Project Status

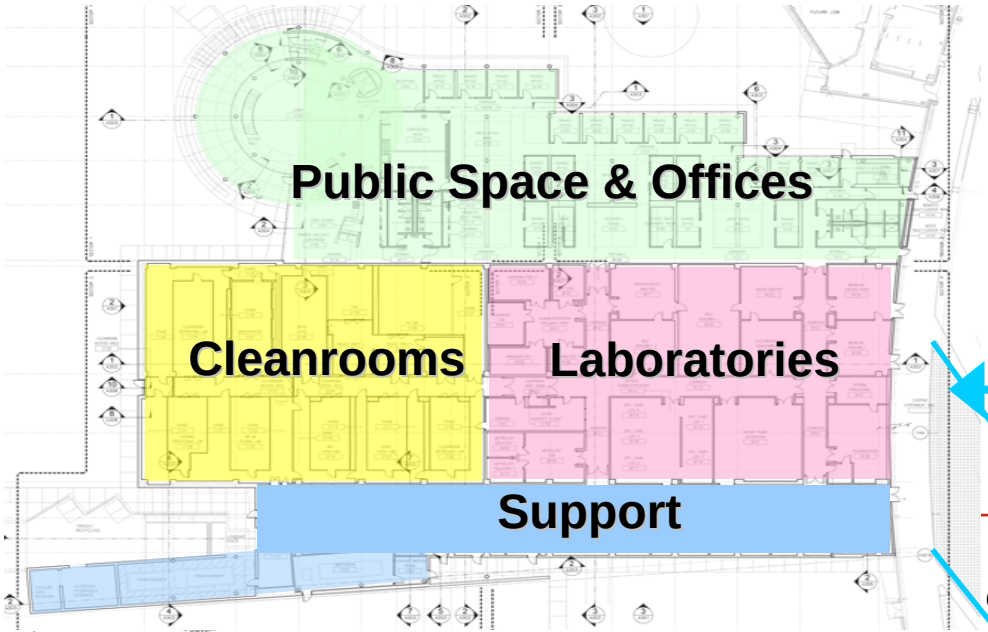
CNM and Hard X-ray Nanoprobe Beamline

Jörg Maser

Advanced Photon Source
Center for Nanoscale Materials
Argonne National Laboratory

Office of Science
U.S. Department of Energy

CNM/Nanoprobe beamline



Center for

Nanoscale Materials

"Explore and develop new approaches to

Fabrication, characterization, understanding

of

Nanoscale confined materials with new properties"

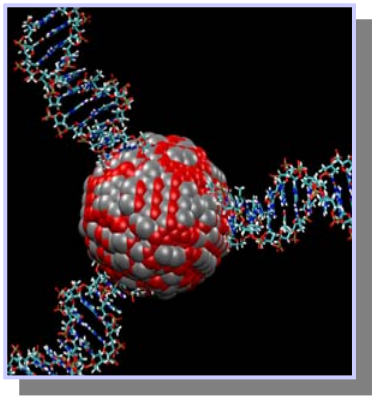
- $36 M DOE equipment.
- $36 M State-of-Illinois building.

- Building completed in FY06.
- $18.5 M DOE Operations funds in FY07.

