Argonne
NATIONAL LABORATORY

*... for a brighter future*

U.S. Department of Energy

UChicago ▸ Argonne LLC

Office of Science
U.S. DEPARTMENT OF ENERGY

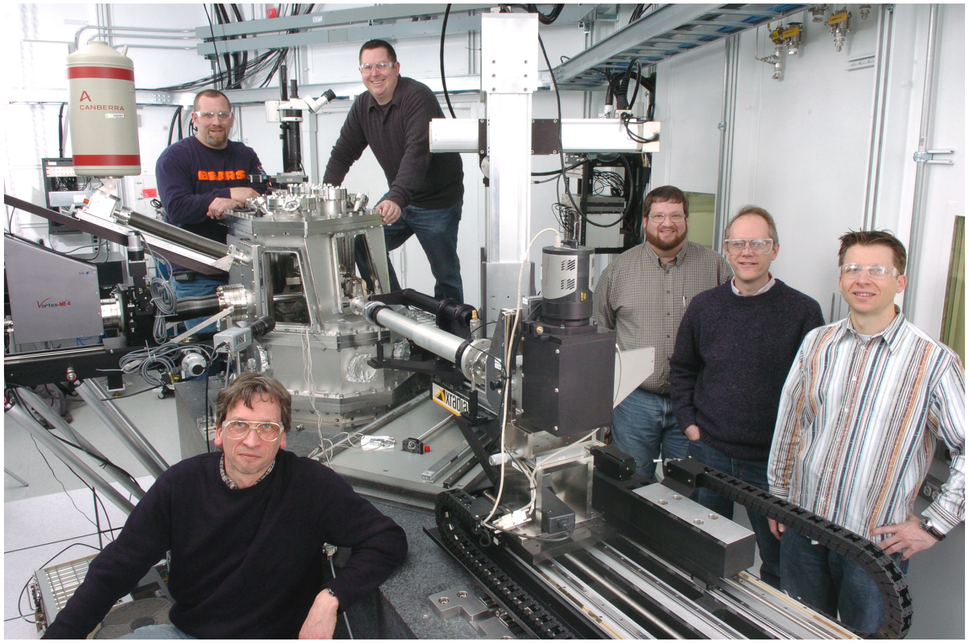
A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

# *New Ways to See a Smaller World: The Hard X-ray Nanoprobe at Argonne National Laboratory*


*Volker Rose*
*Advanced Photon Source*

*Robert Winarski, Martin Holt, Jörg Maser*
*Center for Nanoscale Materials*


# *The Hard X-ray Nanoprobe (HXN) Team*



- Jörg Maser
- Robert Winarski
- Martin Holt
- Brian Stephenson
- Peter Fuesz
- Dean Carbaugh
- Volker Rose (vrose@anl.gov)

http://nano.anl.gov/research/nanoprobe.html

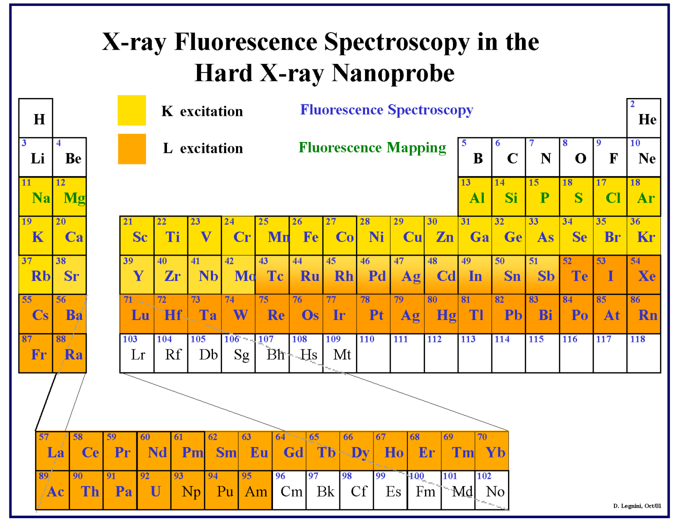
# *Outline*

- **What is the Hard X-ray Nanoprobe?**
- **Nanoprobe Beamline design**
- **Some recent results**

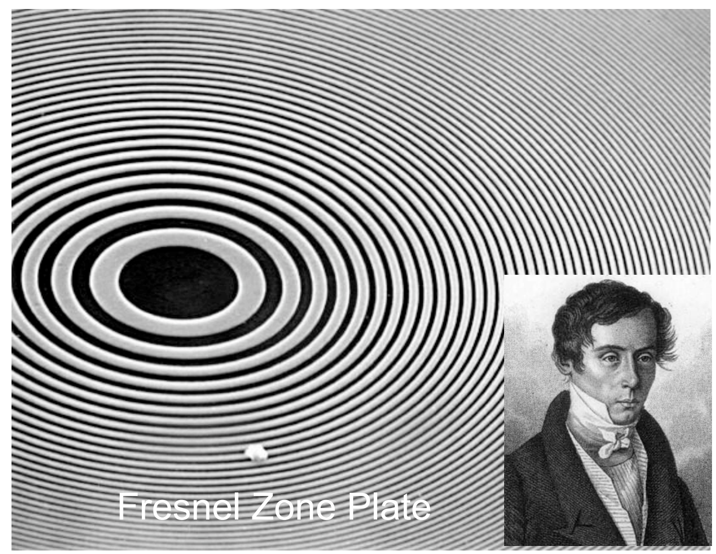
Advanced Photon Source

# Nanoprobe Instrument Overall Specifications

- Hard X-ray microscopy at the highest achievable spatial resolution
  - Initial spot size resolution d = 30nm
  - Energy range 3 - 30keV (nano-spectroscopy excitation of most elements)
  - Large penetration → sample environments/fields

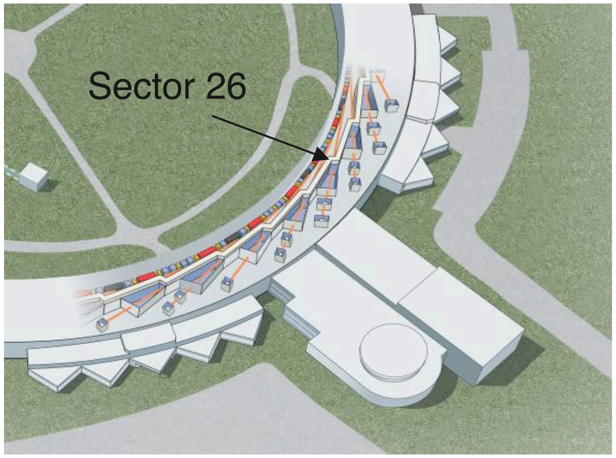



- Modes of operation
  - **X-ray fluorescence**: atto-g elemental sensitivity, chemical state sensitivity
  - **Diffraction**: sensitivity to crystallographic phase, strain, orientation
  - **Tomography**: 100 nm$^3$ resolution of transmission absorption / Zernicke phase contrast imaging
  - **Coherent x-ray studies**: disorder, imaging
  - **Magnetic contrast** using polarized x-rays
  - **Dynamic** studies at 100 ps time resolution
  - **Spectroscopy**



