Exploitation of Coherence in Condensed Matter Systems

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E-XFEL Detector Workshop
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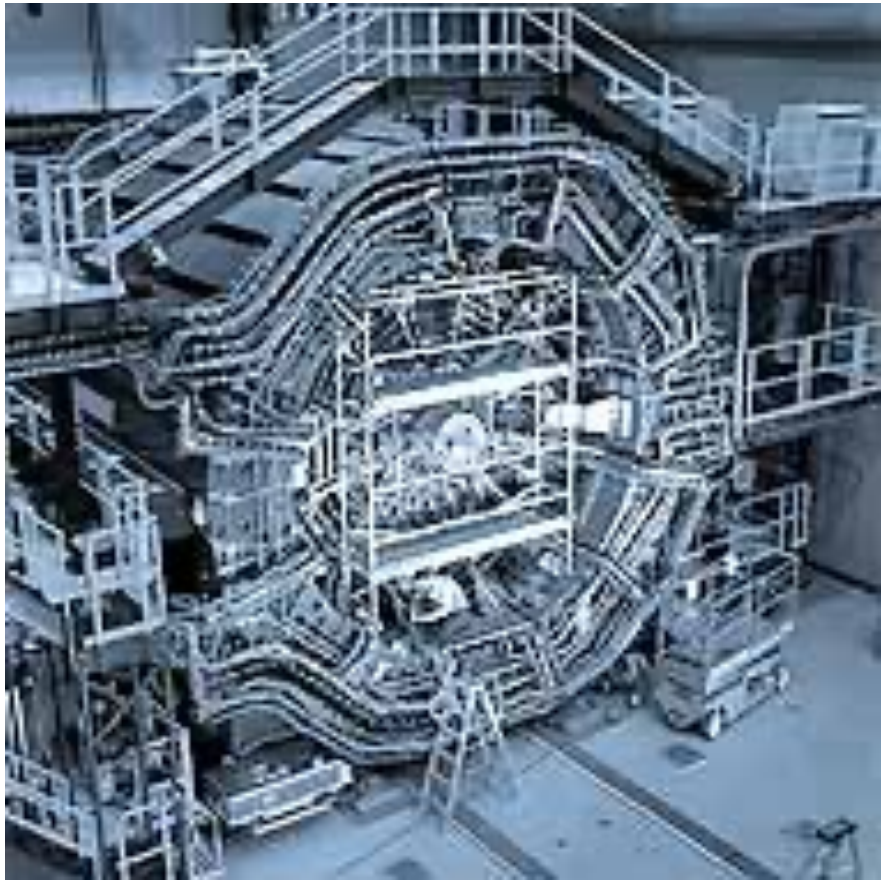
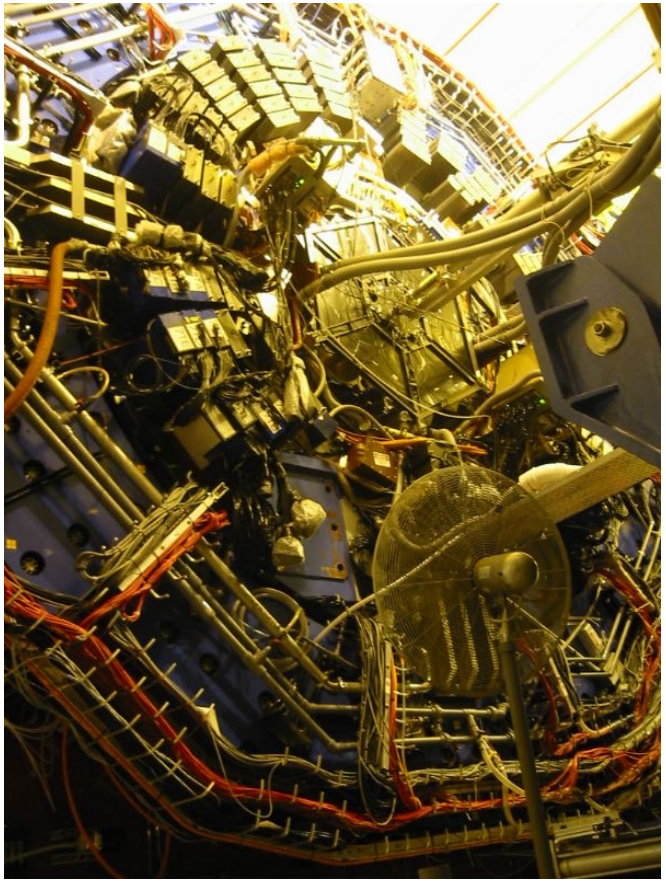
Outline

