SUB-MICRON RESOLUTION X-RAY SPECTROSCOPY (SRX)

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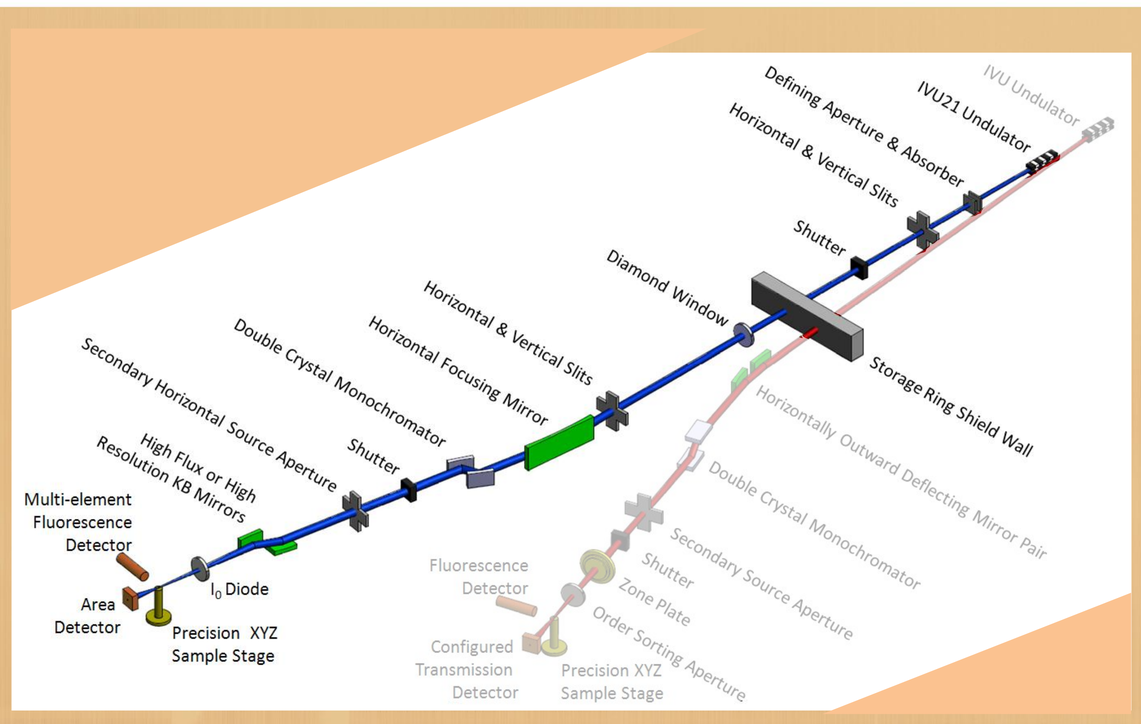
NATIONAL SYNCHROTRON LIGHT SOURCE II project beamlines • funded by DOE