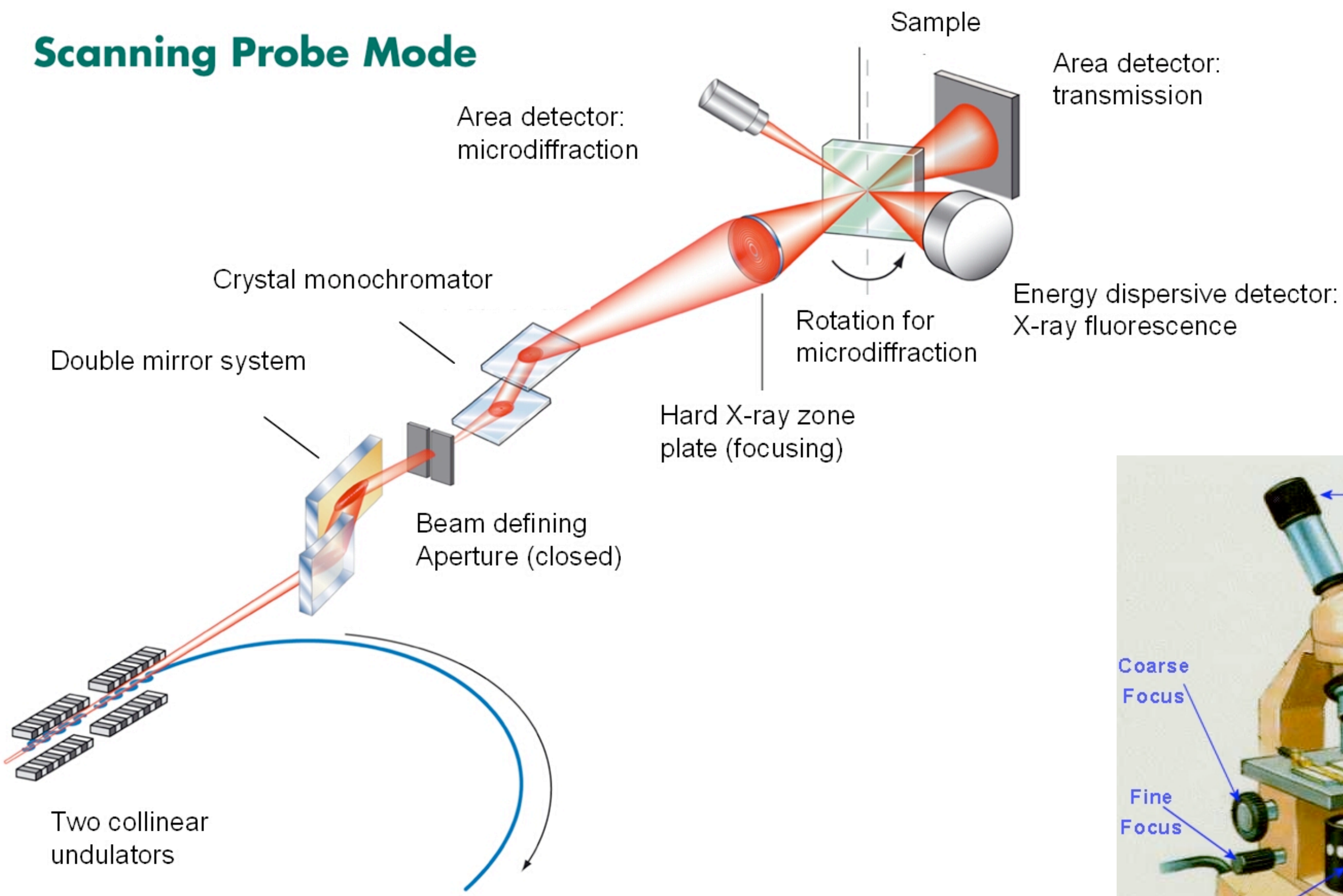
# *X-ray Characterization at CNM and APS*

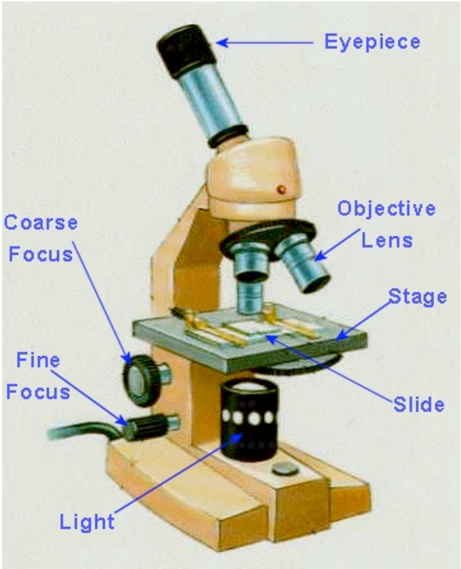
- The goal of Argonne's Center for Nanoscale Materials (CNM) is to create, characterize, and understand the behavior of new functional materials on the nanoscale.




- Located adjacent to the CNM building at Sector 26 of the Advanced Photon Source (APS)
- Developed in partnership with the APS to build a state-of-the-art beamline that will provide stable, powerful, and coherent x-ray illumination for research at the nanoscale

# Hard X-ray Nanoprobe: Combined Analytic and Imaging Mode



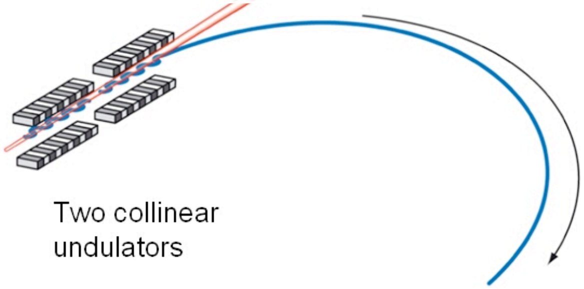



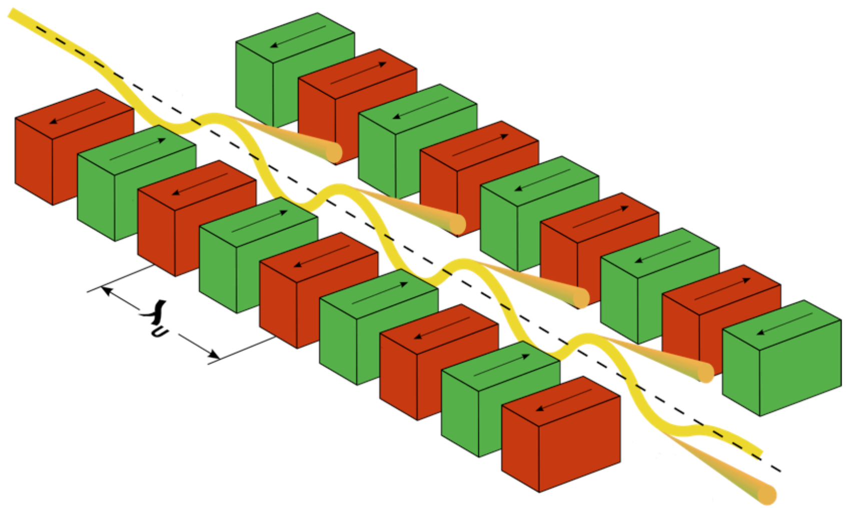
Copyright T. Burke Teachnet (2004)

