Ways to Lose Coherence in Beamlines for Hard X-ray Imaging by Diffraction

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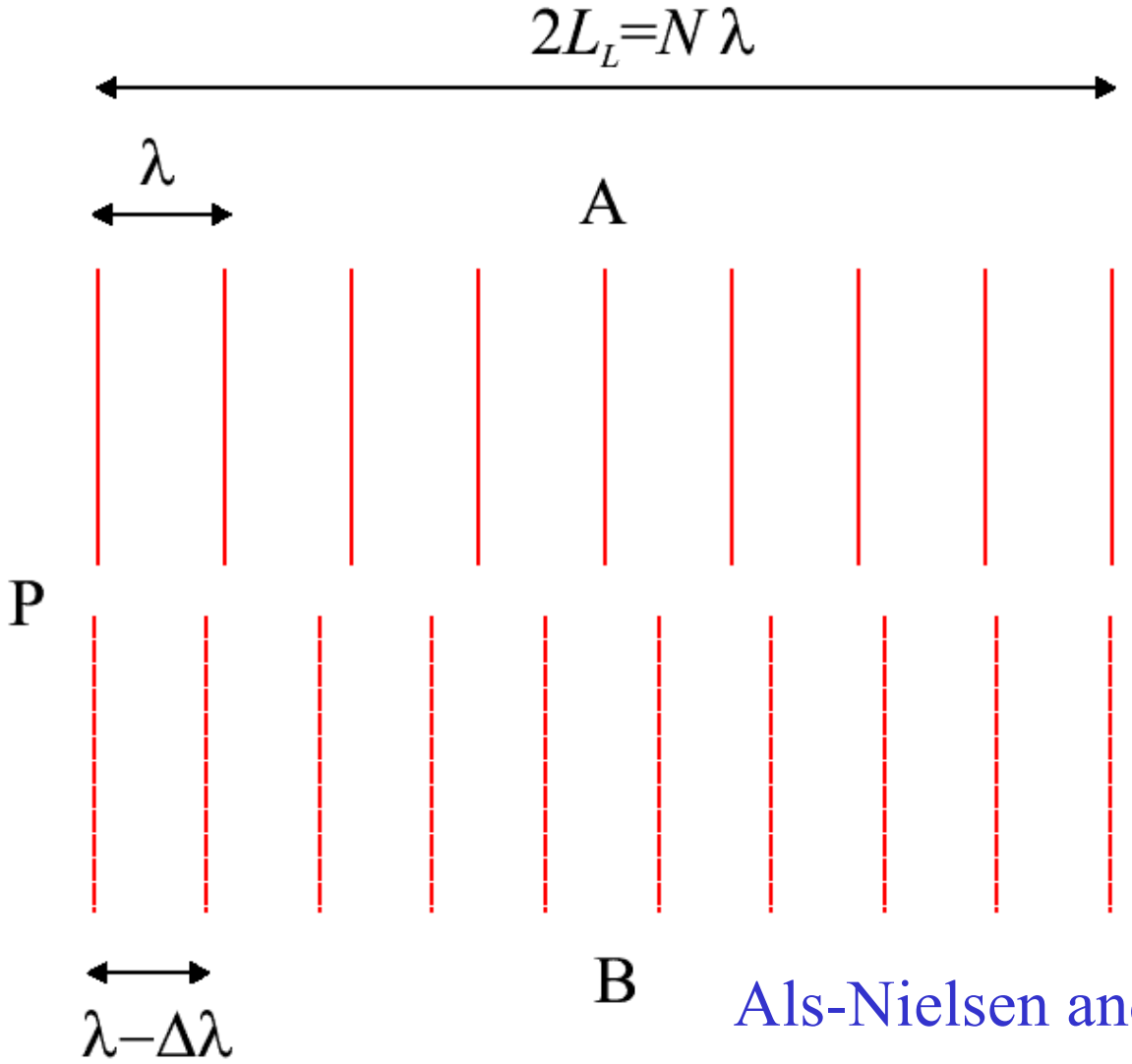
Outline

- Coherence in Diffraction
- Imaging by Coherent Diffraction
- Shapes of Nanocrystals in 3D
- Ways to Lose Coherence
- Possible Remedies

Goals of Coherent Diffraction

- Thermodynamic fluctuations by XPCS
  - No ensemble average in CXD
- Probe of structure on nm scale
  - 1D, 2D and 3D
  - non-periodic object gives continuous F(**q**)
- Oversampling (in reciprocal space) permits solution of the phase problem

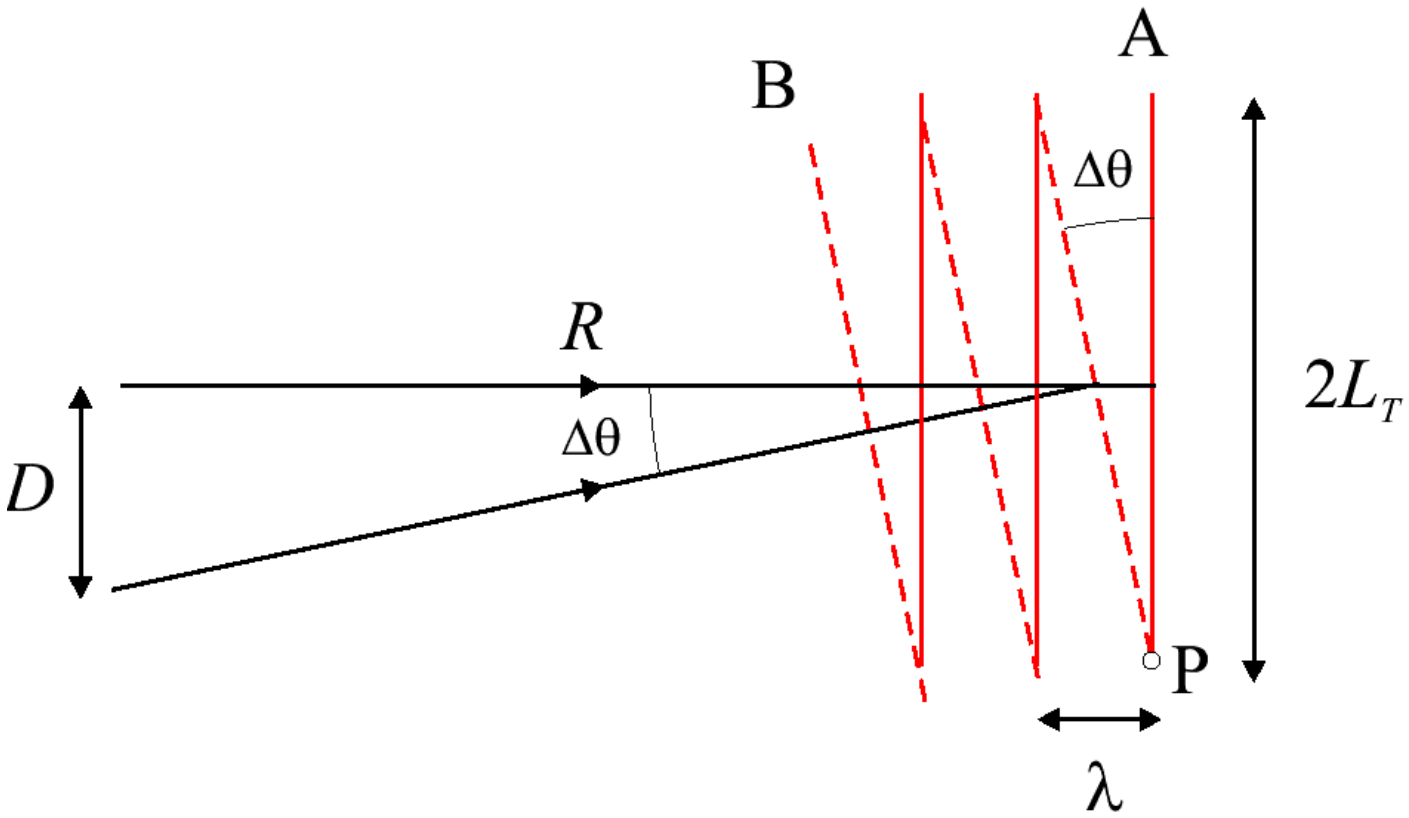
Longitudinal Coherence



$$L_L = \frac{1}{2}\frac{\lambda^2}{\Delta\lambda}$$

Als-Nielsen and McMorrow (2001)

Lateral (Transverse) Coherence



$$L_T = \frac{\lambda}{2}\frac{R}{D}$$

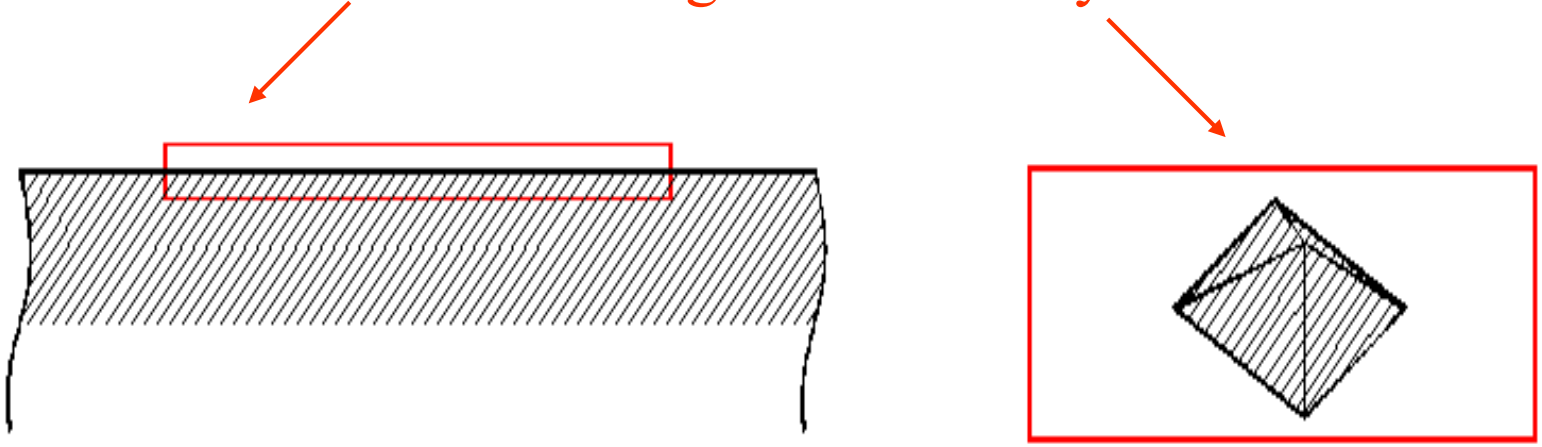
Als-Nielsen and McMorrow (2001)