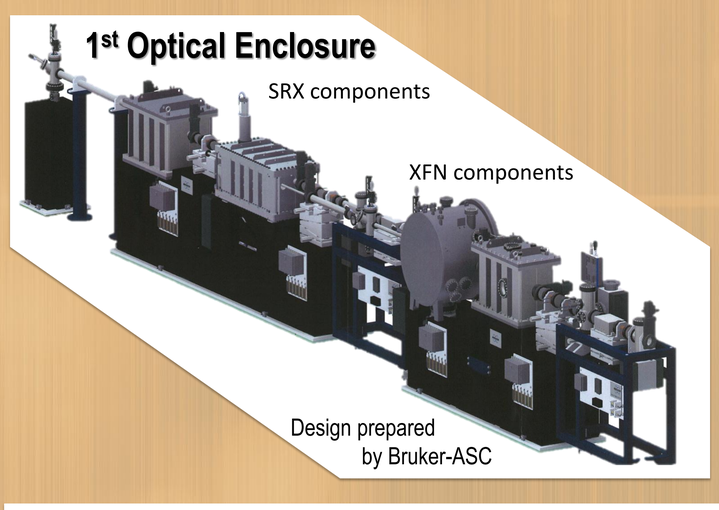
TECHNIQUES AND CAPABILITIES

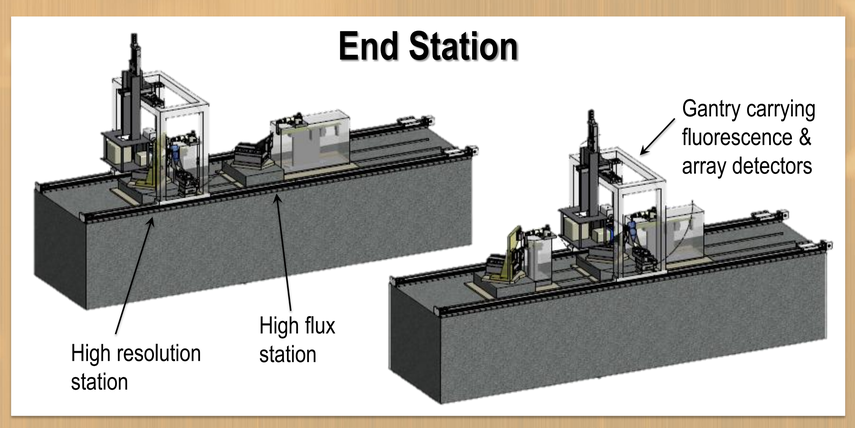
- Versatile but optimized tool for studies in environmental, life, earth, planetary, material & medical sciences, energy research.
- X-ray spectroscopy with either sub-µm or 50 nm spatial resolution.
  Energy range: 4.6 keV ≤ E ≤ 24 keV.
- 2D fluorescence / diffraction imaging, fluorescence/diffraction-tomography
- Outstanding performance for trace elements analysis
- X-ray Fluorescence Nanoprobe (XFN) using zone plates is optimized for E = 2 - 15 keV



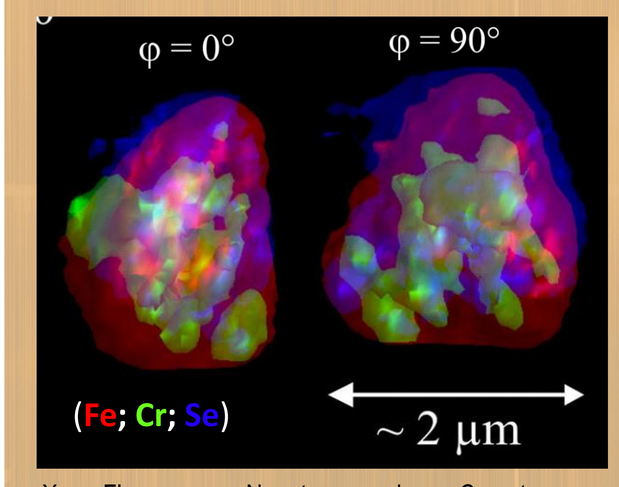
SRX and XFN (grayed out) beamline layout, canted geometry

BEAMLINE DESIGN



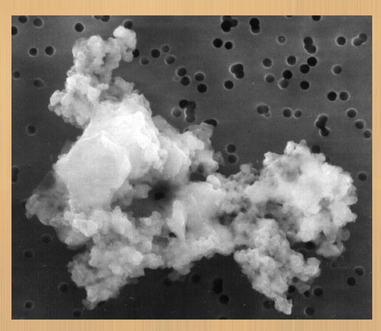


APPLICATIONS

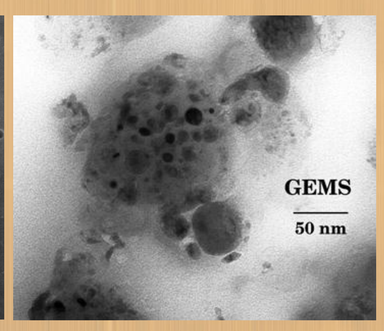


X-ray Fluorescence Nanotomography on Cometary Matter from Comet 81P/Wild2 Returned by ***Stardust*** *(after G. Silversmit et al., Anal. Chem., 2009).*