# Hard X-ray Nanoprobe Beamline

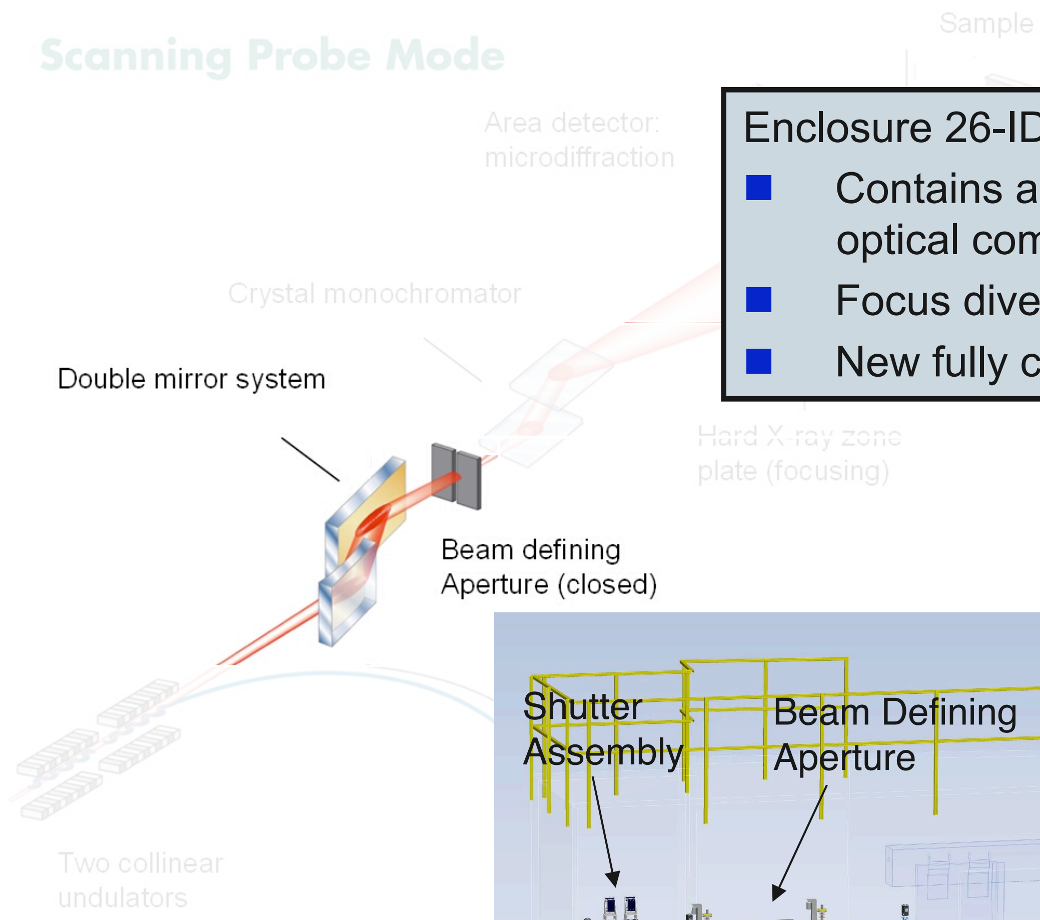
Synchrotron

- Advanced Photon Source: 7 GeV ring
- Two collinear undulators



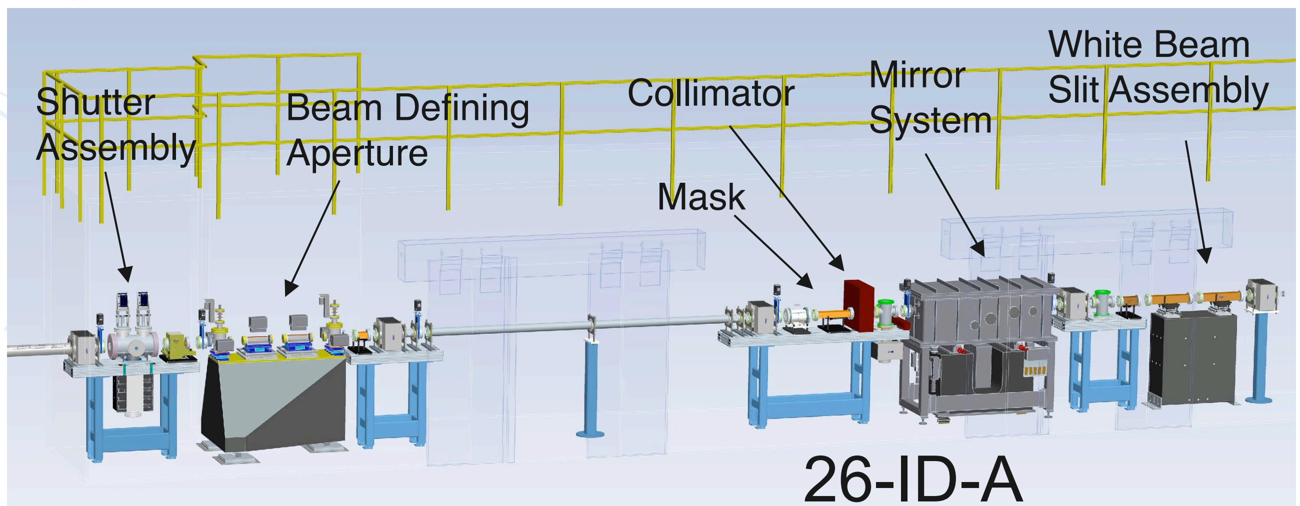