Nanoprobe Beamline

APS Sector 26

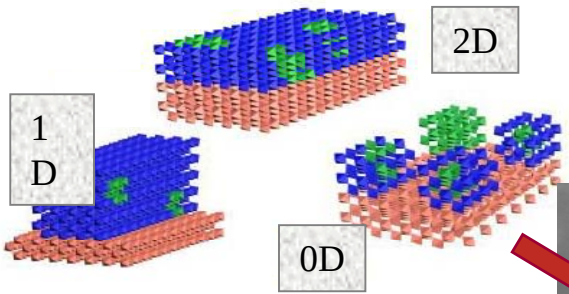
CNM Scientific Themes



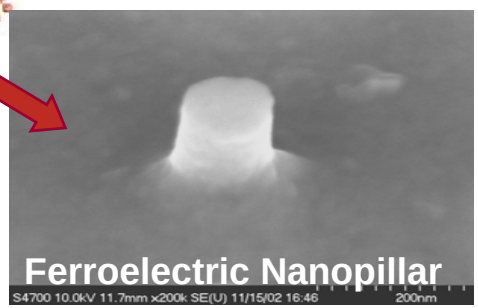
Novel functional nanocomposites

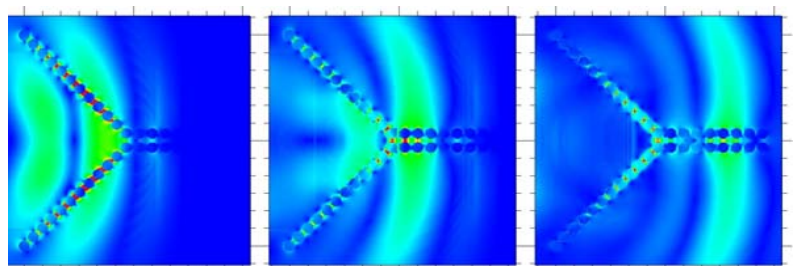
- Bio-Inorganic Interface (*D. Tiede, T. Rajh, M. Firestone*)
- Nanocarbon (*D. Gruen, J. Carlisle*)
- Nanomagnetism (*S. Bader, A. Hoffmann*)
- Complex Oxides (*O. Auciello, S. Streiffer*)
- Nanophotonics (*G. Wiederrecht, S. Gray*)
- Virtual Fab Lab (*S. Gray, P. Zapol*)

- Lithography (*L. Ocola, D. Mancini*)
- X-Ray Nanoprobe (*J. Maser, B. Stephenson*)



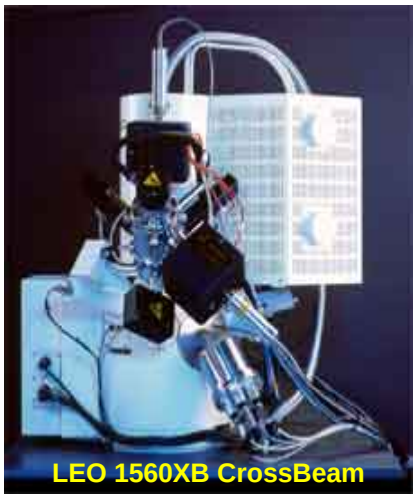
Complex oxides with new functionalities





Sub-wavelength photon confinement/propagation

Fabrication and Characterization Tools in CNM

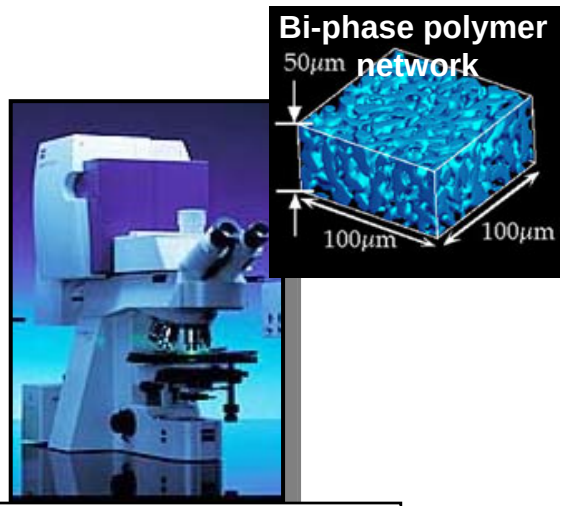


FIB/SEM

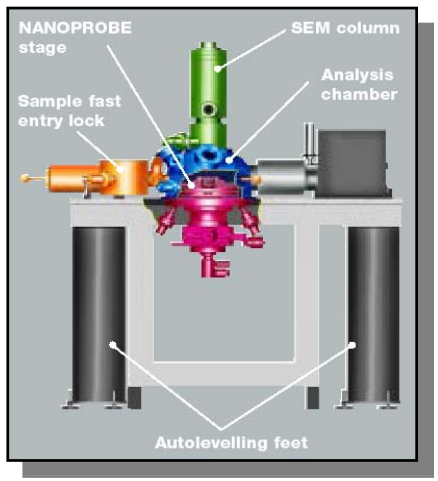
State-of-the-art nanofabrication and characterization tools require highly engineered specialized environments:

- FIB/SEM
- E-beam lithography (25 kV, 100 kV systems)
- Confocal laser scanning Microscope
- SEM/Scanning probe microscopy