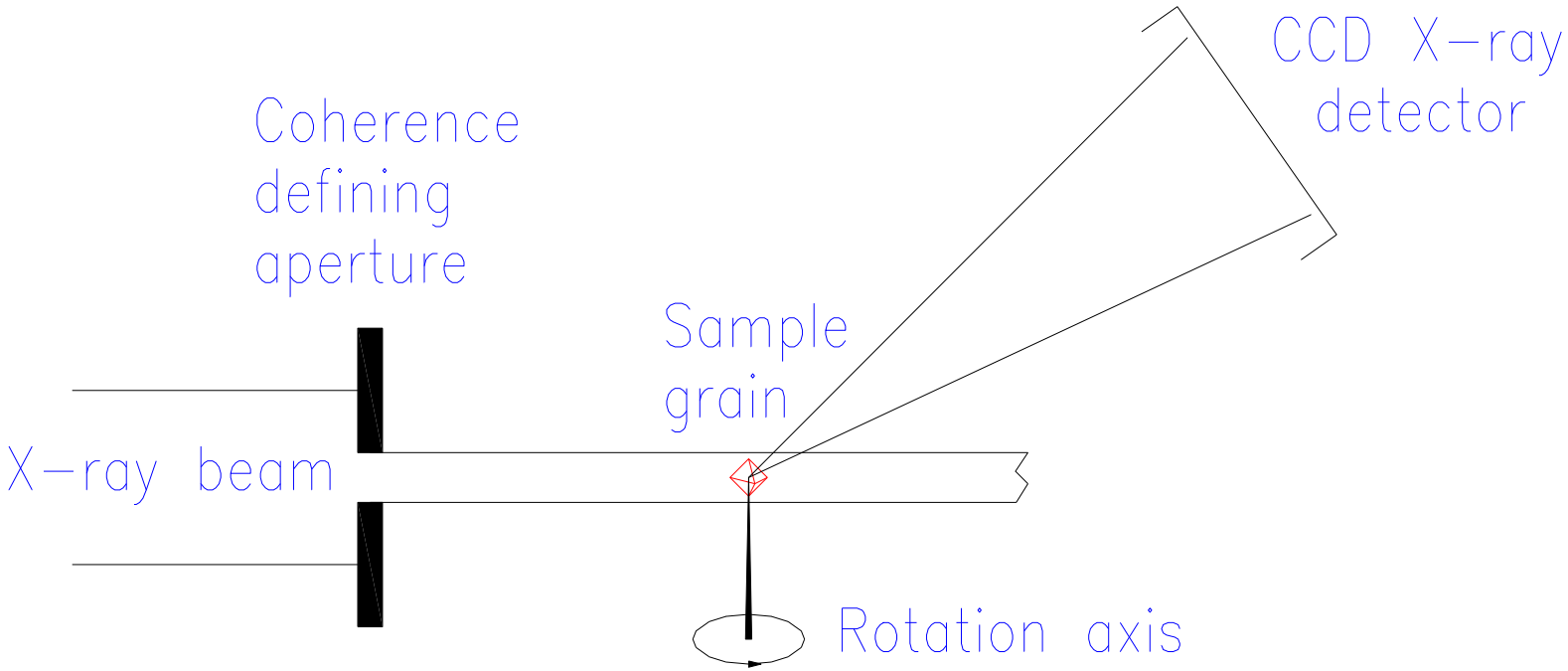
- Coherent X-ray Diffraction Imaging
- X-ray Holography
- Extension to Phase Objects
- Single molecule imaging with Electrons
- High Energy Diffuse Scattering
- Detector Requirements