# *Hard X-ray Nanoprobe Beamline*




Enclosure 26-ID-A

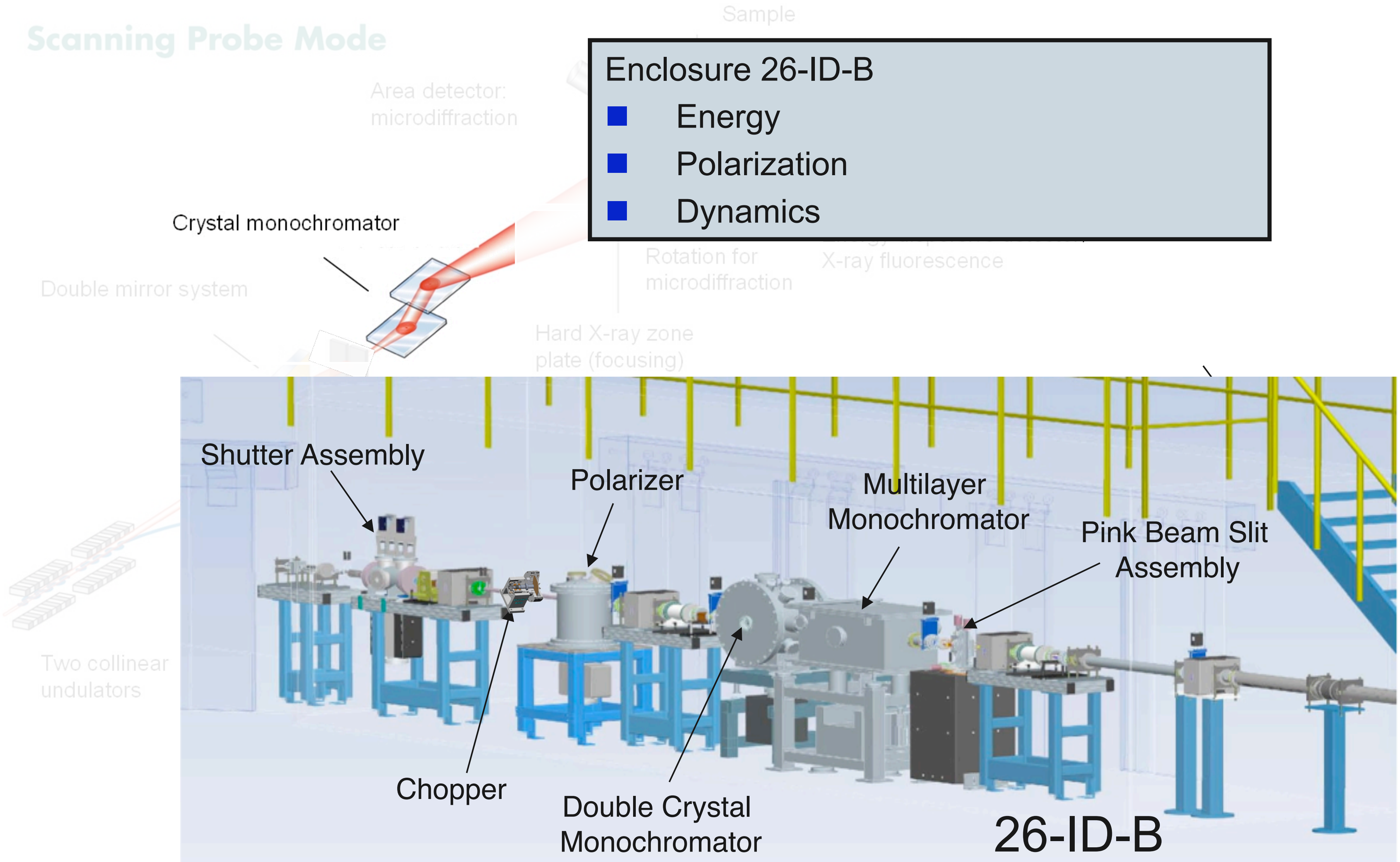
- Contains all of our high-heat-load optical components
- Focus divergent beam
- New fully coherent source at BDA