Coherence at the APS

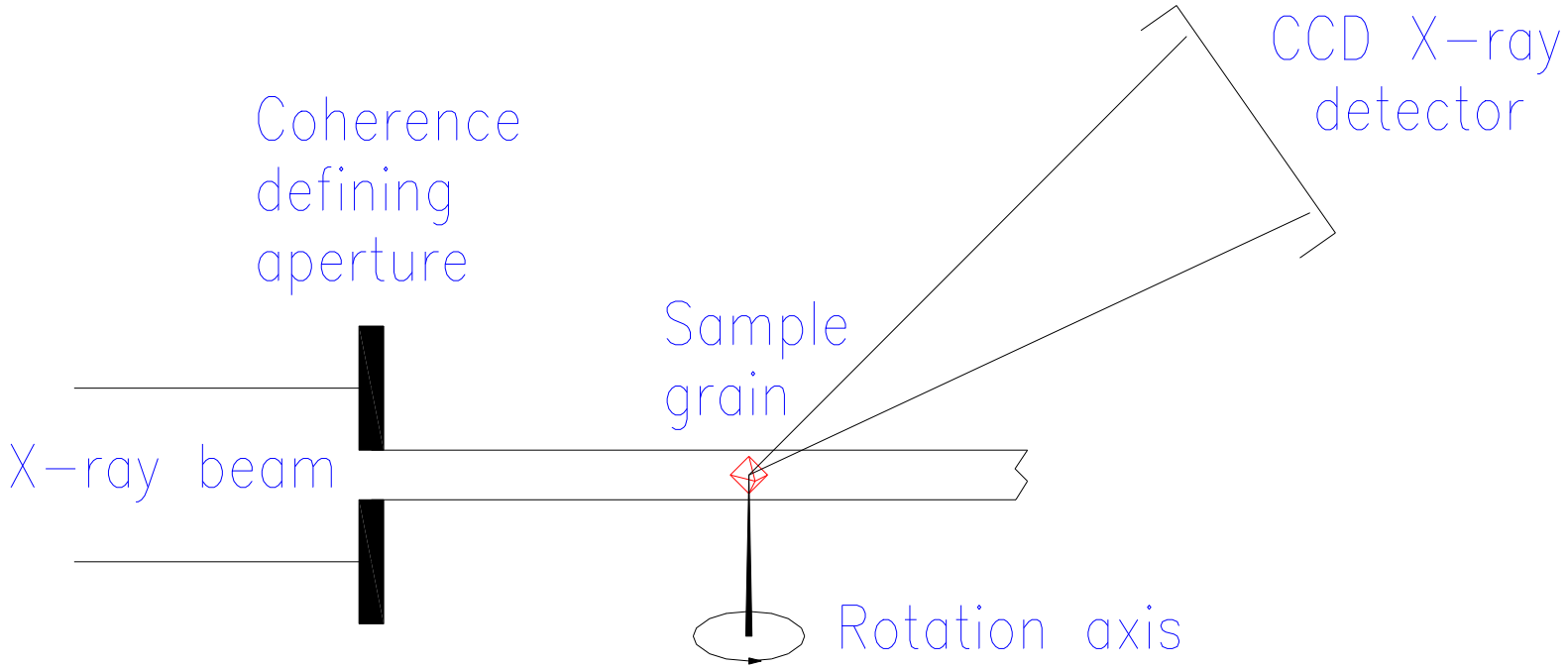
Typical 3rd Generation (undulator) Synchrotron Source

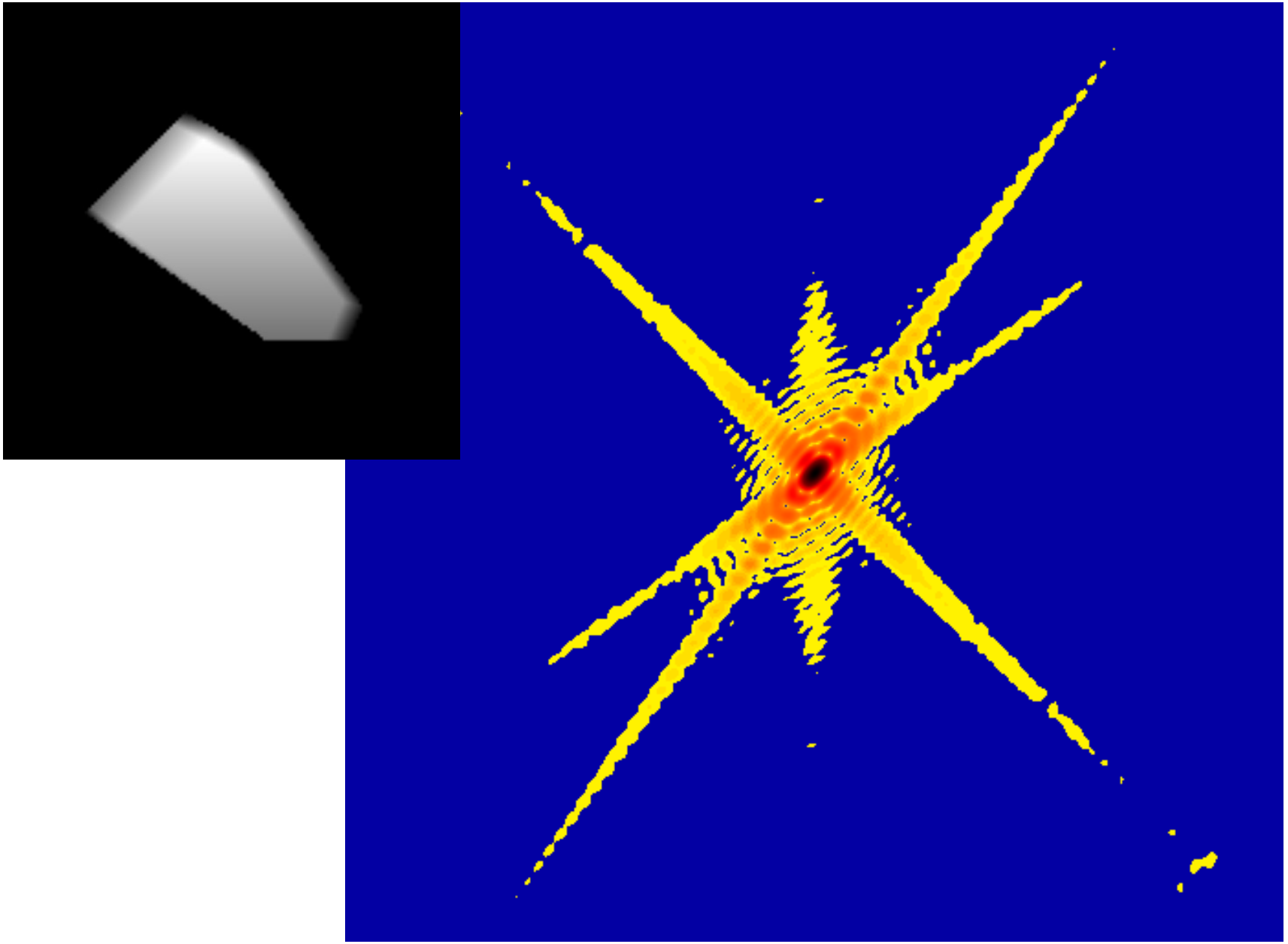
Coherence of	ξ_{VER}	ξ_{HORIZ}	ξ_{LONG}	Flux
Raw Undulator	35μm	9μm	0.004μm	2×10^{12}
Si(111) Monochromator	35μm	9μm	1μm	1×10^{10}
C(111) Monochromator	35μm	9μm	3μm	3×10^{9}