The HEP approach: detectors drive the science

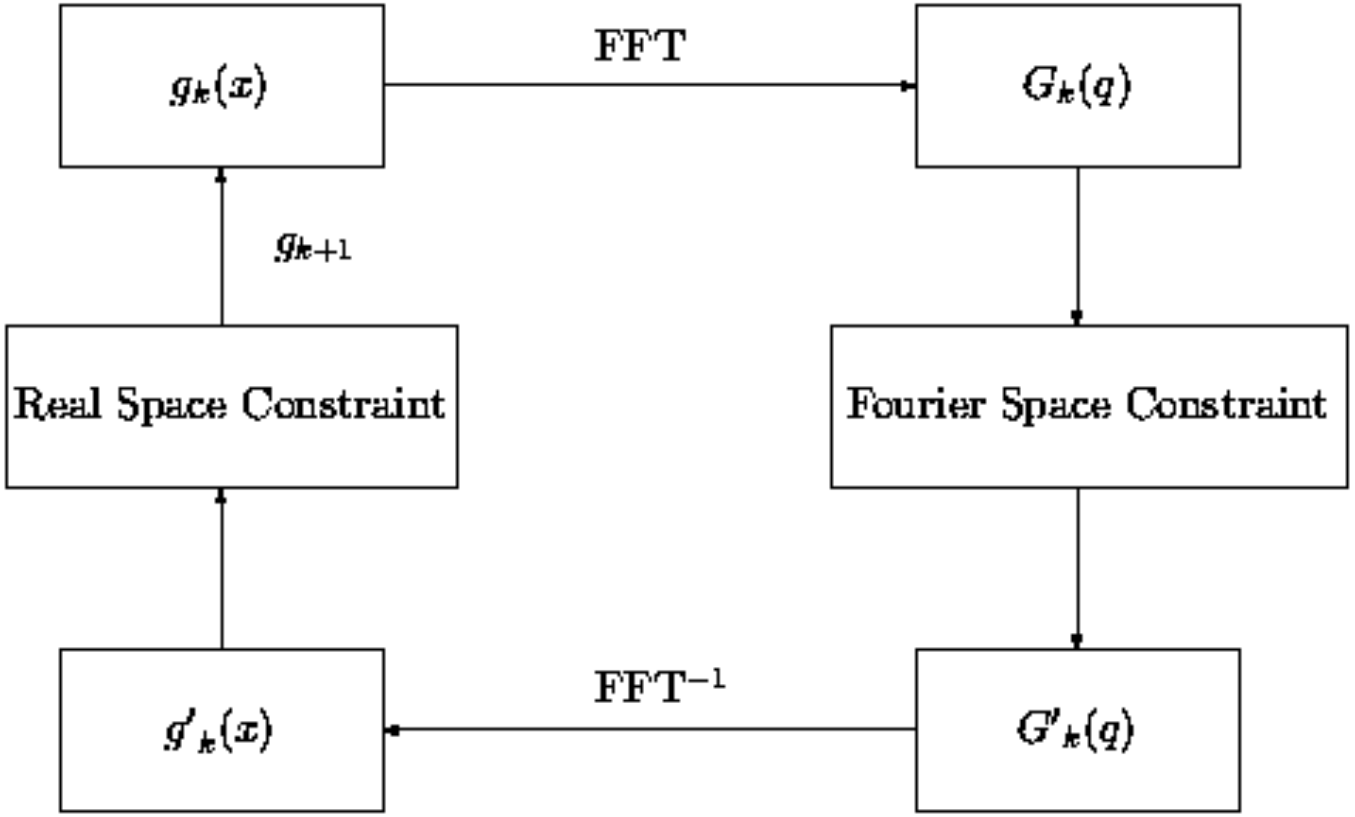




CXDI configuration: Lensless X-ray Microscope



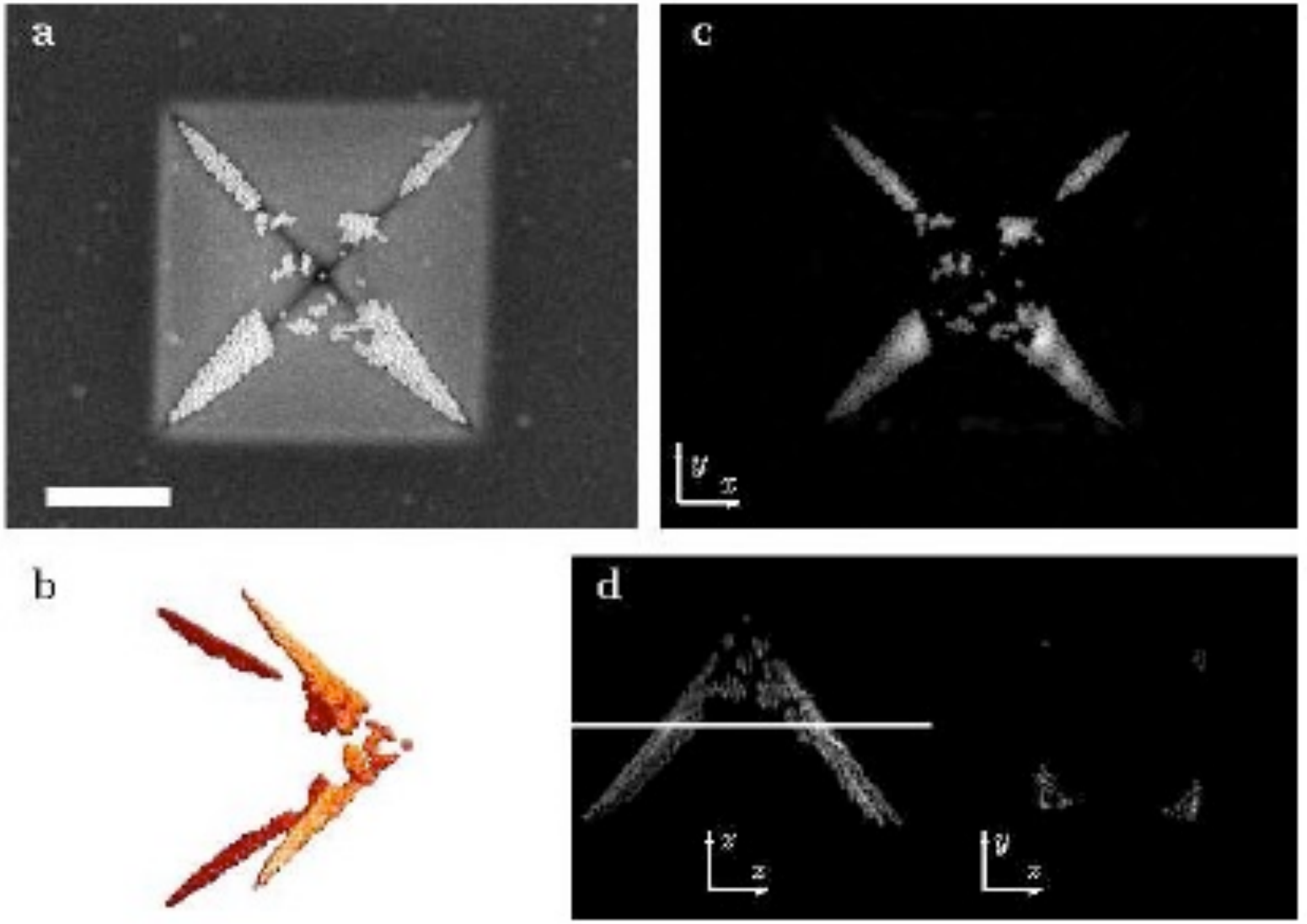
Generic "Error Reduction" method



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

Au spheres on SiN membrane at 750 eV (1.65 nm)