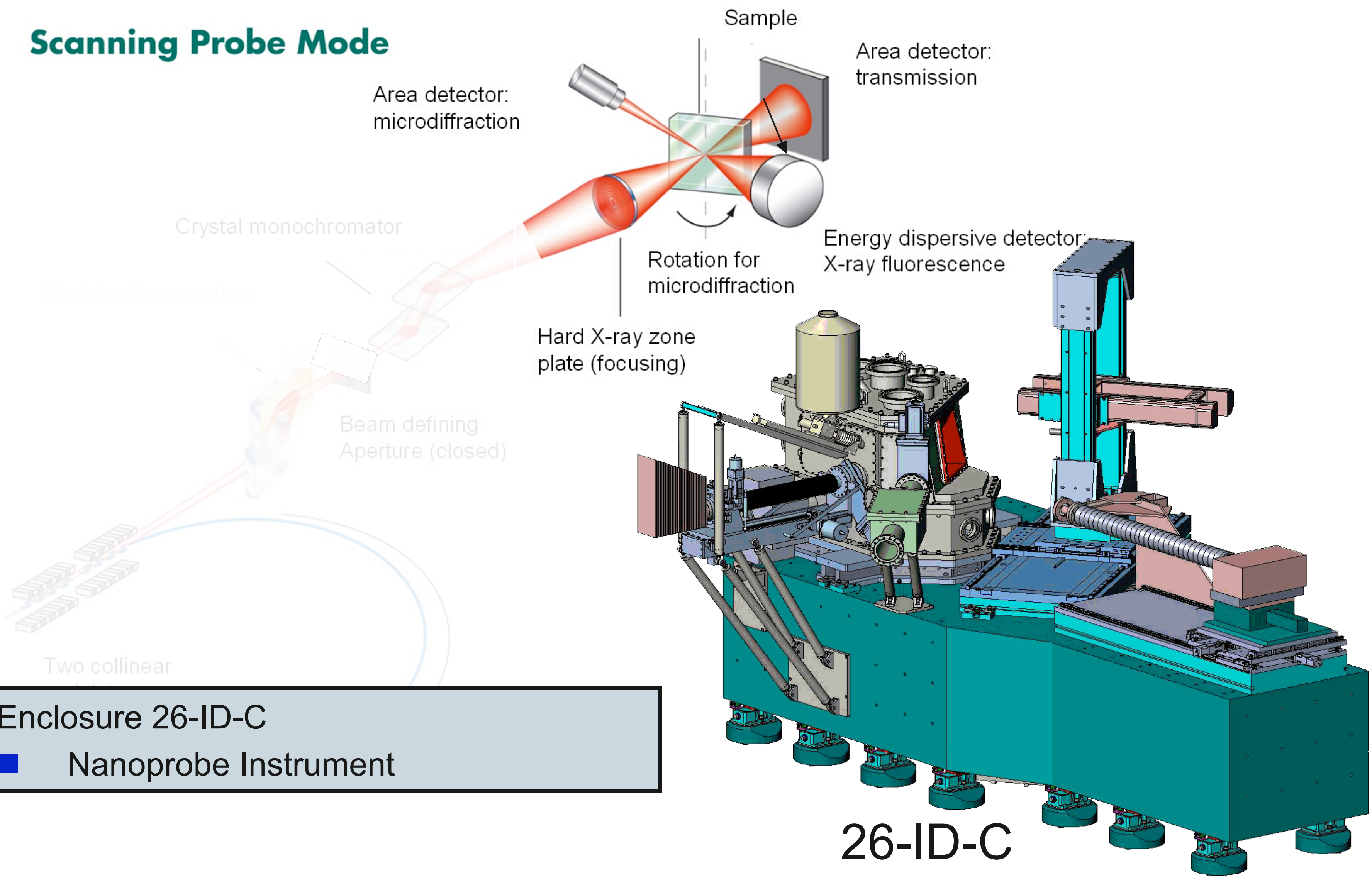
# *Hard X-ray Nanoprobe Beamline*

Enclosure 26-ID-B

- Energy
- Polarization
- Dynamics



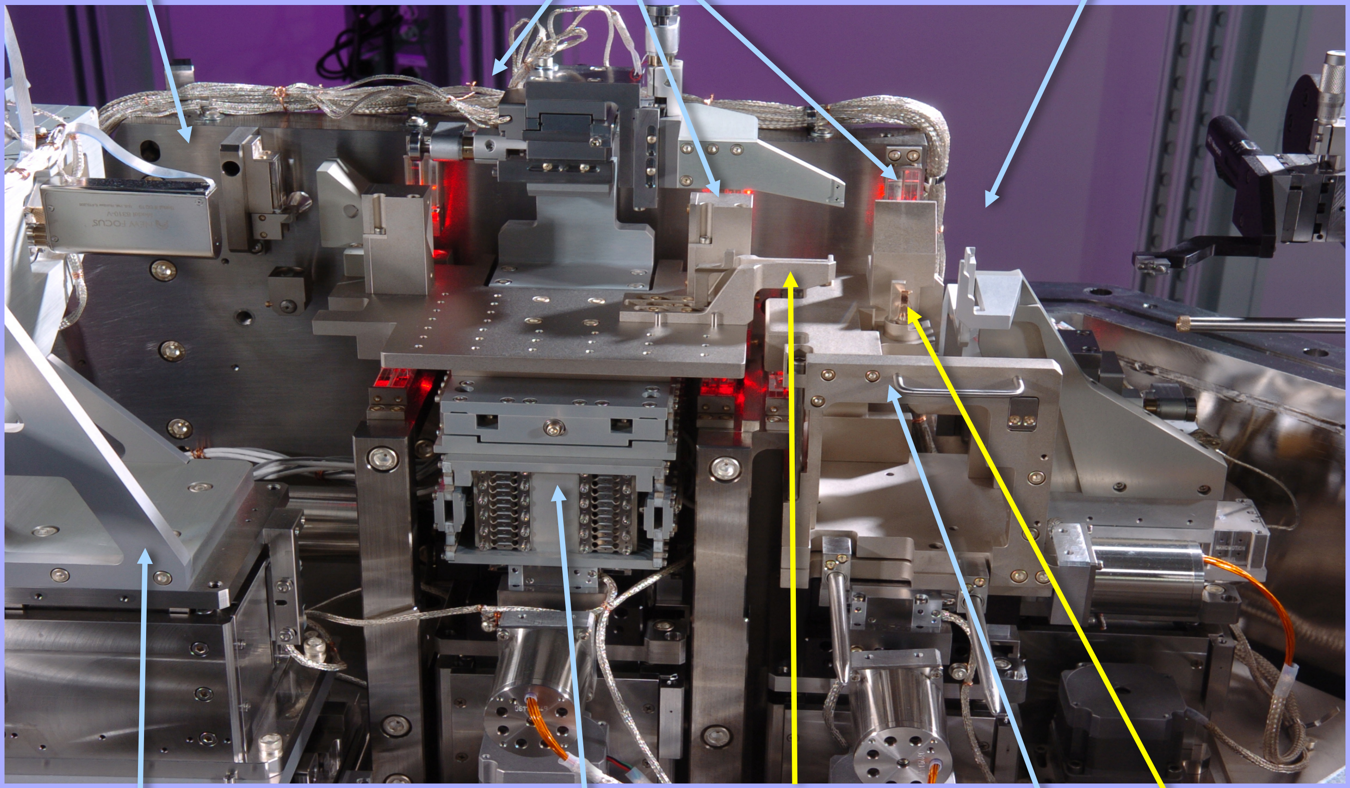
# Hard X-ray Nanoprobe Beamline



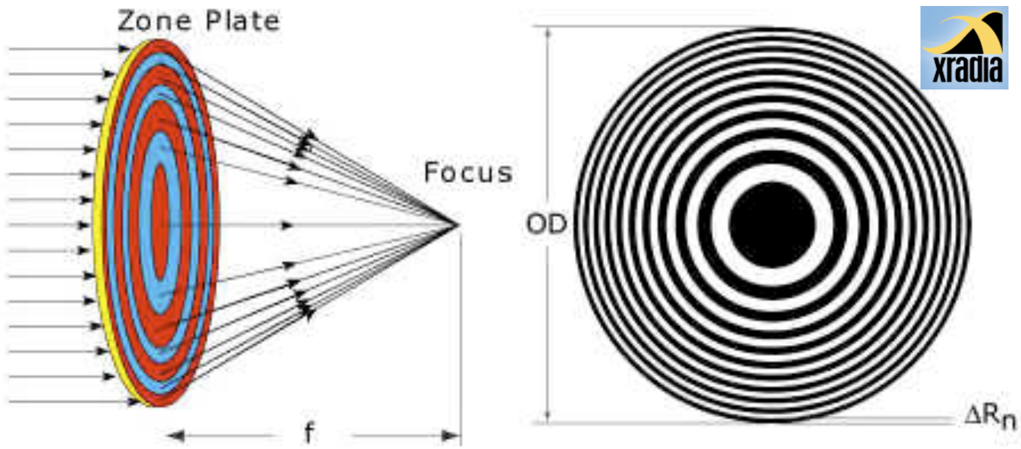

Enclosure 26-ID-C

- Nanoprobe Instrument

# Hard X-ray Nanoprobe Instrument



# *Focusing X-rays With Zone Plates For Synchrotron Use*

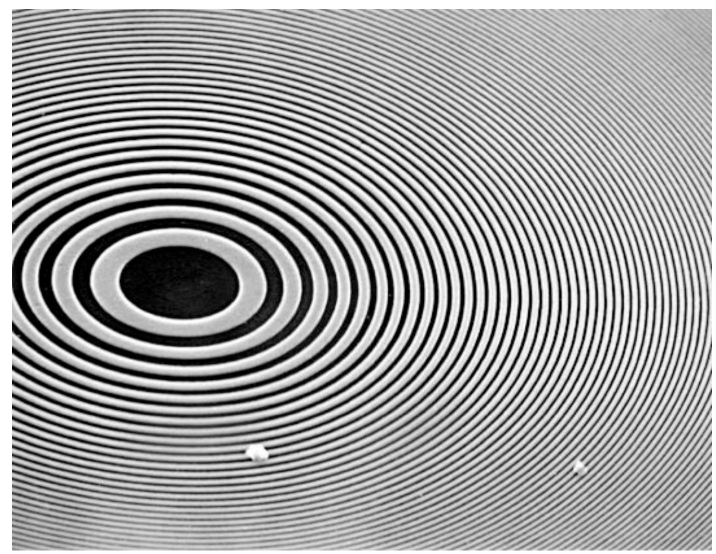



Constructive interference from adjacent zones

Focal length f = OD•ΔRn/λ

Resolution limited to 1.22•$\Delta R_n$ (Raleigh criterion):

- ➔ Spatial coherence / source demagnification (combination of source size and distance)
- ➔ Temporal coherence / monochromaticity (small wavelength spread)