Coherent region defined by slits



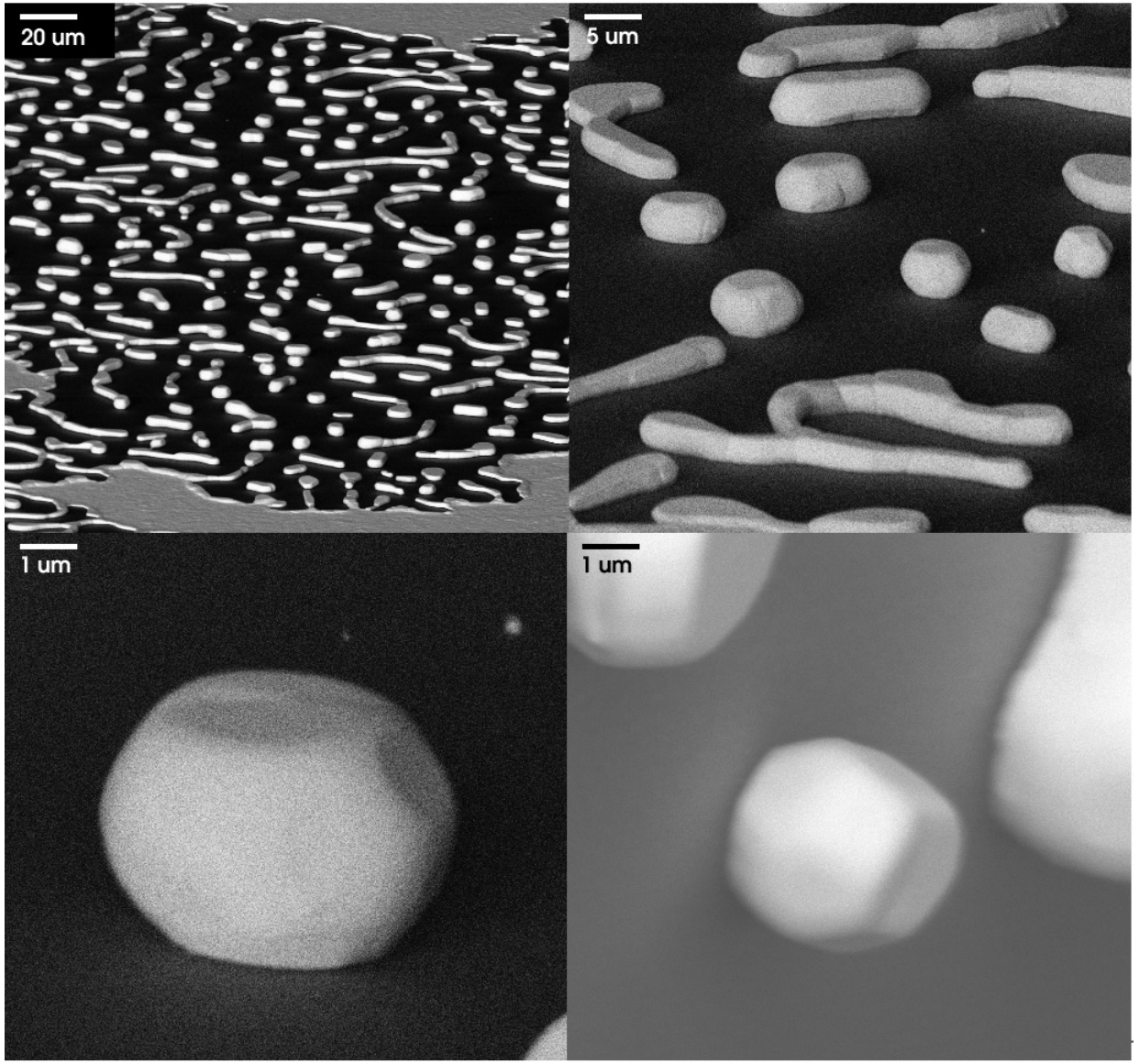
Lensless X-ray Microscope



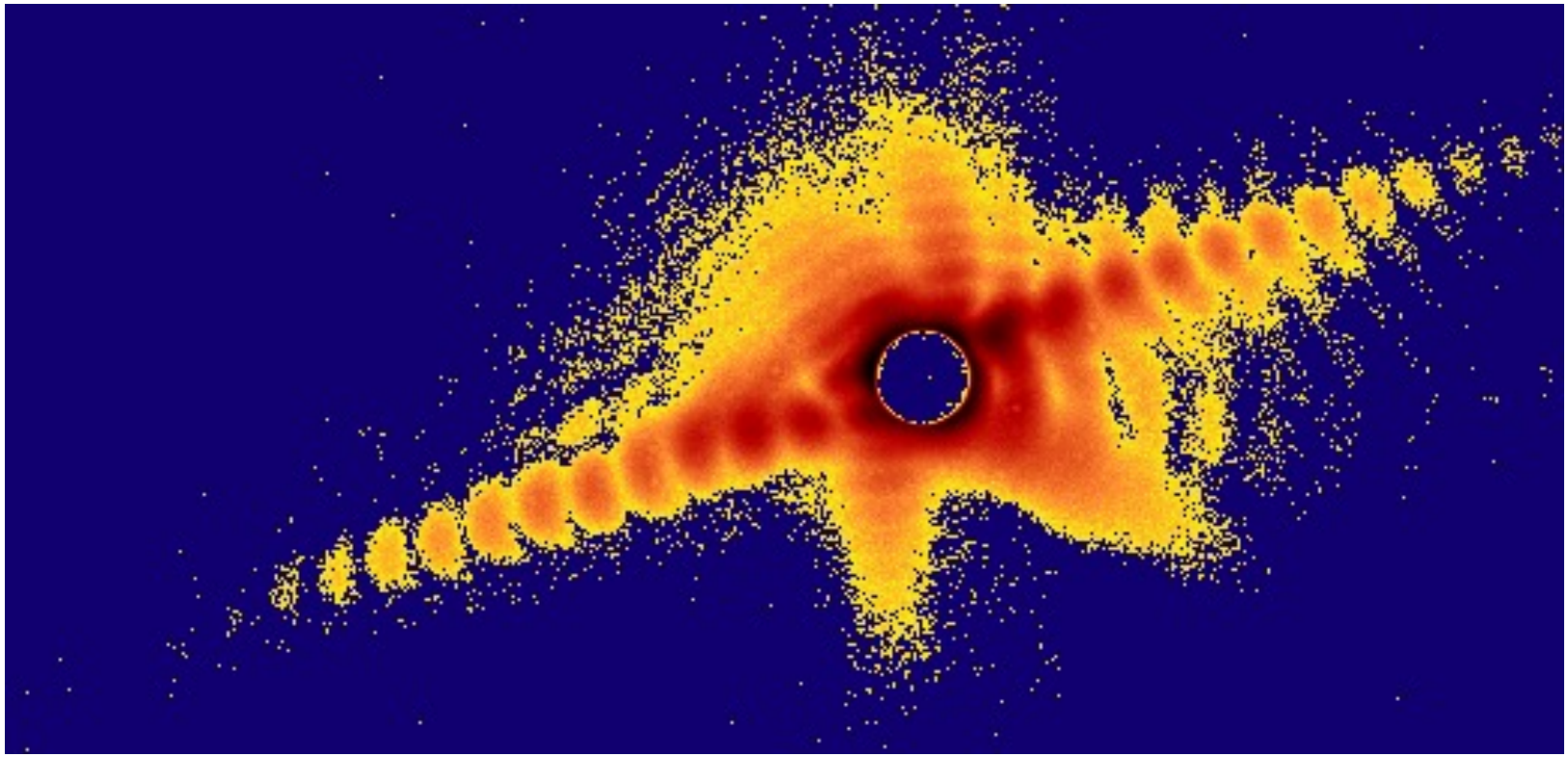


SEMS

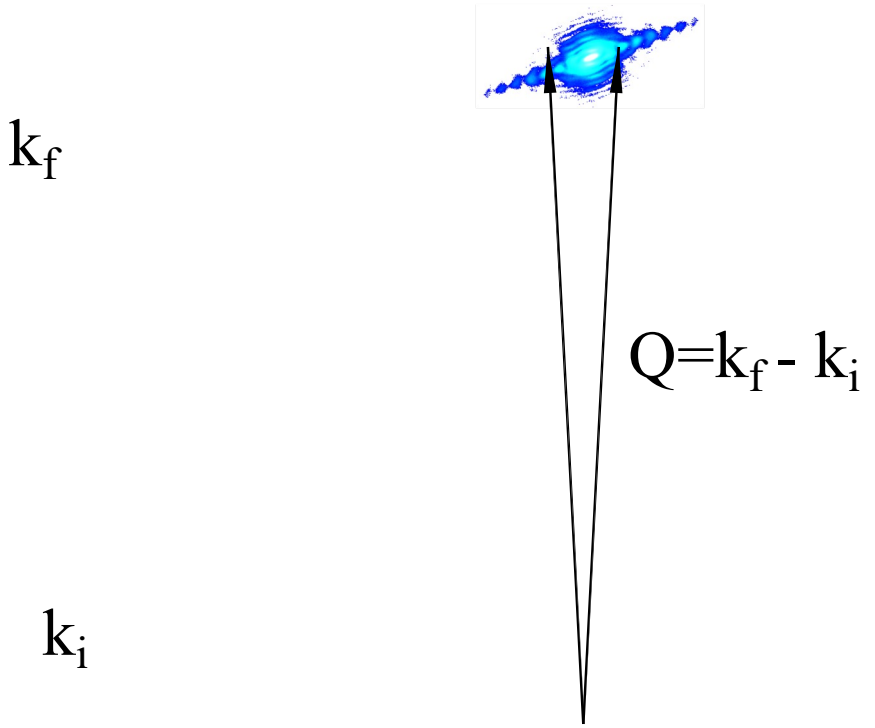
- Au blanket film
- Quartz substrate
- Annealed at 950°C for 70 hrs.



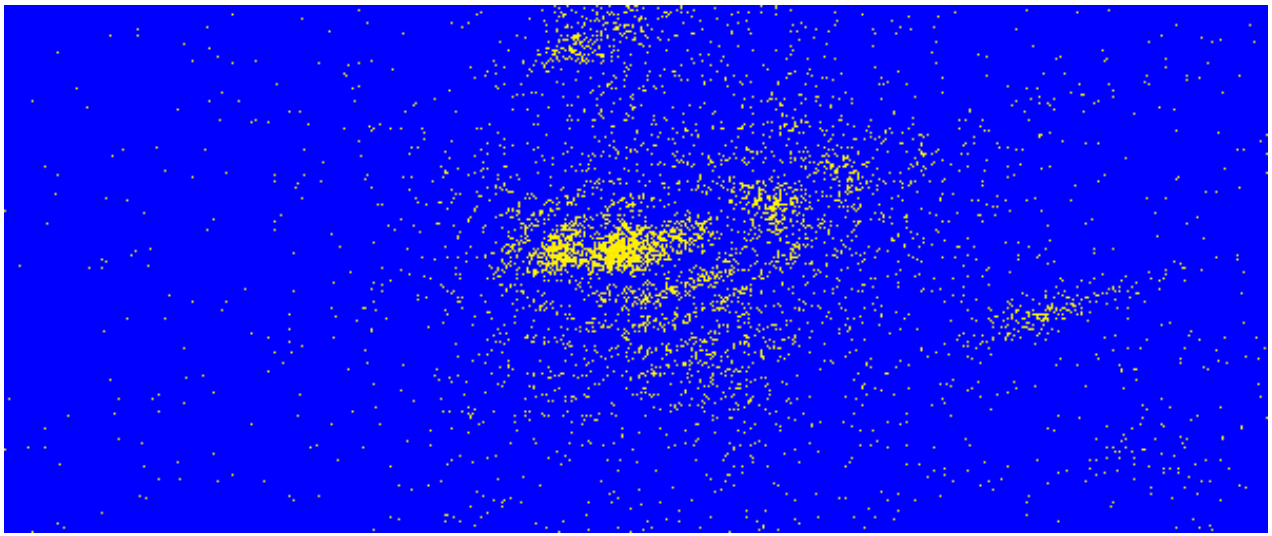
Micron-sized gold crystal: (111) Bragg reflection



3D Diffraction Method

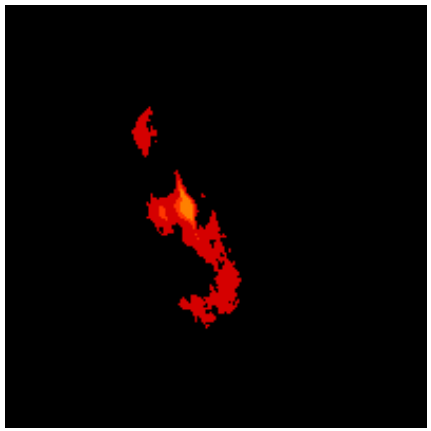


3D Diffraction Data
1 micron Au crystal

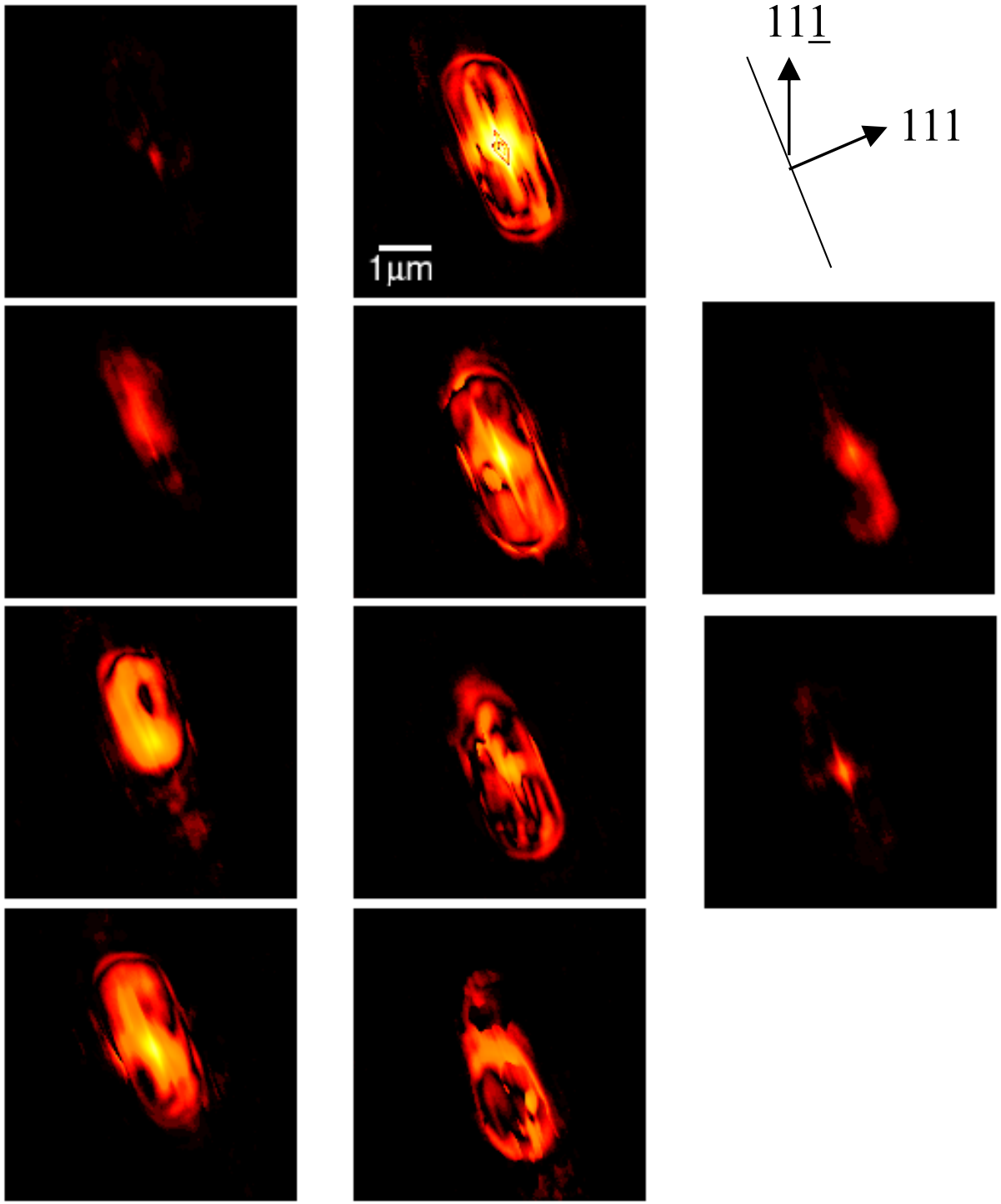


* Center is Symmetric *

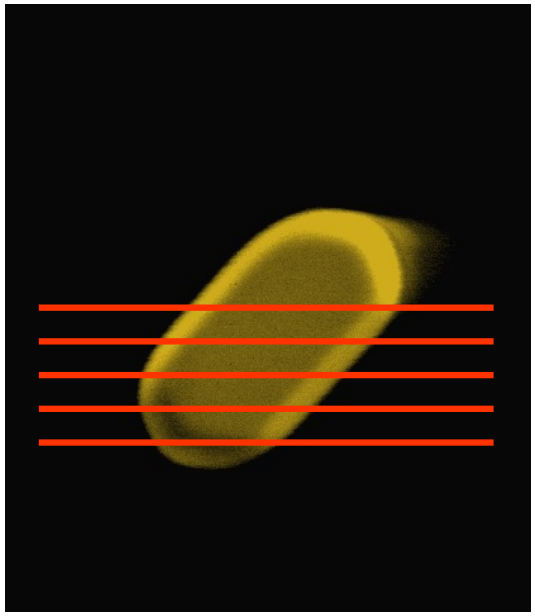
30 frames of 3D reconstruction 1 micron gold crystal