E-beam Lithography

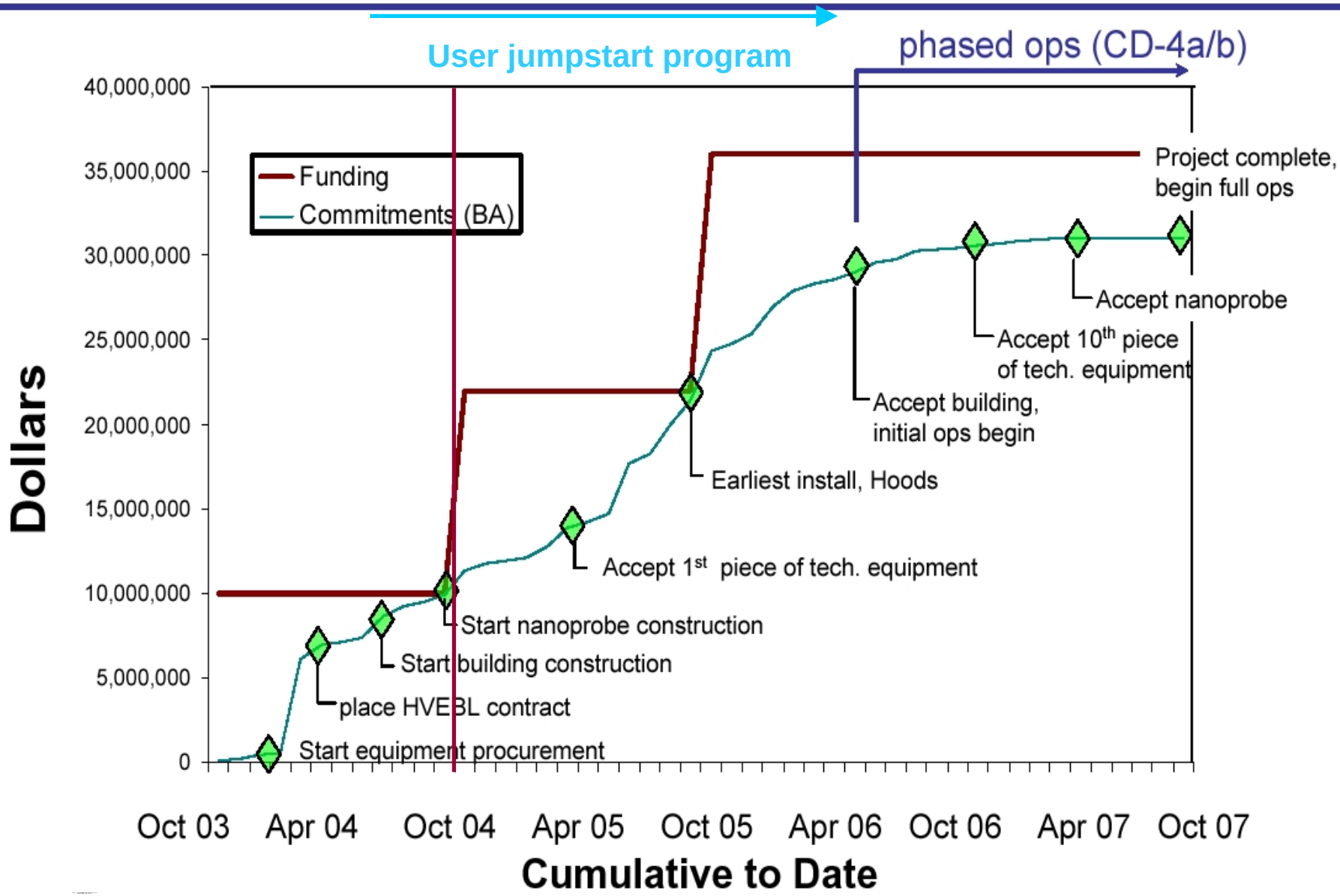


Confocal Laser Scanning Microscopy

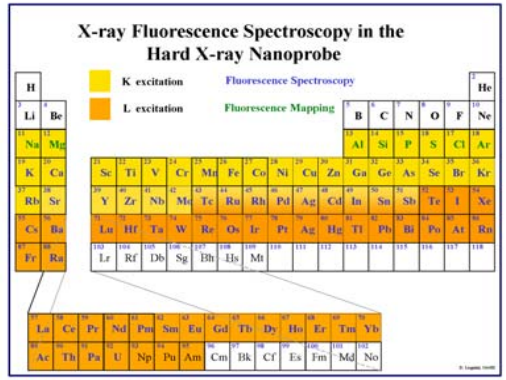


Combined SEM/SPM

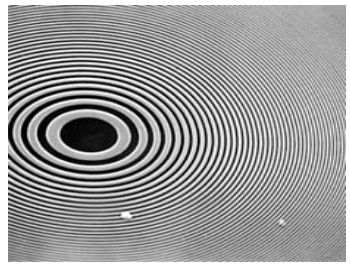
Equipment Cost/Schedule



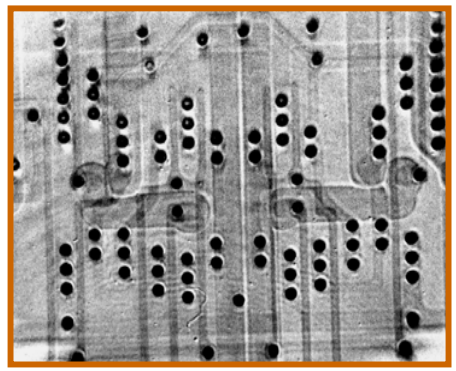
Hard X-ray Nanoprobe



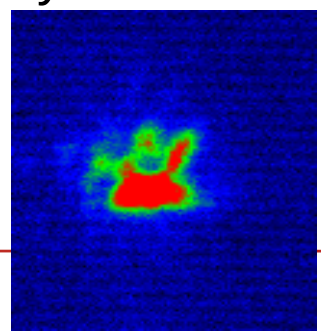
- **Overall specifications:**
  - Energy range: 3 – 30 keV
    - Excitation of most elements
  - Spatial resolution: δ = 30 nm
    - Limited by x-ray optics.
  - Tomographic transmission imaging.
  - Full nano-spectroscopy capability
    - Near-edge spectroscopy.
  - Diffraction-contrast Imaging



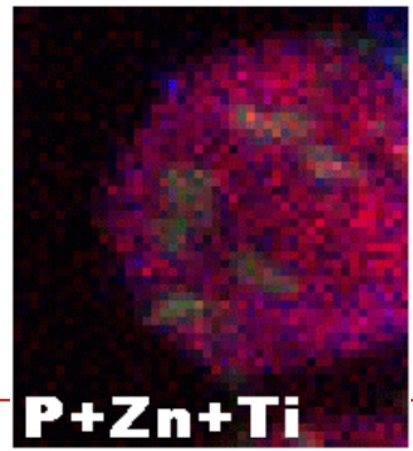
Courtesy R. Divan, CNM



Courtesy J. Susini, ESRF



Courtesy Z. Cai, APS



Courtesy T. Paunesku, NWU

Why diffractive optics?

X-ray optics	Diffractive Optics	Mirror Optics	Refractive Optics
Numerical aperture	• High NA possible (Limit: manufacture)	– Limited NA (θ_c)	Limited NA (D_{eff}) Compton scattering
Efficiency	20% - 30% (60%)	70% - 90%	20% - 30%
Chromaticity	f ~ 1/λ	Non-chromatic	f ~ $1/\lambda^2$
Field of view	Y (δ > 10 nm)	• Kirkpatrick/Baez: N • Wolter Y (> 13nm)	Y
Other	• Monochromatic beam • On-axis geometry • Any x-ray energy	• White (pink) beam • Grazing incidence geometry. • Any x-ray energy	• Monochromatic beam • On-axis geometry • Long lenses • Limited energy range

Diffractive optics allow sub-10 nm resolution (technical challenges)