ID22NI: 60 nm spot size, no spectroscopy possible
SRX: spectroscopy (in addition to diffraction & fluorescence in 1, 2 or 3D) with <50 nm resolution



10 µm large interplanetary dust particle (*from NASA website*)



GEMS (glass with embedded metal and sulfides) dust particle. GEMS are a major subcomponent of one of the most primitive classes of interplanetary dust (cf. *NASA website*).

Spectroscopy + ptychography on Interplanetary Dust Particles
Experiment foreseen at the ESRF on ID21 in July with a 700 nm probe → 20 nm targeted resolution.
With **SRX**, the beam stability and 50 nm probe size will allow to achieve resolution close 1 nm in ptychography mode.

PERFORMANCE

Flux & spot size: (assessed by ray tracing calculations & wave front propagation simulations)

✓***High flux KB -*** *Flux:* 1.56 x 10^{13} ph/s @ 12 keV,
Spot size: 0.8 x 0.5 µm^2

✓***High Resolution KB -*** *Flux:* 10^{11} – 10^{12} ph/s @ 12 keV,
Spot size: 50 x 50 nm^2

✓ ***XFN:*** 7 x 10^9 ph/s @ 12 keV, resolution ≈30 nm

Comparison of energy range, spot size and flux of similar beamlines. This compilation does not claim to be complete (*Source: www).*

Name	Energy range / keV	Spot size / µm²	Photon flux in spot
SRX @ NSLS-II	4.7 – 23	0.5 x 0.8 0.05 x 0.05	1.5 x 10^{13} 1 x 10^{12}
ID21 @ ESRF	2 – 9	0.35 x 0.7	10^{10}– 10^{11}
ID22 @ ESRF	6.5 – 18	3.5 x 1.5	10^{12}
NINA @ESRF	discrete 11.2/17/33.6 (NI) 5-70 (NA)	0.01 – 0.1 (NI) 0.05 - 1	2.5 x 10^{12} 1.8 x 10^{11}
2-ID-B @ APS	2 – 4	0.06 x 0.06	10^9
2-ID-D @ APS	5 – 30	0.2 x 0.2	4 x 10^9
2-ID-E @ APS	7.5 – 10	0.5 x 0.3	5 x 10^9
13-ID-C,D @ APS	4 – 45	2 x 2	10^{11}
20-ID-B,C @ APS	4.3 – 27	2 x 2	10^{11}
XFM @ AS	4 – 25	0.06 x 0.06	10^{10}
MicroXAS @ SLS	5 – 20	1 x 1	2 x 10^{12}
Nanoscopium@ SOLEIL	5 – 20	0.1 x 0.1	1.4 x 10^{10}

TECHNICAL CHALLENGES

To fully benefit from the high stability & ultra-low emittance of the NSLS-II source, state-of-the-art optical components are required.

- Ultra stable <u>horizontally diffracting DCM</u>
  → angular stability < 50 nrad
- Ultra stable <u>Horizontally Focusing Mirror:</u>
  slope errors in bent conditions < 0.3 µrad
- <u>2 KB systems:</u>
  → high flux set: 35 & 30 cm long mirrors with slope errors ≤ 0.2 µrad
  → high resolution set: small ultra-stable & high surface quality (s.e: 0.1 µrad; 0.5 nm 1σ) mirrors with fixed curvature to reach the diffraction limit (De Andrade et al., SPIE 2011).
- <u>Fluorescence Detection:</u>
  SRX will support R&D on a new generation of energy-dispersive detectors (MAIA upgrade) that will provide exceptional count rates for trace element analysis.