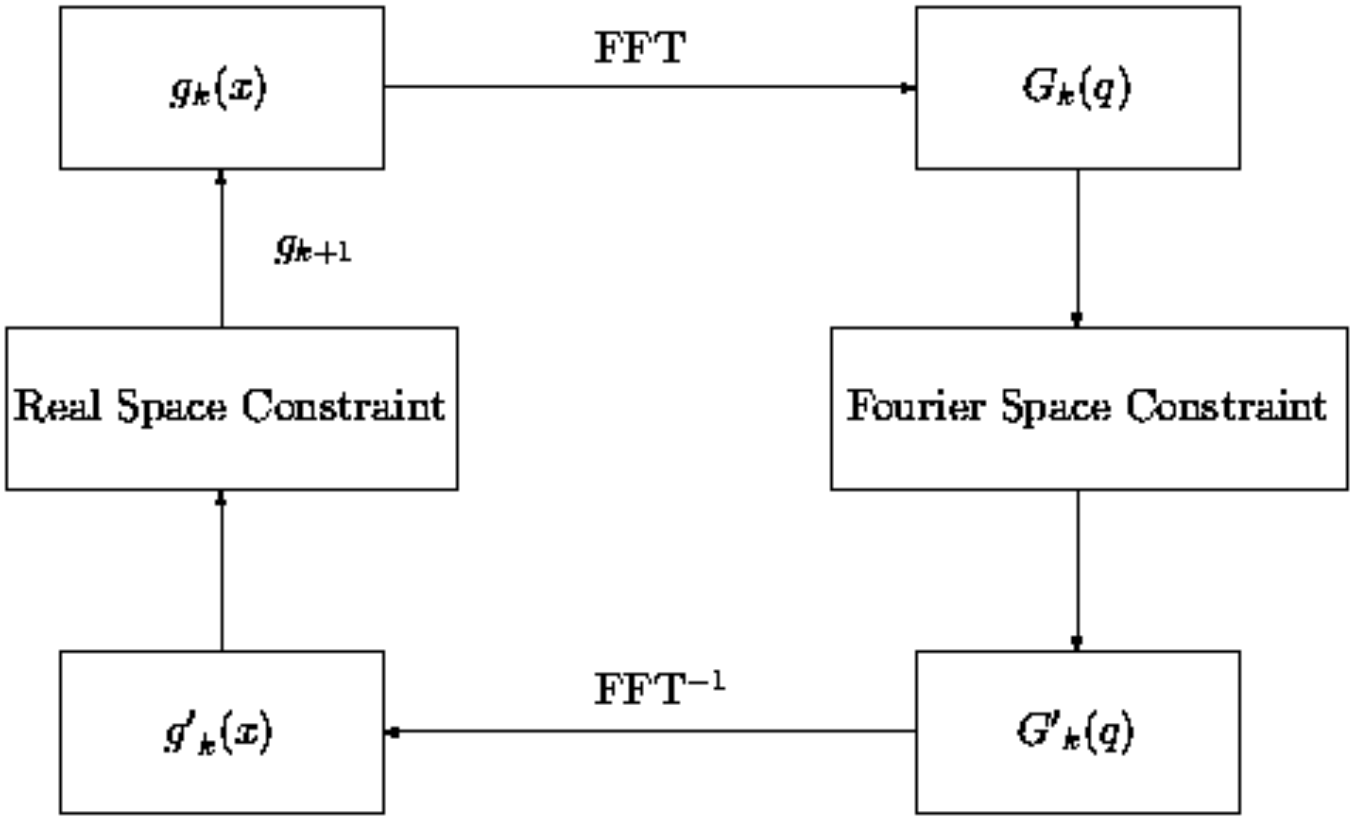
* CENTER *



Slices through plan view SEM:

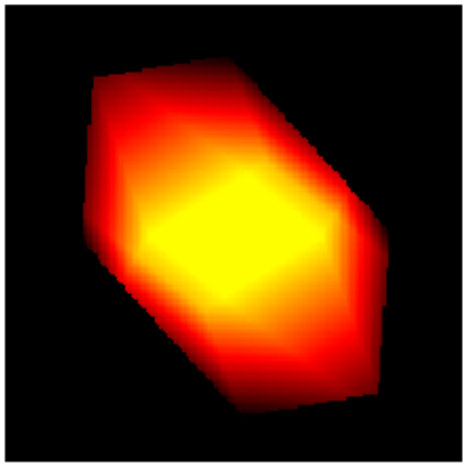
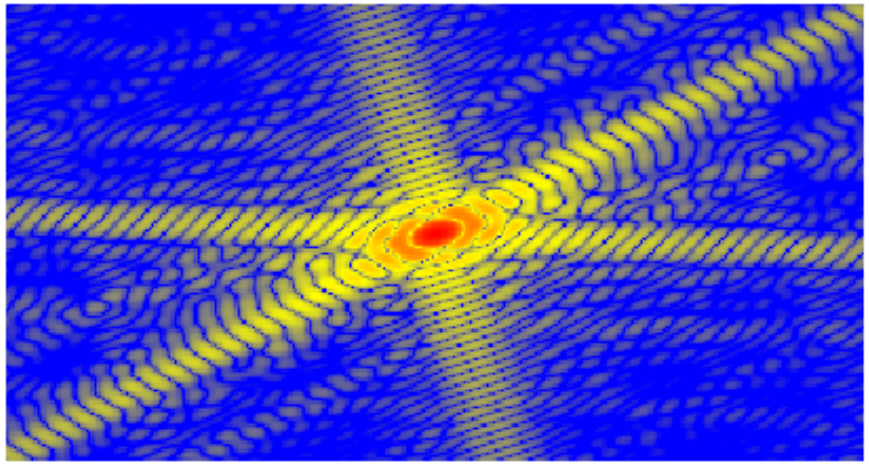
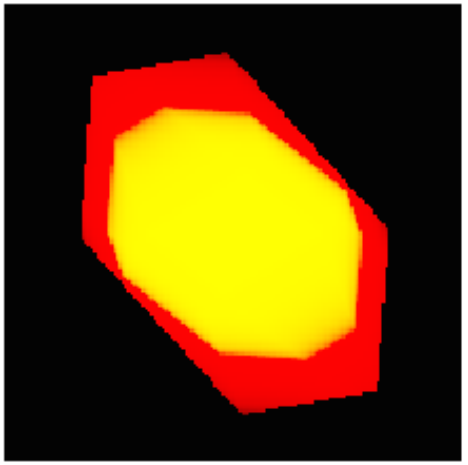


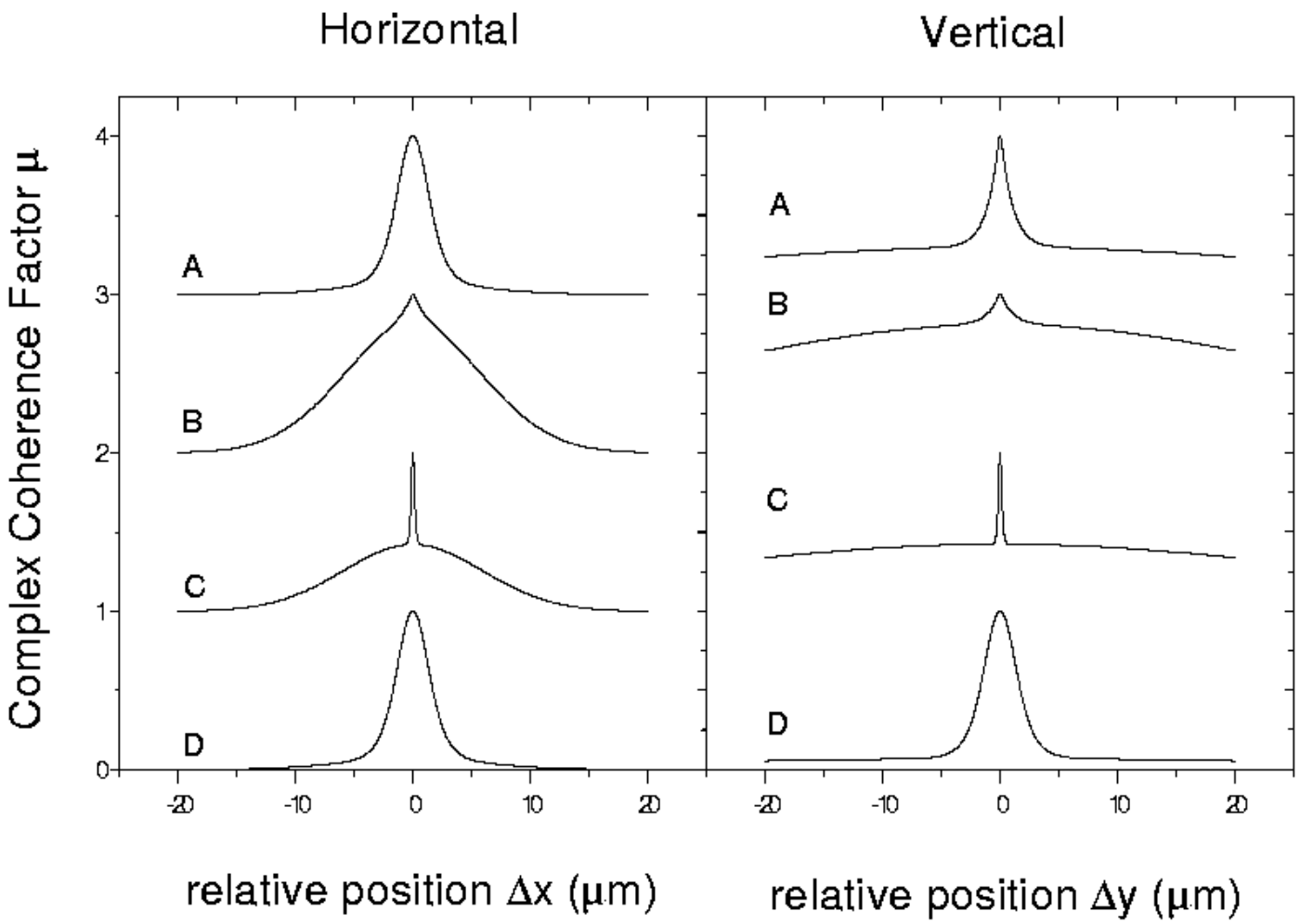
Generic "Error Reduction" method



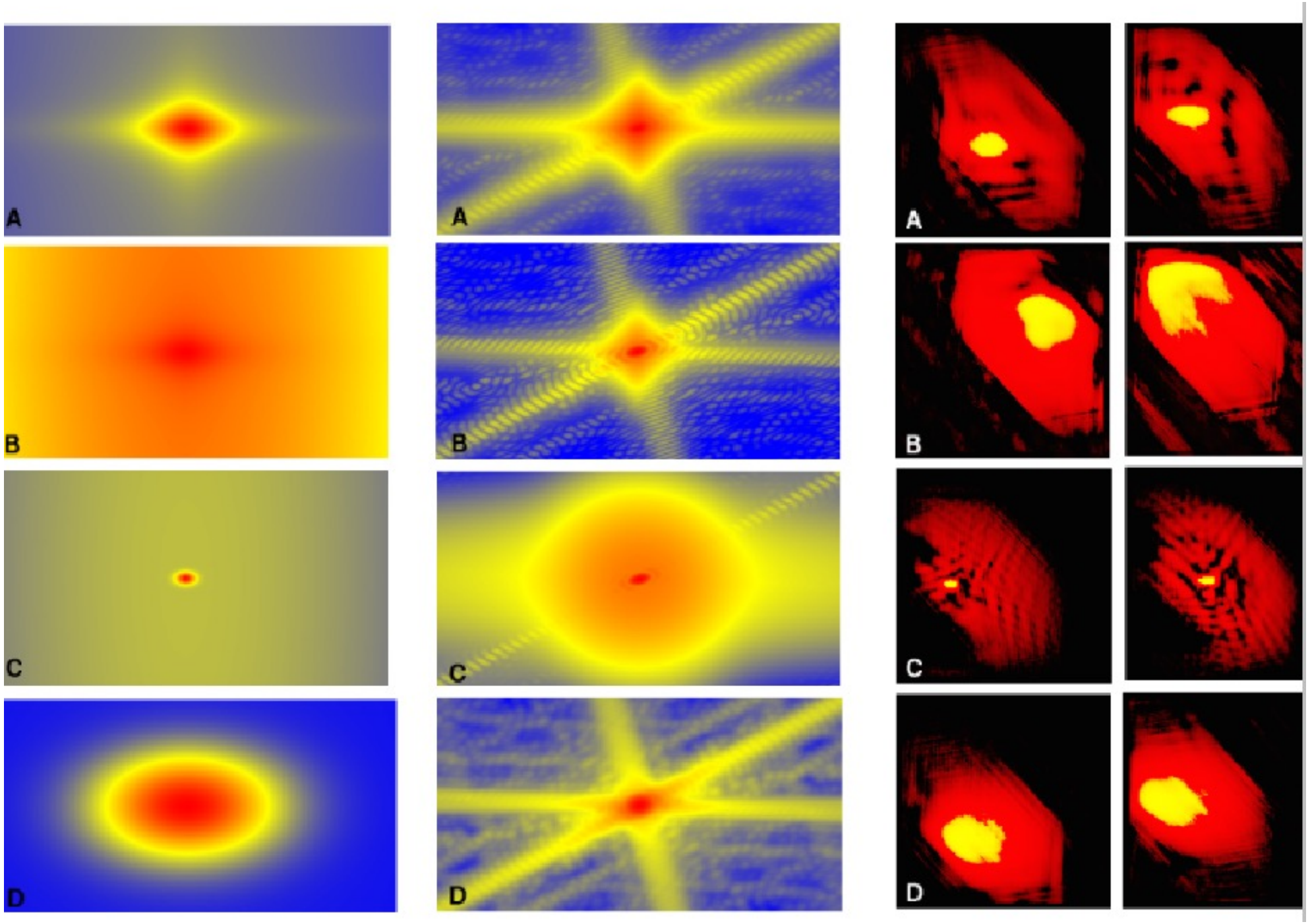
J. R. Fienup Appl. Opt. 21 2758 (1982)
R. W. Gerchberg and W. O. Saxton Optik 35 237 (1972)