Hard x-ray Nanoprobe beamline layout

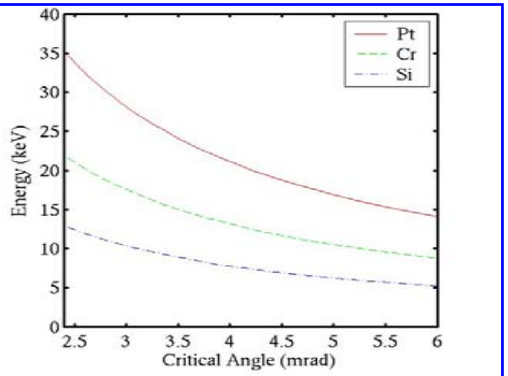
LN_2 cooled crystal monochromator

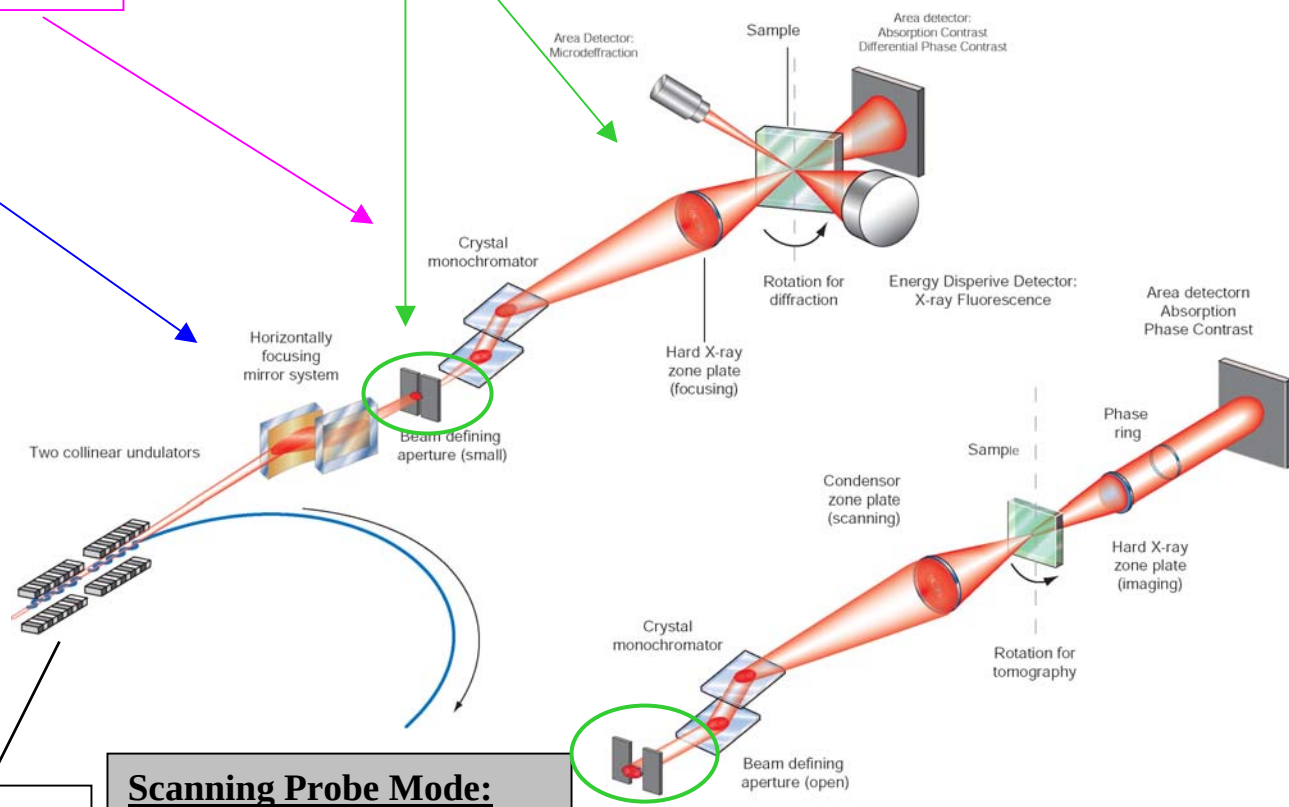
Spatially coherent wavefront, BDA closed

Double mirror system:

M1a: fully illuminated, elliptically bent

M1b: flat





Twin undulators: λ_u = 3.3 cm

10^{20} hν/s/mm/mrad/0.1%BW

> 10^{13} hν/s/um^2 (8 keV)

Scanning Probe Mode:

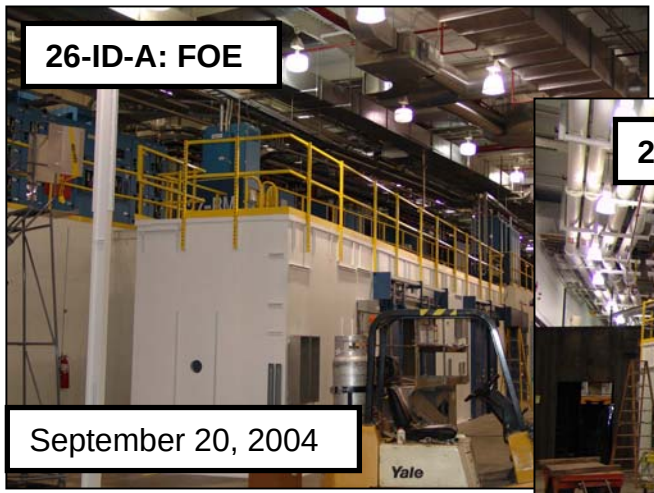
BDA closed to provide coherent illumination of zone plate

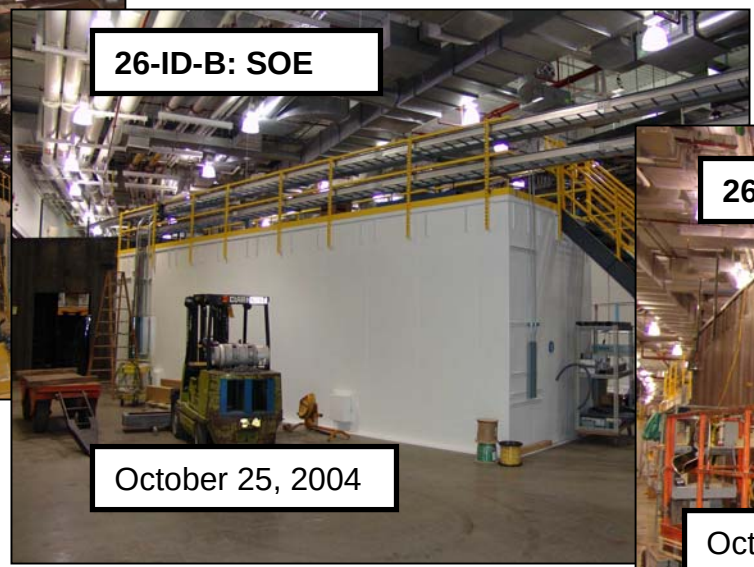
Full-Field Transmission mode:

BDA open to use full undulator flux

Nanoprobe BL status

- Radiation enclosures and standard components being installed on APS floor





- Shielding verification: Mar/05
- Major components (zone plates, mirror system, monochromators) being ordered
- Beamline components to be installed by Dec/06
- Nanoprobe instrument design ongoing; installation by Mar/07
- User jumpstart instrument being commissioned

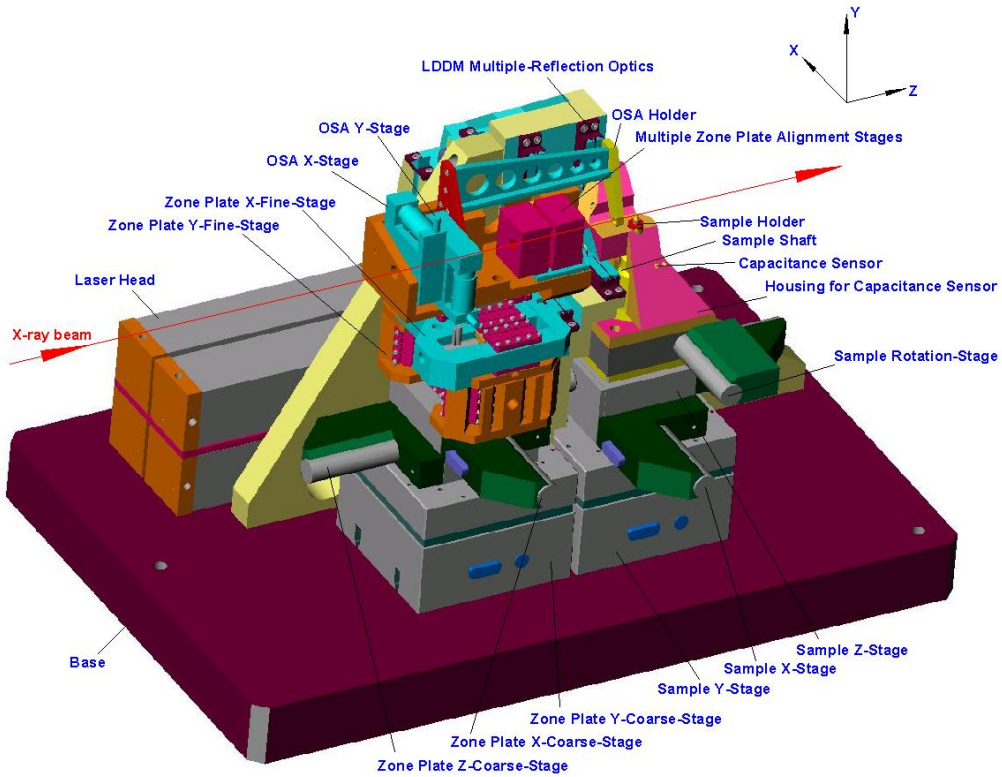
Courtesy R. Winarski

First Steps: Hard x-ray nanoprobe instrument

- Requirements:
  - 4-5 nm mechanical resolution,
  - active vibration control
  - μrad resolution for spectral scans

- Approach:
  - Laser Doppler interferometer on reference frame measures *absolute* position of optics, sample.
  - SMALL-RANGE flexures + piezo-feedback respond to laser interferometer input
  - Fine scan x/y of zone plate

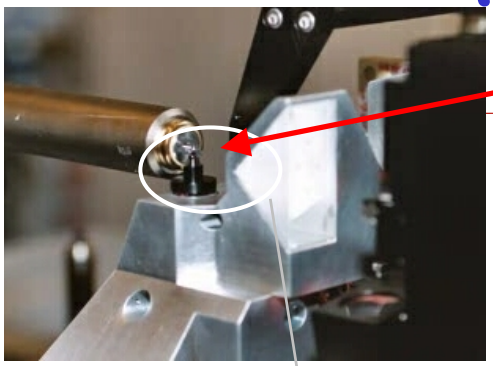
Hard X-ray Nanoprobe Prototype Instrument