# *Examples for Research at the Hard X-ray Nanoprobe*

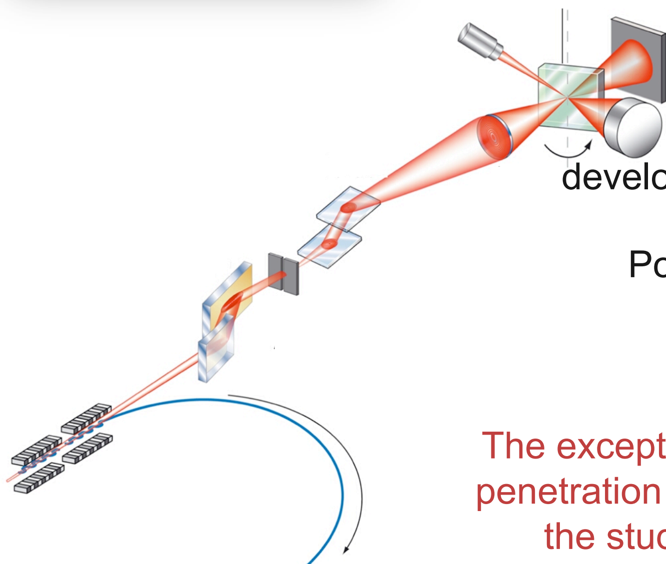
1. Fluorescence: Characterization of heterogeneous Ca and heavy metal distributions in geopolymers

2. Nanodiffraction: Strained Si-on-oxide hetero structures

3. Tomography: Scanning Tunneling Microscopy tip

# The Hard X-ray Nanoprobe (HXN) Goes Green

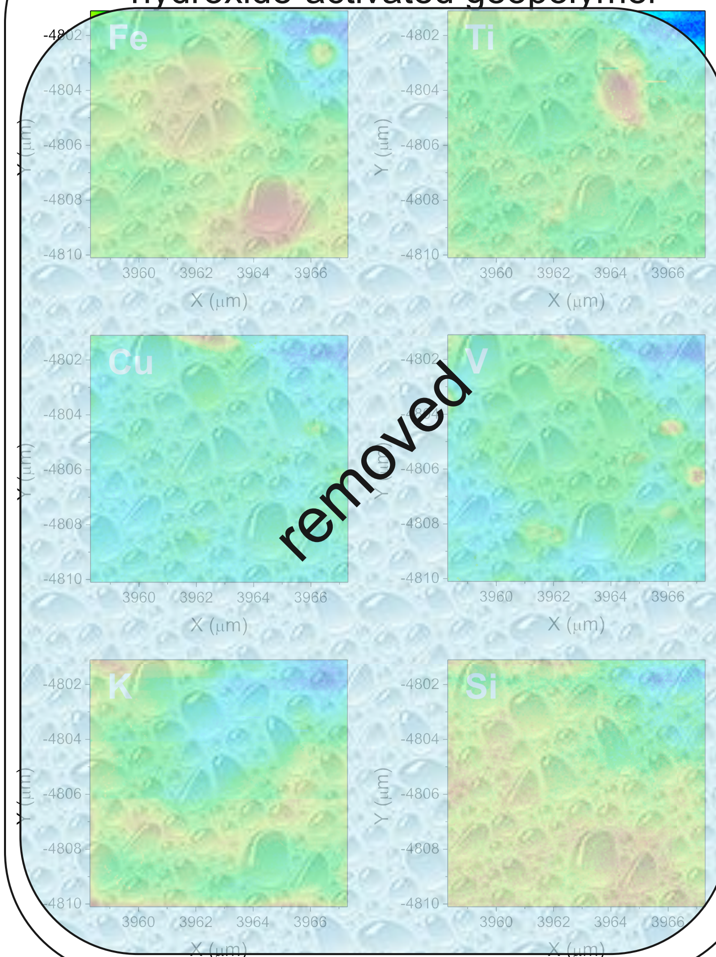
*Research may reduce $CO_2$ Greenhouse gas emissions by at least tens of millions of tones per annum worldwide*



Geopolymers are being developed as an environmentally beneficial replacement to Portland cement for concrete production

The exceptional spatial resolution and penetration power of the HXN enables the study of the poorly understood heterogeneity and complex chemistry of geopolymers