Test Calculation: 2D Projection

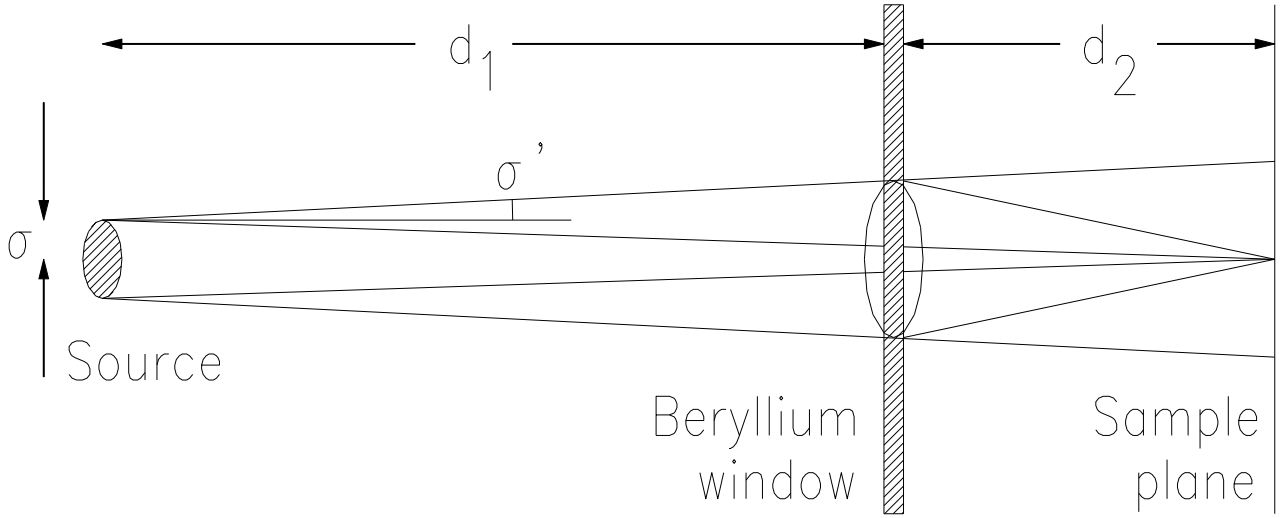






App mm	Var rad^2	Tau μm
1.5	0.1	1
1.5	0.01	1
1.5	0.1	0.1
0.15	0.1	1


A
B
C
D
A
B
C
D
A
B
C
D

Window as a Secondary Source

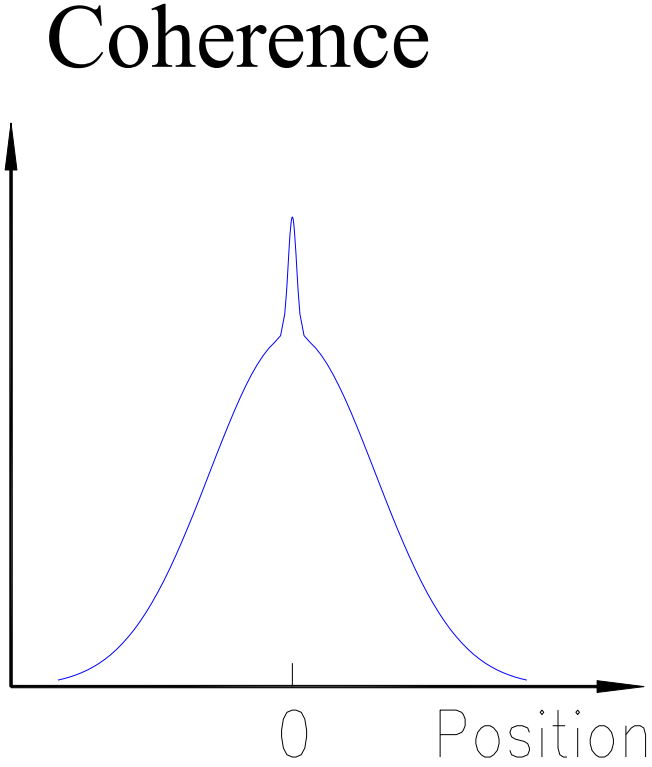


$$L_T = \frac{\lambda D}{2\sigma}$$

$$L_{T2} = \frac{\lambda D}{2\sigma} \frac{(1-\frac{d_1}{D})}{(1+\frac{\sigma' D}{\sigma}\frac{d_1}{D})}$$

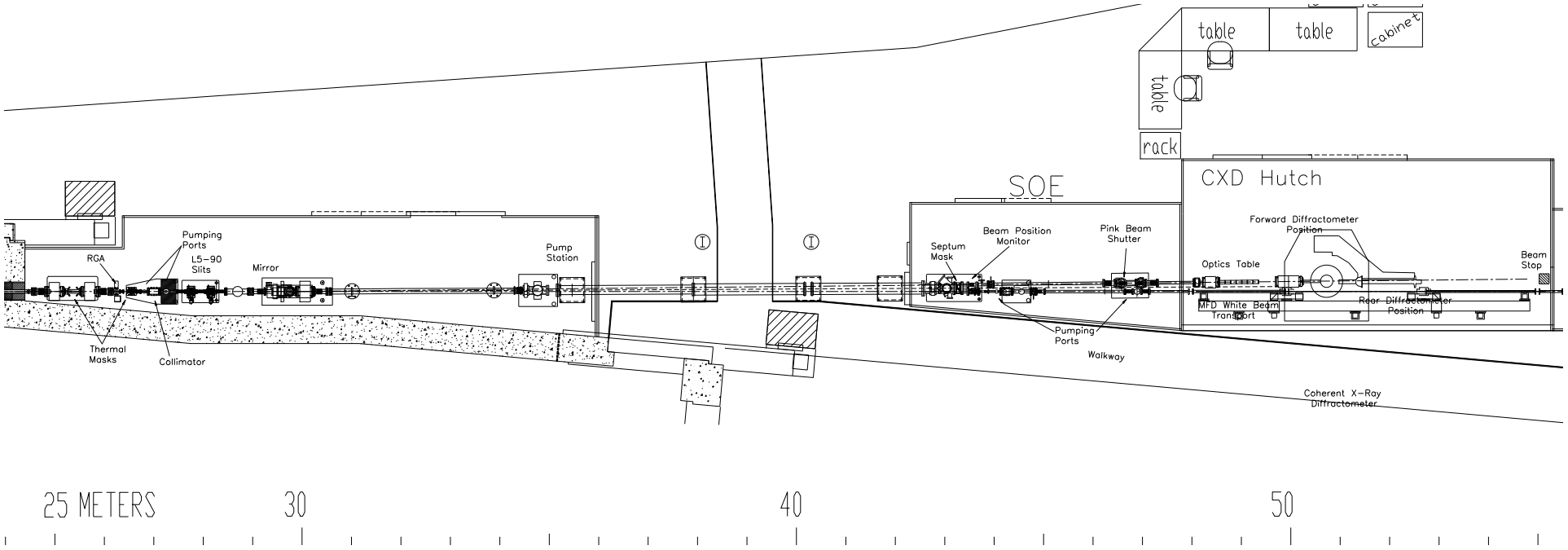
Vert ~50
Horiz ~3

Two Components to MCF

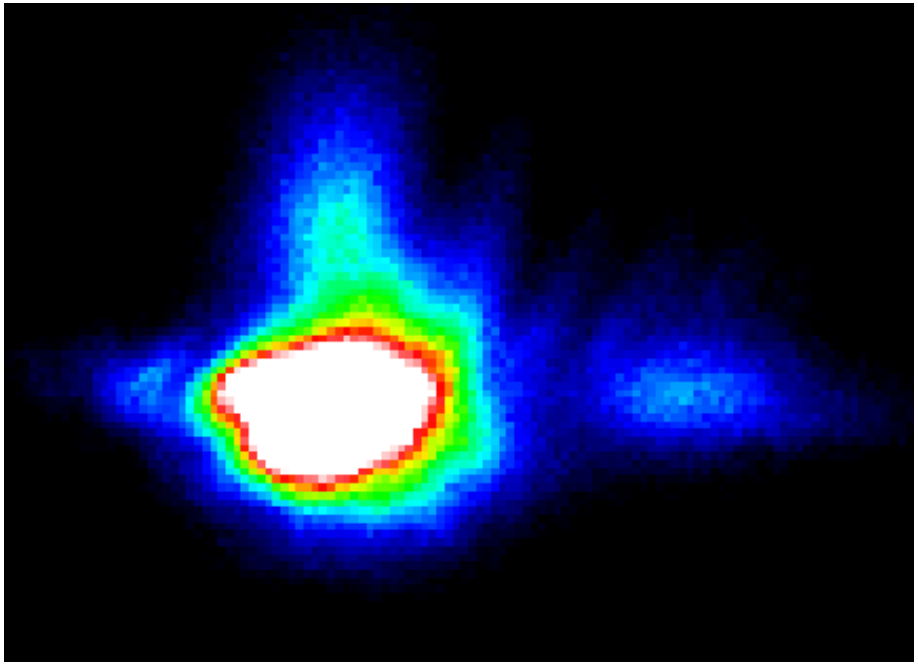


- Width of narrow component is very sensitive to location of window
- Amplitude of narrow component depends on level of diffuse scattering from window
- Amplitude increases with distance (for phase object)