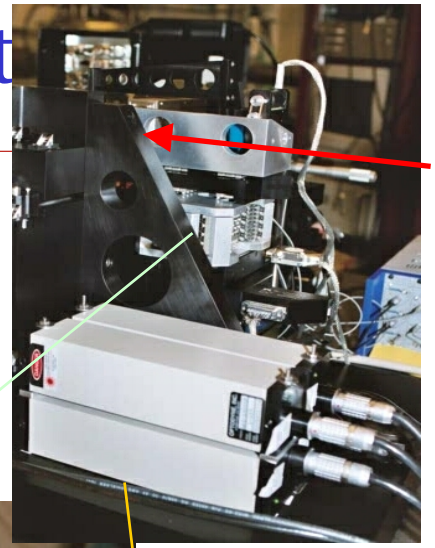


"User Startup" Instrument

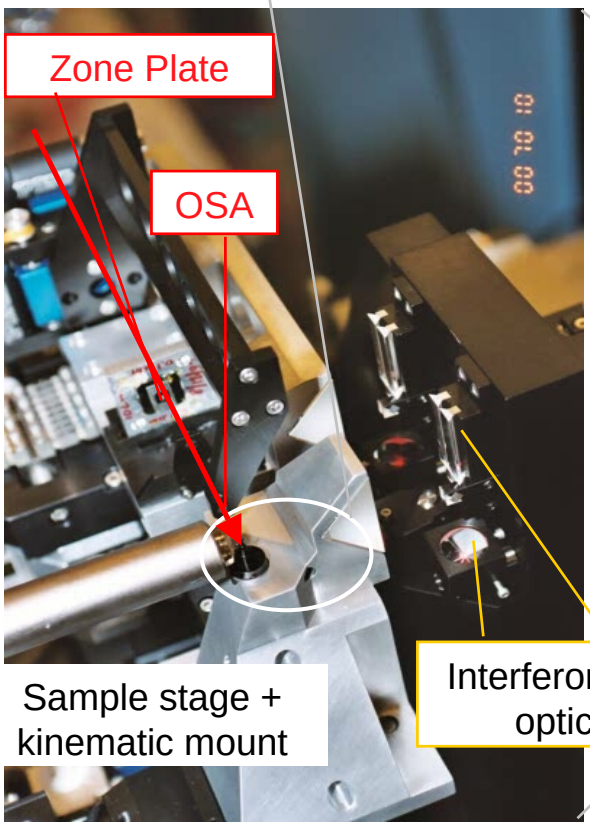
D. Shu, J. Maser, B. Lai, S.Vogt

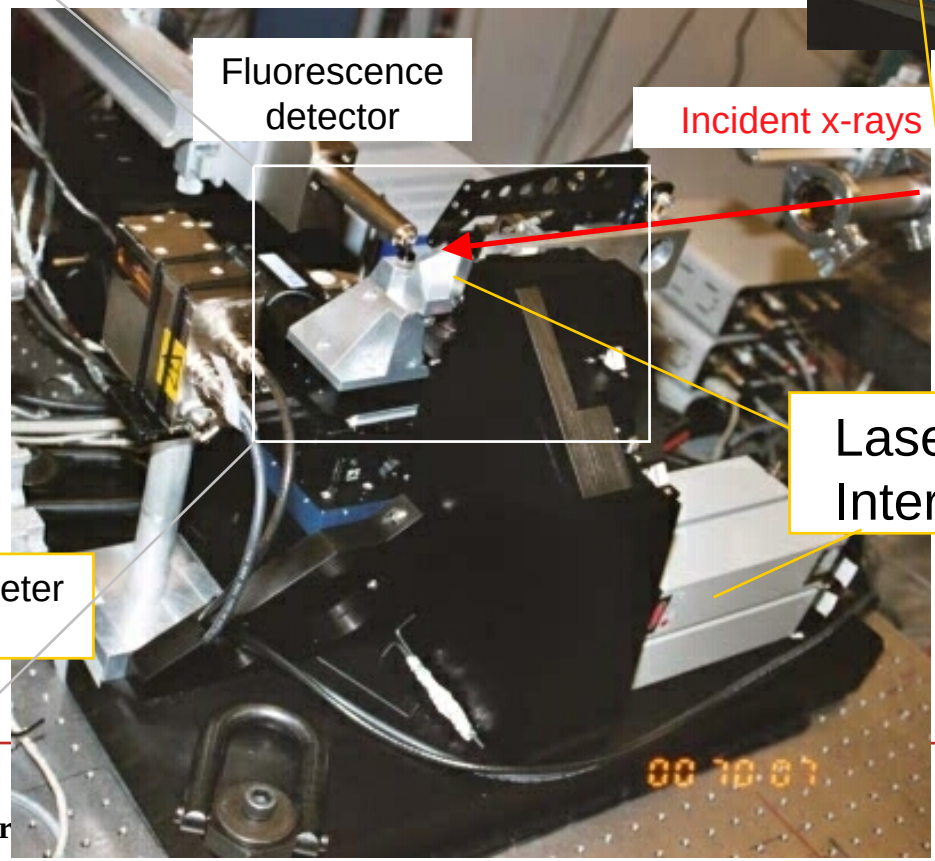
Y. Han, C. Preissner, R.Winarksi,M. Holt