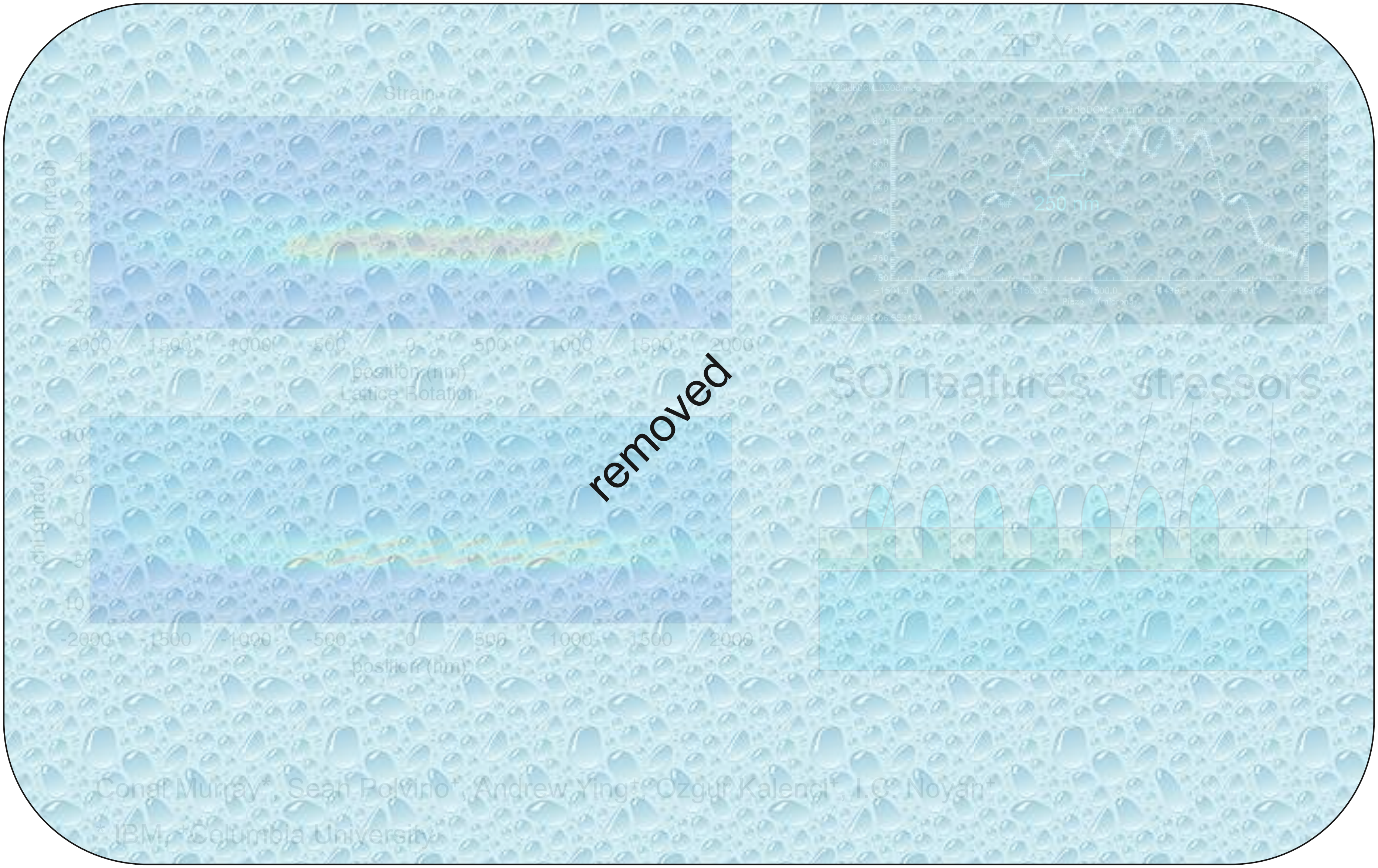
X-ray fluorescence maps of a hydroxide-activated geopolymer



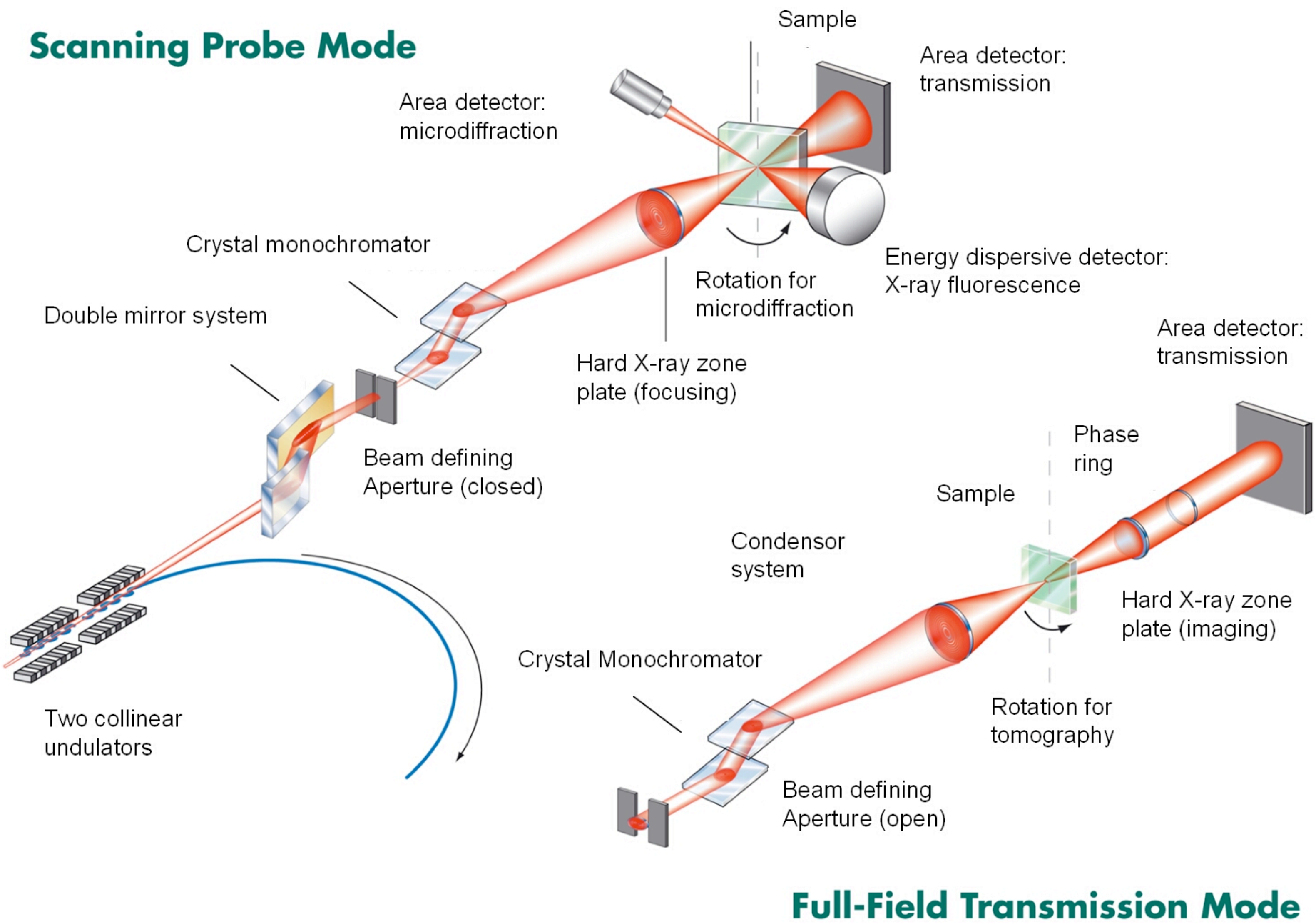

John Provis[1], Volker Rose[2], Susan Bernal[1], Jany van Deventer[1]