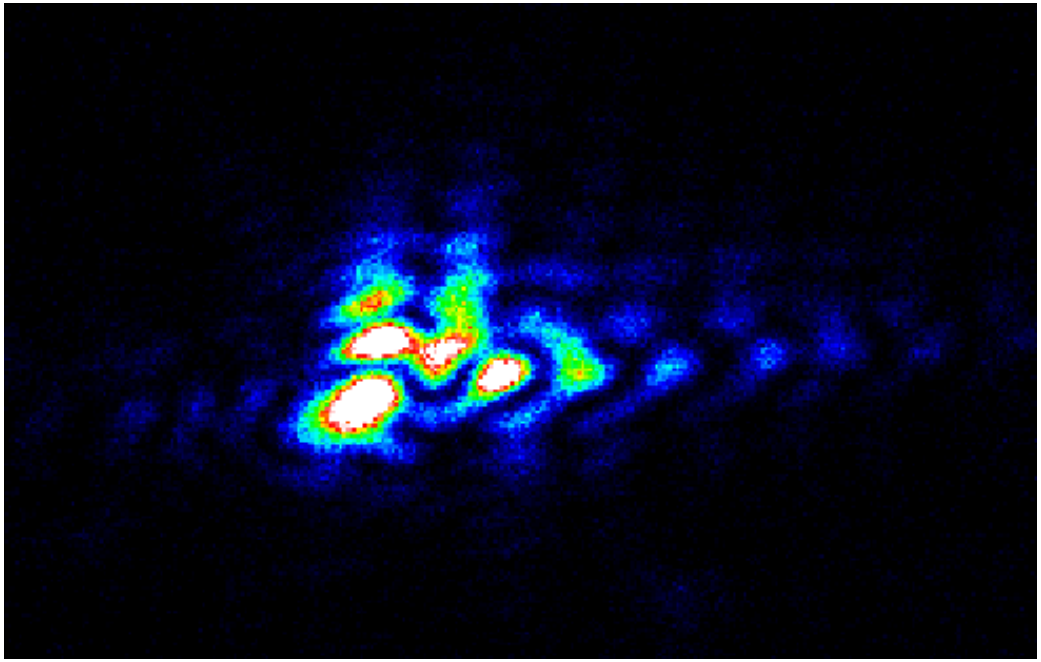
CXD Beamline at APS Sector 34



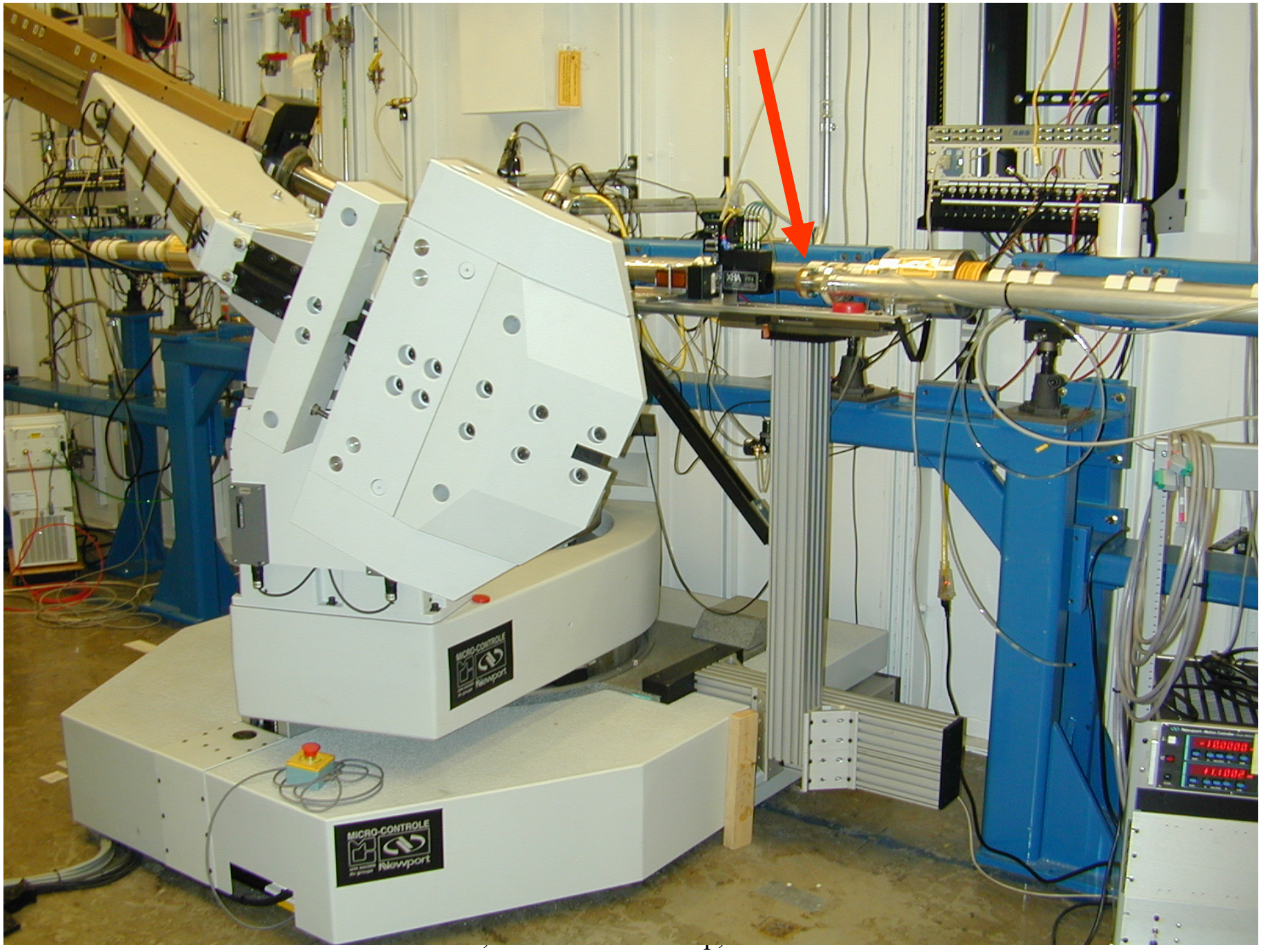
Au Nanocrystal CXD at Sector 34



BN-coated window

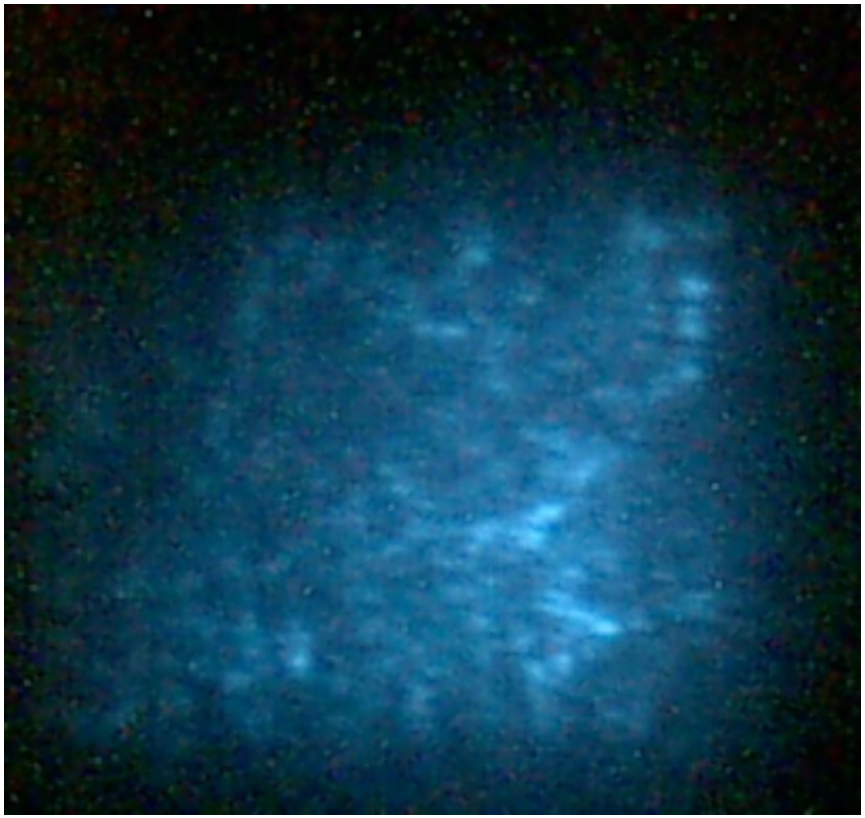


BN removed Sept 2002

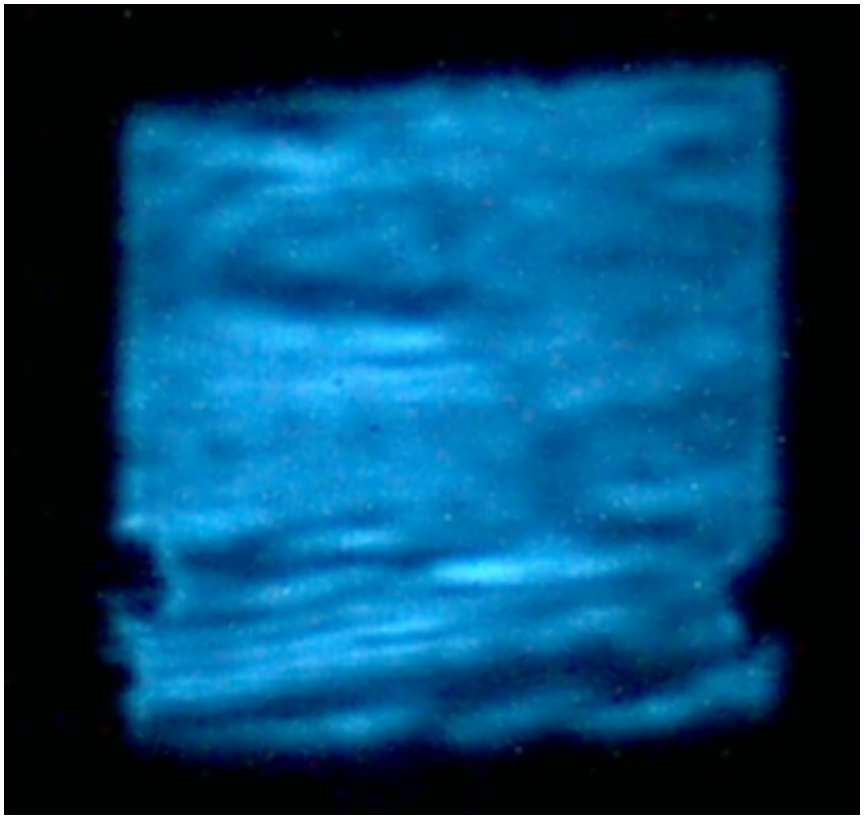

MICRO-CONTROLE
Newport
MICRO-CONTROLE
Newport

BN Coating on Sector 34 Window

protects against corrosion of Window by pink beam

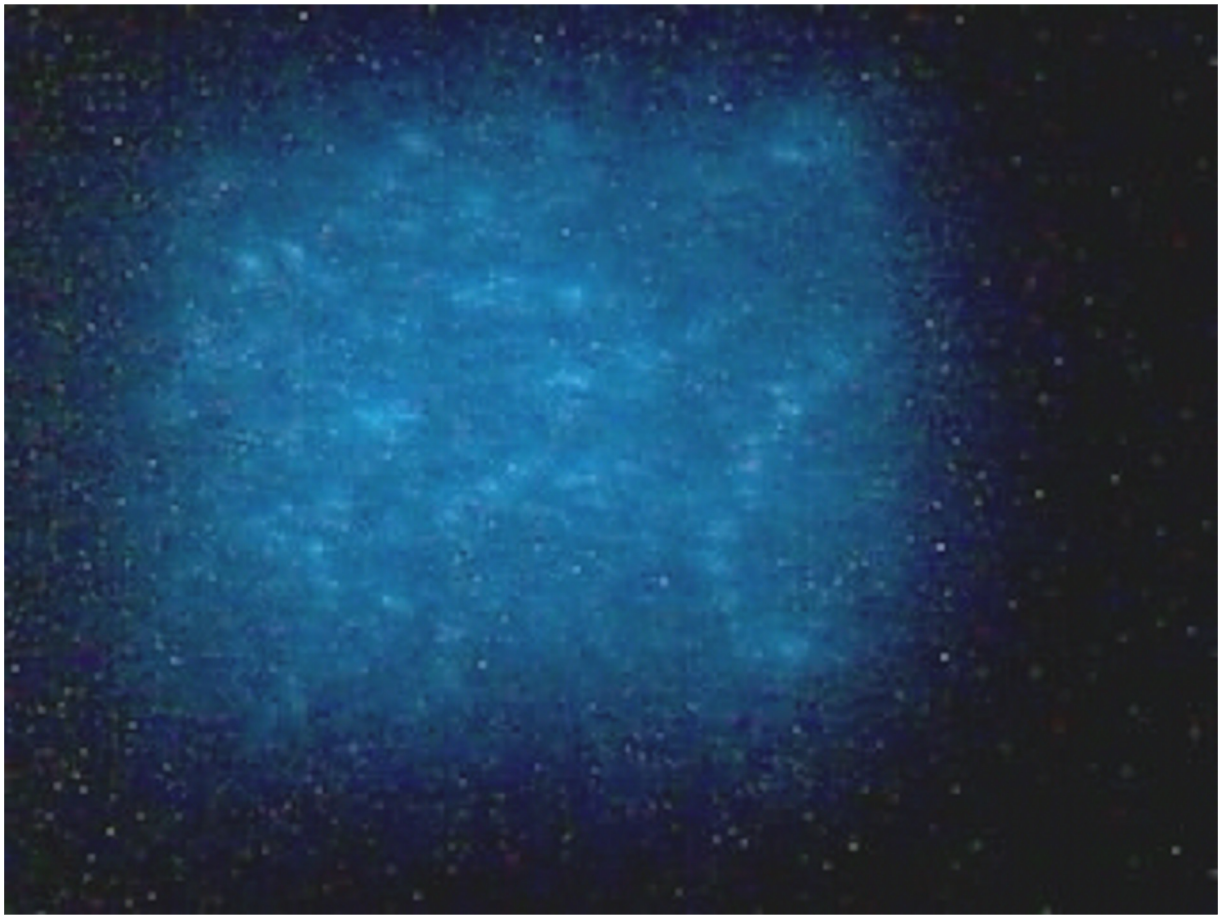


BN spray coating



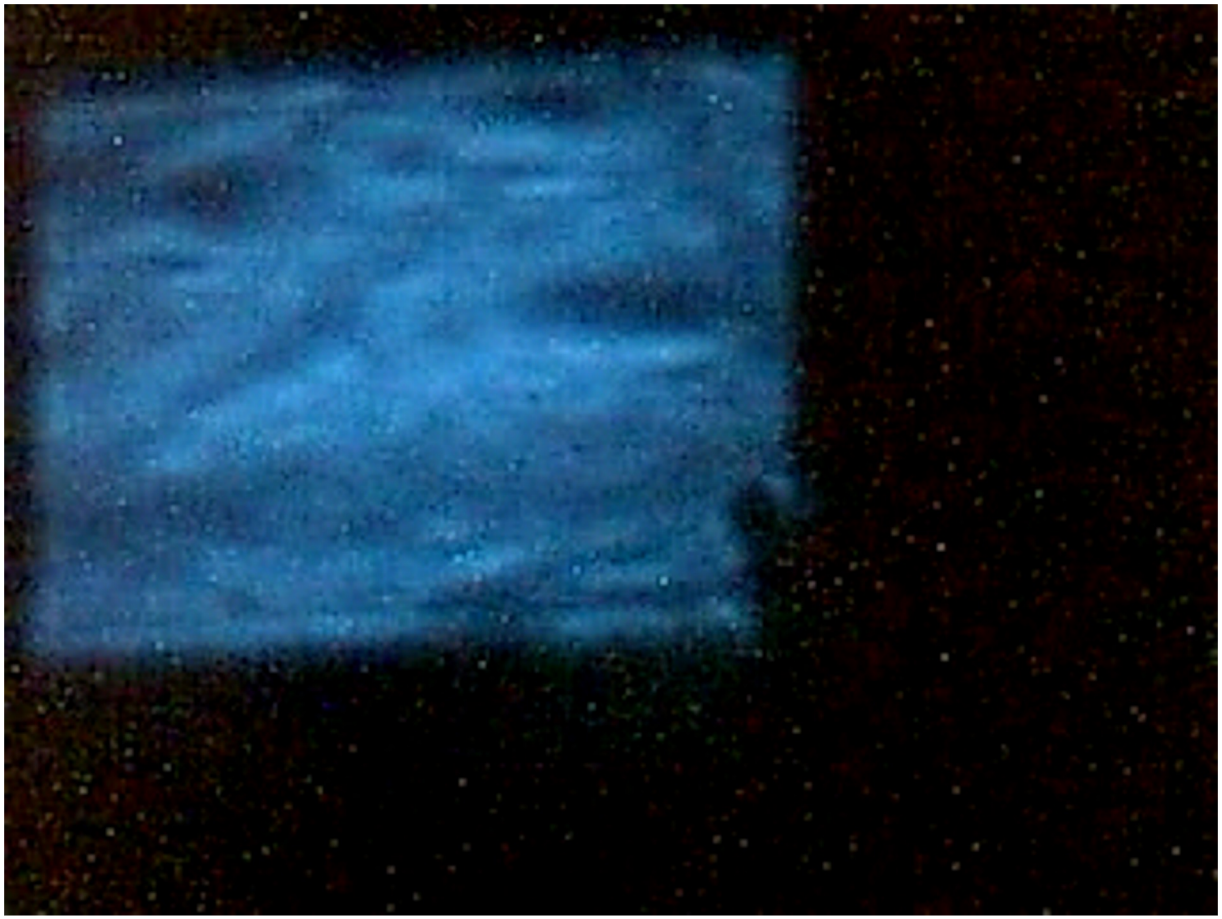
Coating removed

Origin of the Incoherence?



