- *X-ray scan across LH spot*

2023 → **2024**



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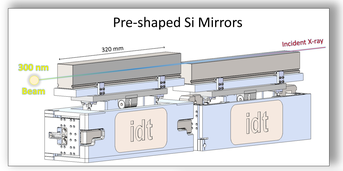
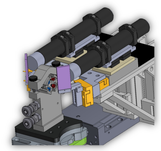
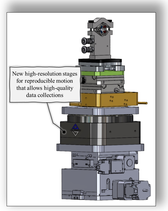
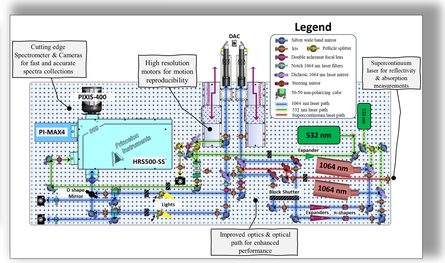




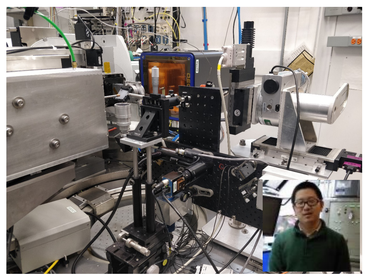




13-BMC

X-ray energy 15 or 28.6 keV, ~ 20 μm
sXRD, radiography, on-line laser heating, Raman and VIS spectroscopy

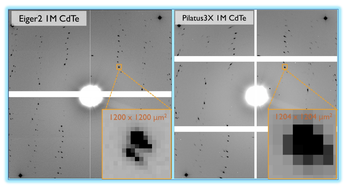
New Eiger2X 9M CdTe X-ray detector

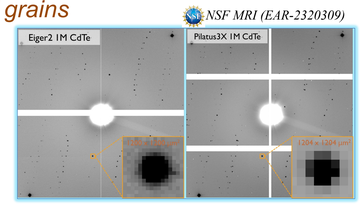


- *High energy x-ray efficient Pilatus3 1M CdTe detector will be available for most DAC experiments*
- *Fast shutter-less gated optical detector PI-MAX3 will be installed for radiometric temperature measurements above 1000 K with optional synchronization with laser heating pulses*

- *Detect photons with energies of up to 100 keV with a spatial resolution at the single-pixel level of 75 μm*
- *Fast frame rate, dead-time free readout*
- *The second energy discriminating threshold allows imaging of samples in two energy bins or cut higher harmonics to reduce bkg*
- *High spatial resolution and precise peak for single crystal structural information on individual grains*

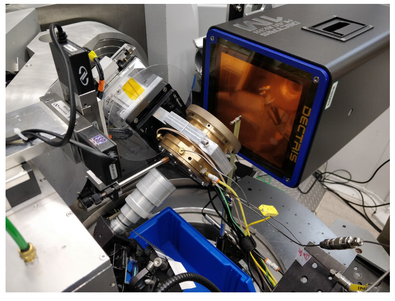
NSF MRI (EAR-2320309)



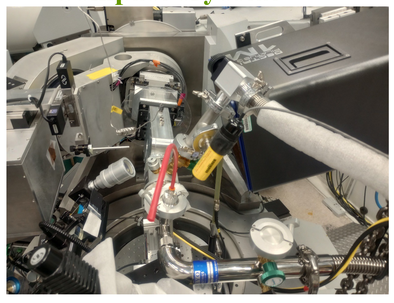


- *Updated enclosure for precise high temperature experiments with resistive-heating DAC up to 1400 K*
- *Compact cryostat for low temperature DAC experiments with rotation capabilities for sXRD measurements*
- *Rowland circle monochromator upgrade: adding another Si crystal to enable energy >35 keV.*

EH-DANCE enclosure



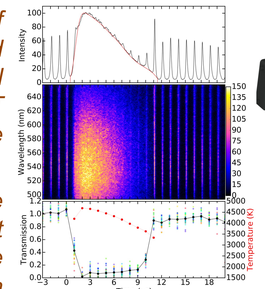
Compact cryostat



Supercontinuum laser for spectroscopy at high P-T

In radiometric temperature determination of laser heated samples T is usually derived indirectly by fitting Planck's law to the thermal radiation spectrum in assumption that at high T optical properties of sample doesn't change and emissivity is wavelength-independent.

For improved accuracy in temperature determination in the LH-DAC we will install at 13ID-D station the optical system to measure sample reflectivity/absorption in-situ at high temperatures with superbright supercontinuum laser in both transmission and reflection geometries.



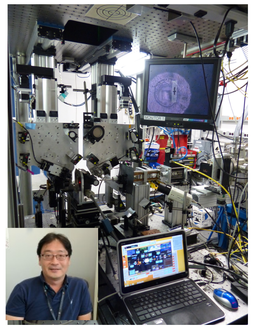
The middle panels are the raw streak camera images (wavelength (nm) vs time (us)) from the sample heating event (spectrograms). The top panels show the averaged streak camera image along the horizontal axis (black) with a broad thermal background (red). The vertical lines are the optical probe (supercontinuum laser) spaced every microsecond apart

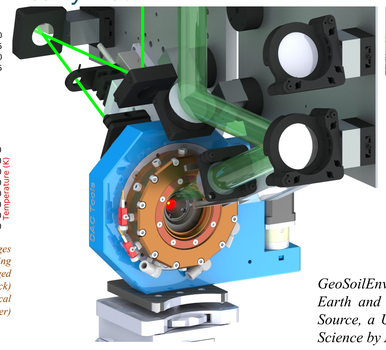
Prakapenka et al, *Nature Physics* (2021)

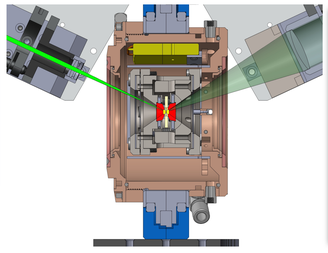
13-BMD

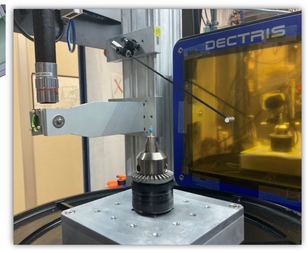
X-ray energy 5-80 keV, beam size ~6 x12 μm
XRD, sXRD, 3D tomography with sXRD, on-line Brillouin, Raman, VIS-IR spectroscopy

- *High resolution (spatial and spectral) Raman spectroscopy in backscattering geometry with dedicated optical path*
- *High precision motorised stages for 12x zoom microscope to improve sample imaging, alignment and reproducibility*
- *Modification of the focusing and collecting platforms in the Brillouin system to fit new large high temperature enclosure for externally heated DAC with custom designed rotation stage. The system has been developed in collaboration with Dactools (booth 403) and Hanyang University (Prof. Kim)*
- *Combination of 3D computer tomography with tightly focused XRD (sing-crystal or powder) to study micro-inclusions inside bulky matrix*









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