[1]Melbourne University, [2]Argonne National Laboratory

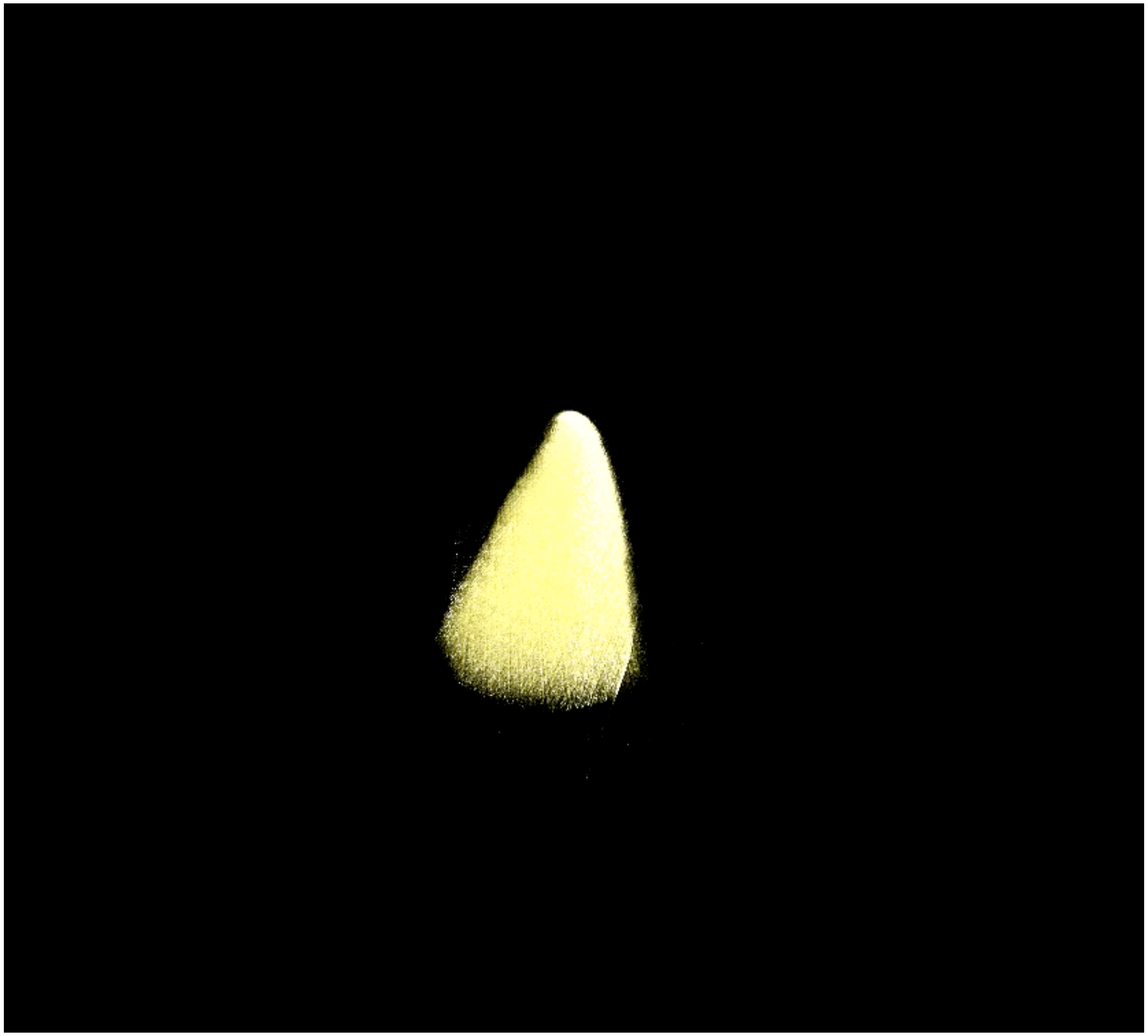
## *Nanodiffraction of strained SOI heterostructures*



# Hard X-ray Nanoprobe: Combined Analytic and Imaging Mode

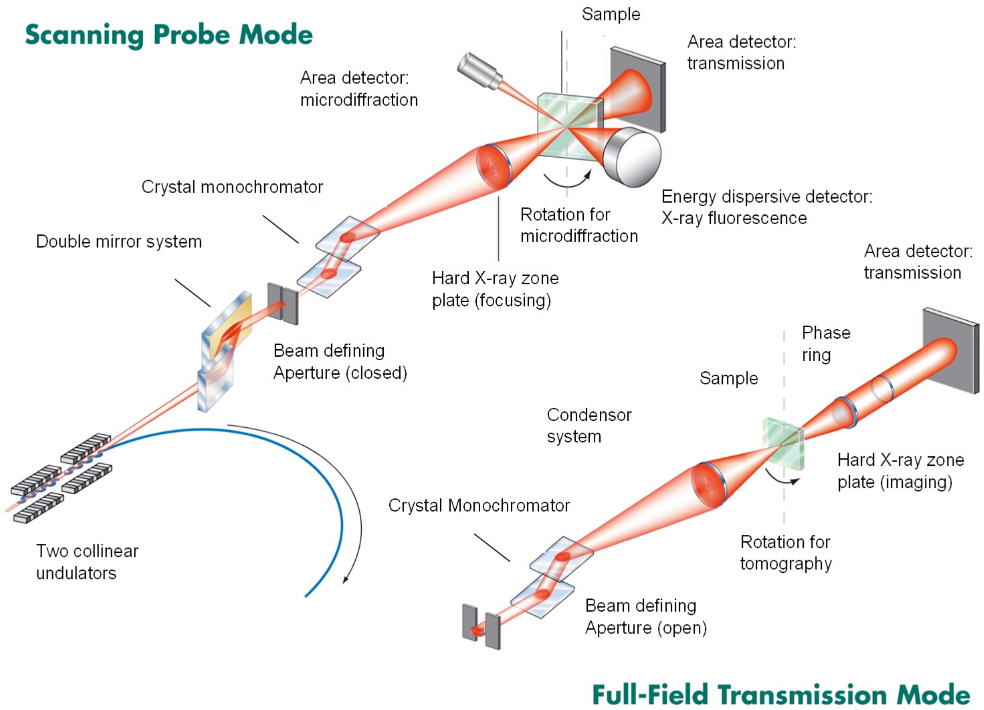


# Tomography Of Scanning Tunneling Microscopy Tips



# Summary - To Go

- Designed to resolve objects smaller than 30 nanometers in size using intense x-rays with energies between 3 and 30 keV
- Modes of operation:
  - *Transmission*
  - *Fluorescence*
  - *Diffraction*
  - *Spectroscopy*
  - *Polarization*
  - *Tomography*
  - *Dynamics*




This work was supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.

## *Become a User Today!*

# Go to www.aps.anl.gov