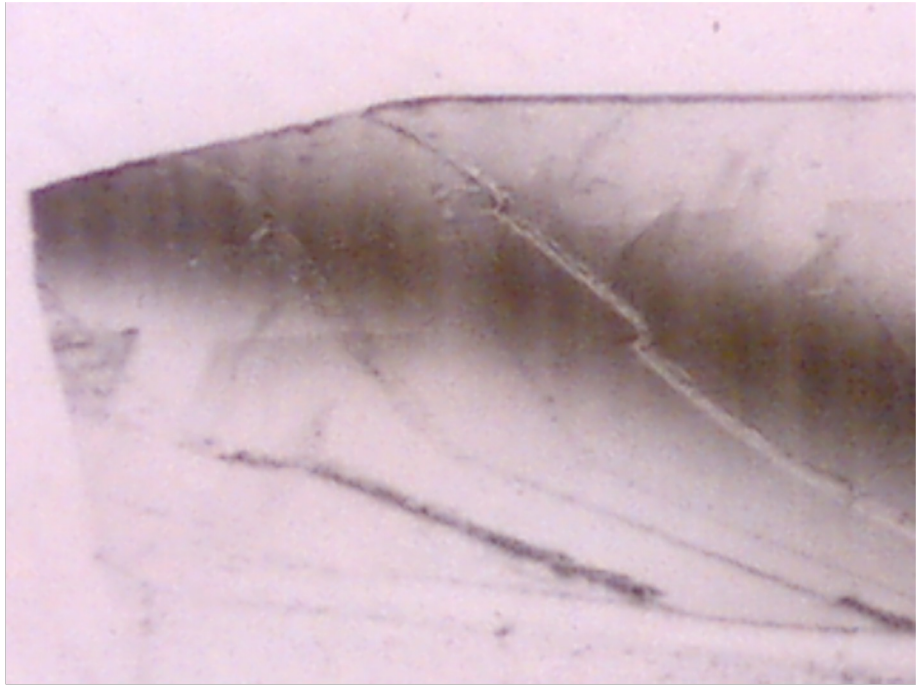
Remaining Incoherence

Scan monochromator position



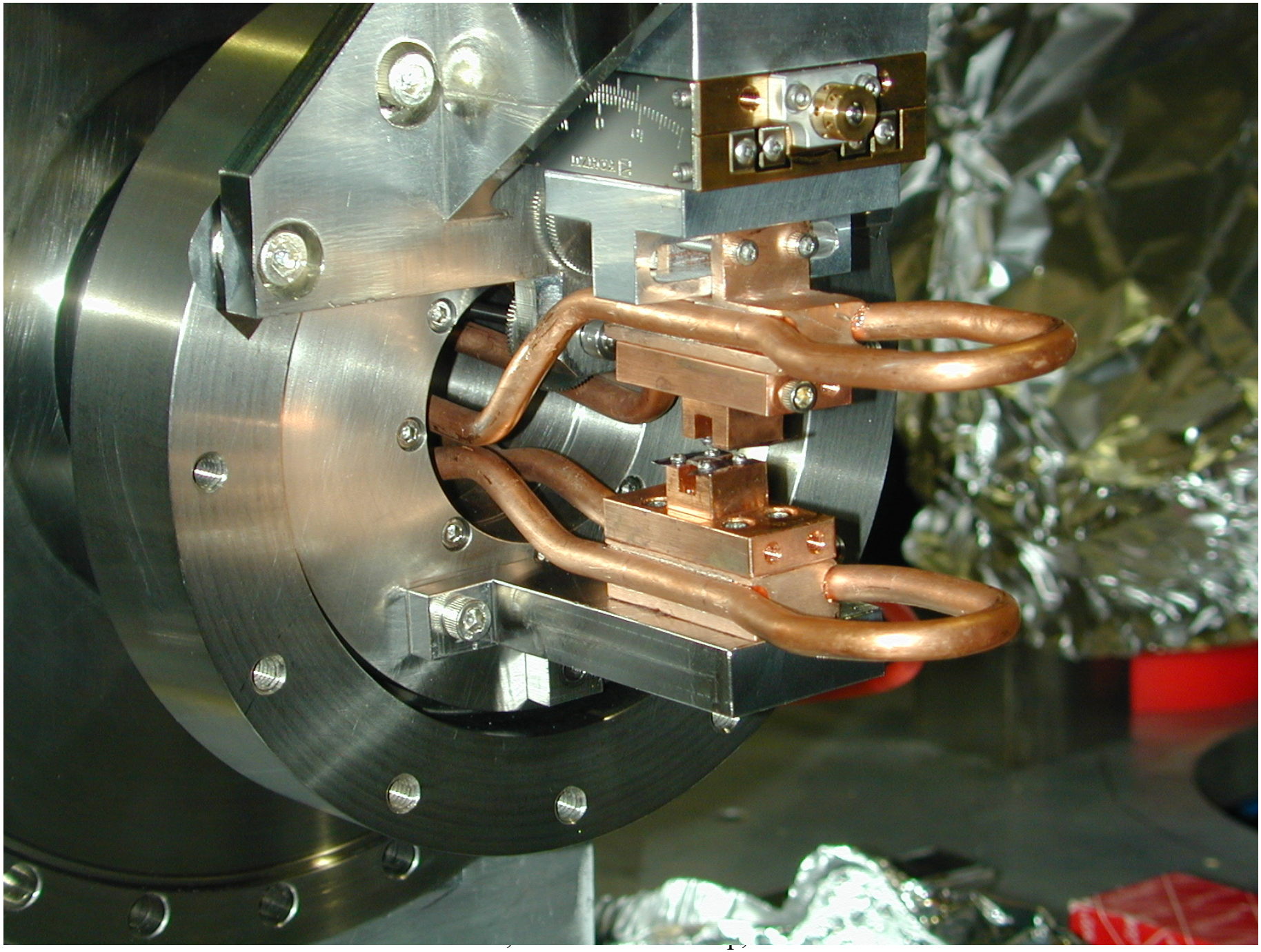
Topography of Diamonds

Measured at 33-BM on Kodak dental film

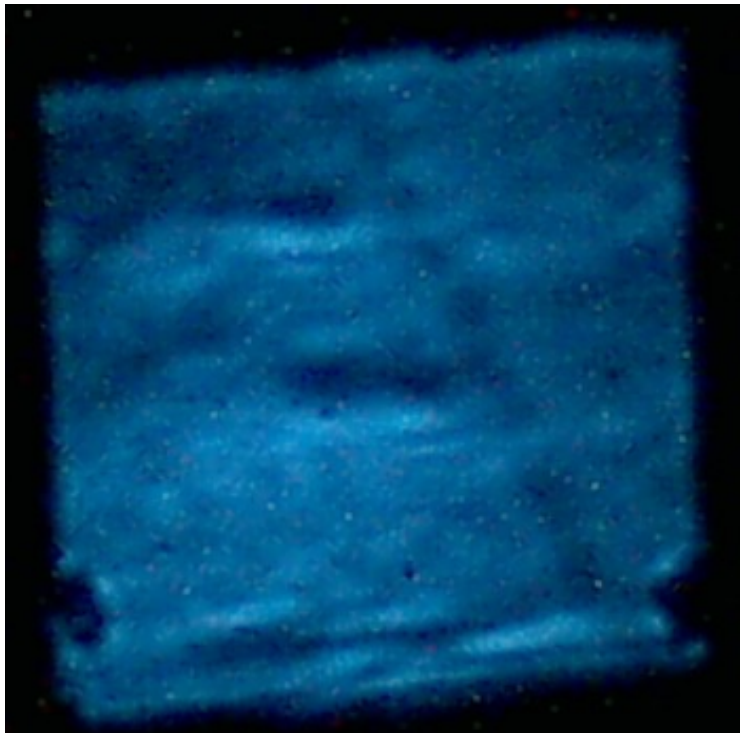


Second crystal, as mounted

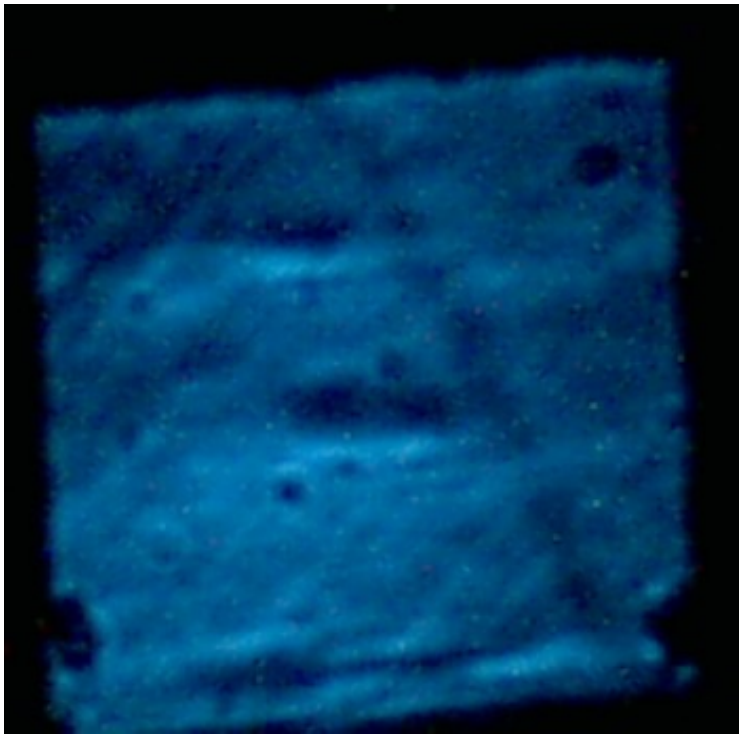
After losening clamping screws



Typical Be Window Defects



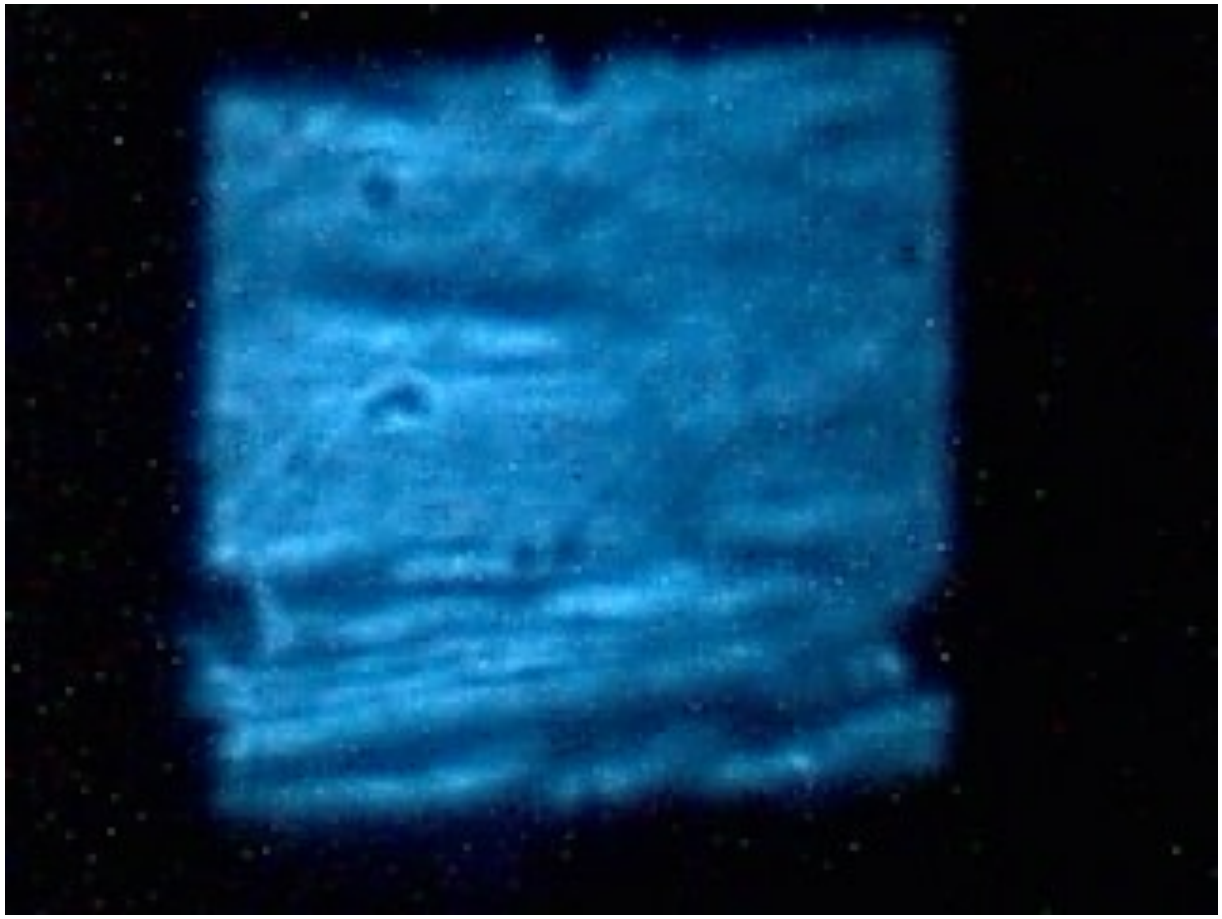
Detector at 350mm



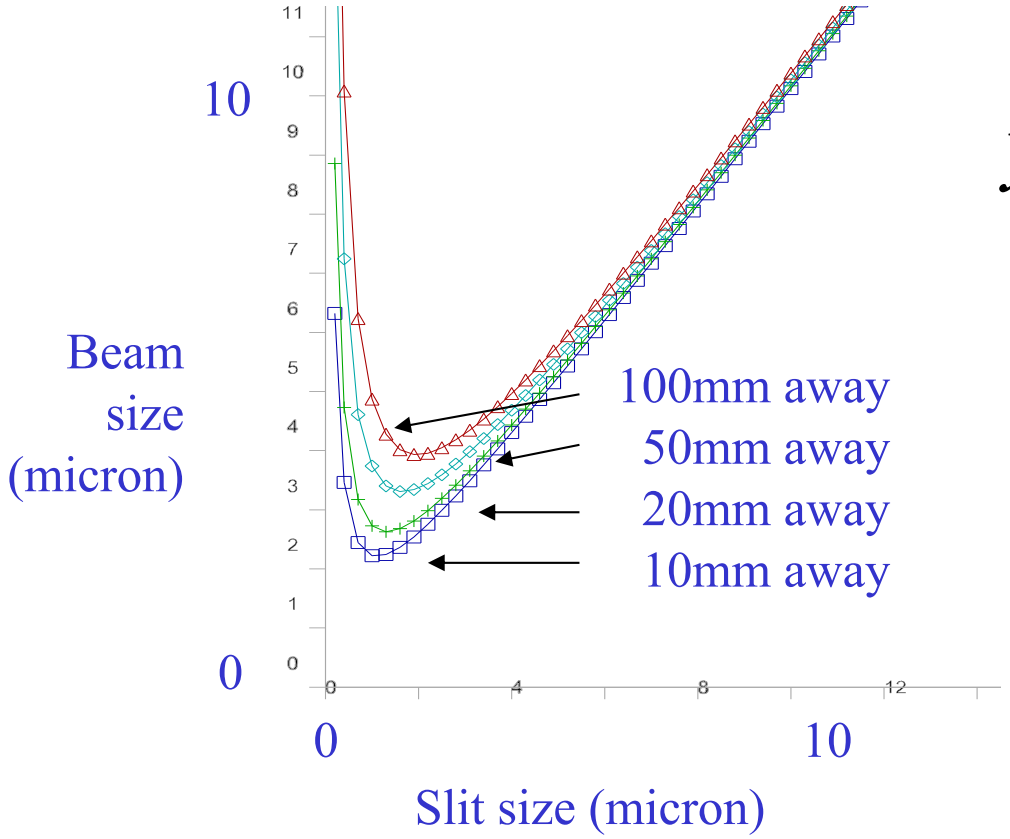
Detector at 2400mm