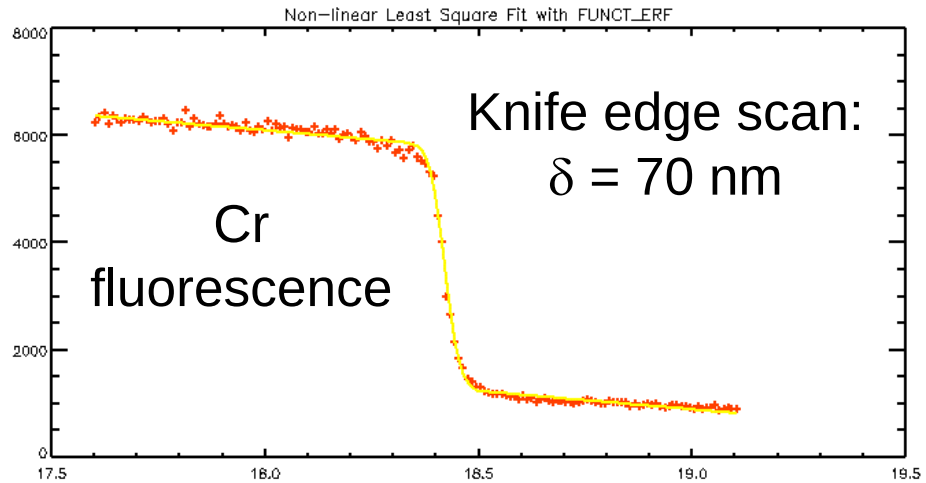


2D Zone plate flexure stage

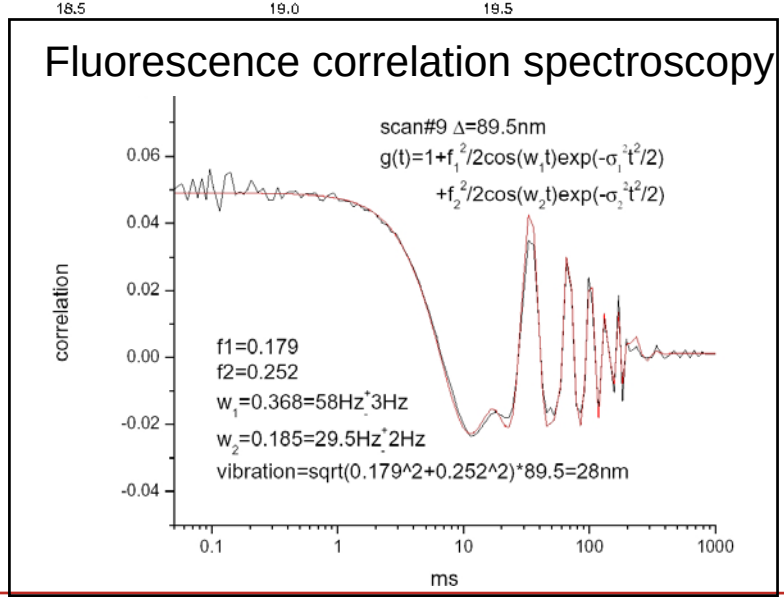




First system characterization 8-ID-E



Fluorescence correlation spectroscopy analysis courtesy Yujie Wang



Aug/04:

ZP: dr_N = 50 nm

Demagnified source:

d = 70 nm

Measured spot size:

80 (70) nm

Total system noise (including synchrotron and beamline):

28 nm

Conclusion

- **CNM project has begun construction**
  - Building construction under way
  - Long leadtime equipment (HVEBL system) ordered
  - Hard x-ray Nanoprobe beamline under construction at 26-ID
  - Phase-in of CNM operation: summer, 2006
  - Full operations CNM, Nanoprobe beamline: Fall 2007
  - User startup program accepts proposals:

http://nano.anl.gov

The people involved

- **CNM project:**

  Eric Isaacs, Derrick Mancini, Stephen Streiffer, L. Ocola, K. Hellman

- **Nanoprobe beamline project**
  - Brian Stephenson, J. Maser, Bob Winarski, M. Holt, Christa Benson, B. Tieman.

- **Instrument development:**
  - Deming Shu, B. Lai, S. Vogt, Curt Preissner, Yufeng Han, Alex Smolyanitskiy.

- **Many others:**
  - G. Schneider, A. Khounsary, Y. Li, L. Assoufid, M. Ramanathan, Y. Jaski, B. Brajuskovic, E. Rossi.
  - Bill Wesolowski, Kevin Randall, Gary Edgell, Steve Davey, Bruce Stockmeier, Tom Barsz, Jon Hawkins, Greg Markovich, Ann Boron