Be Window Moved across Beam

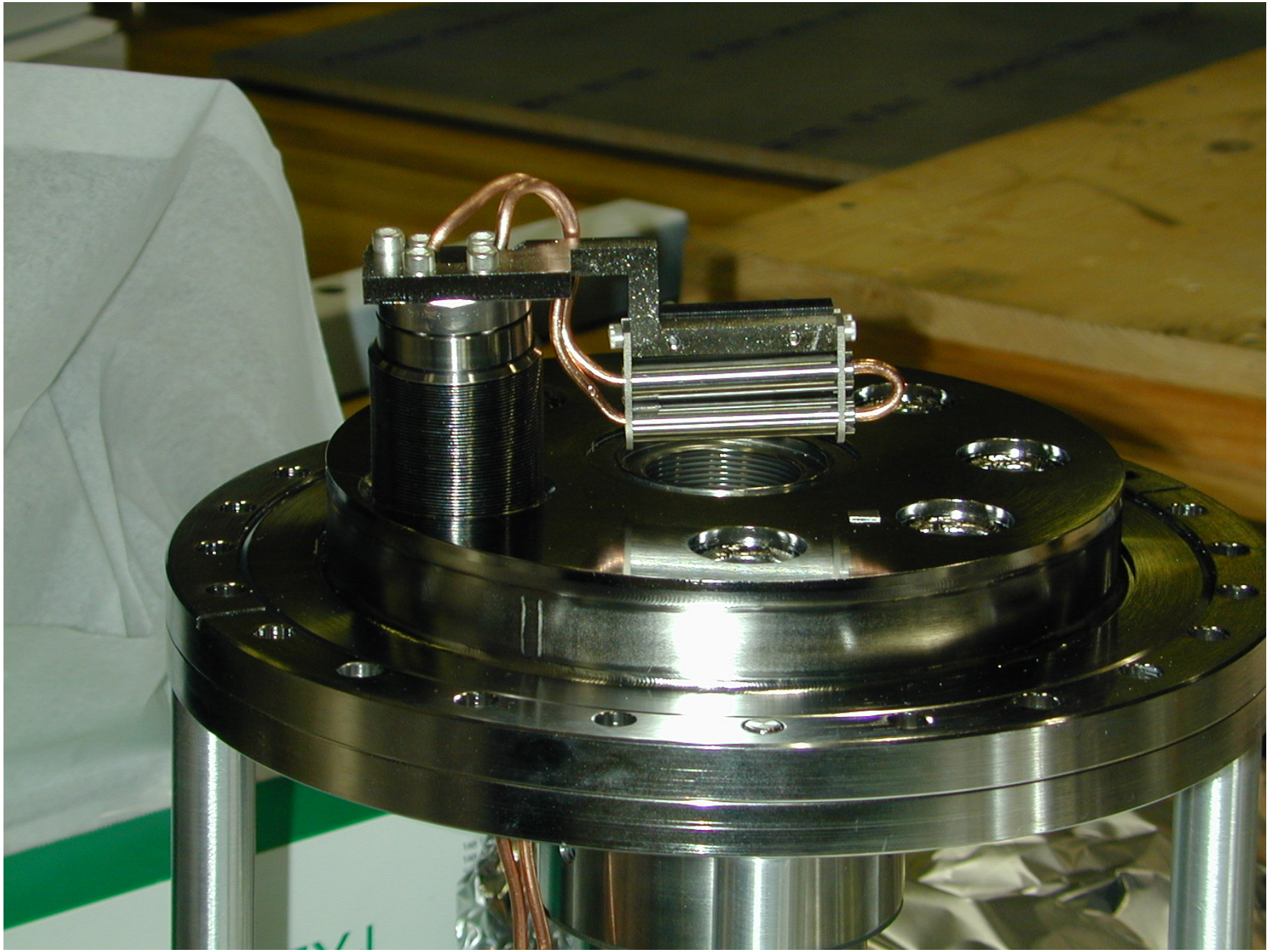
0.5mm view behind $CdWO_3$ crystal at 2.4m



Smallest Beam using Slits (9keV)



$$y(x) = x + \frac{\lambda d}{x}$$



Remedies

Specific to imaging uses of CXD

- Keep optics away from second half of BL
- Use small apertures at critical components
- Best polish available of mirrors and windows
- Avoid slits, except with guard slits
- Use KB mirrors to adjust coherence
- Could use waveguides or zone plates