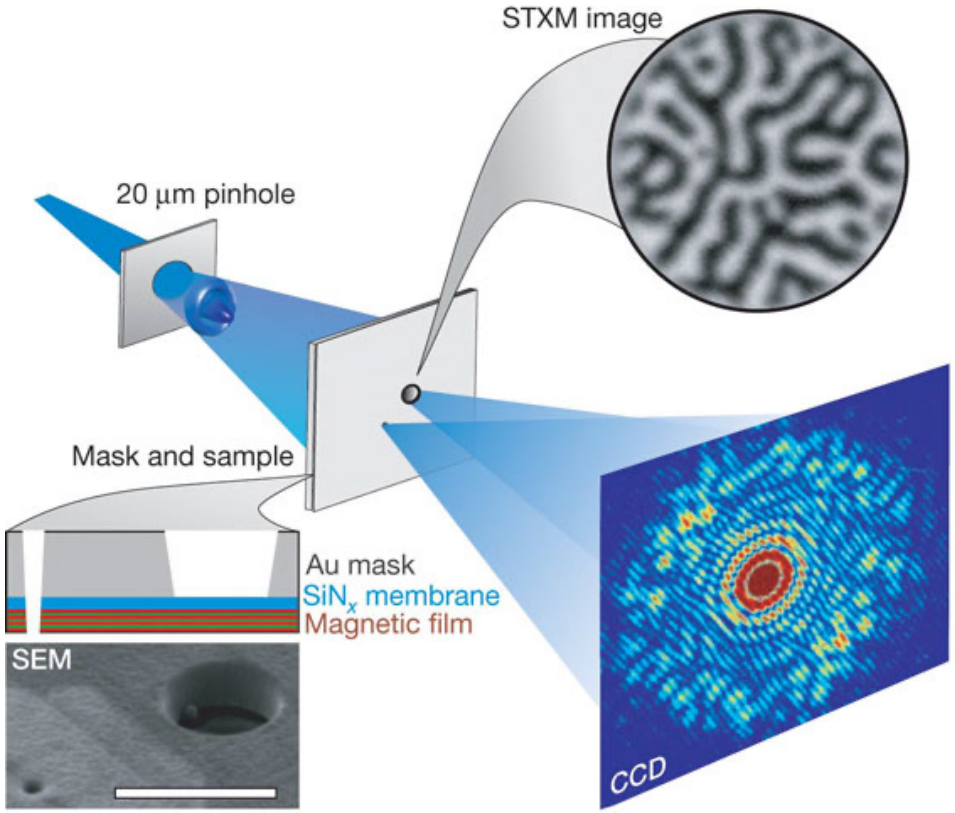
H.N.Chapman, A. Barty, S. Marchesini, A. Noy C. Cui, M. R. Howells, R. Rosen, H. He, J. C. H. Spence, U. Weierstall T. Beetz, C. Jacobsen, and D. Shapiro, "High-resolution ab initio three-dimensional X-ray diffraction microscopy" JOSA. (2006)

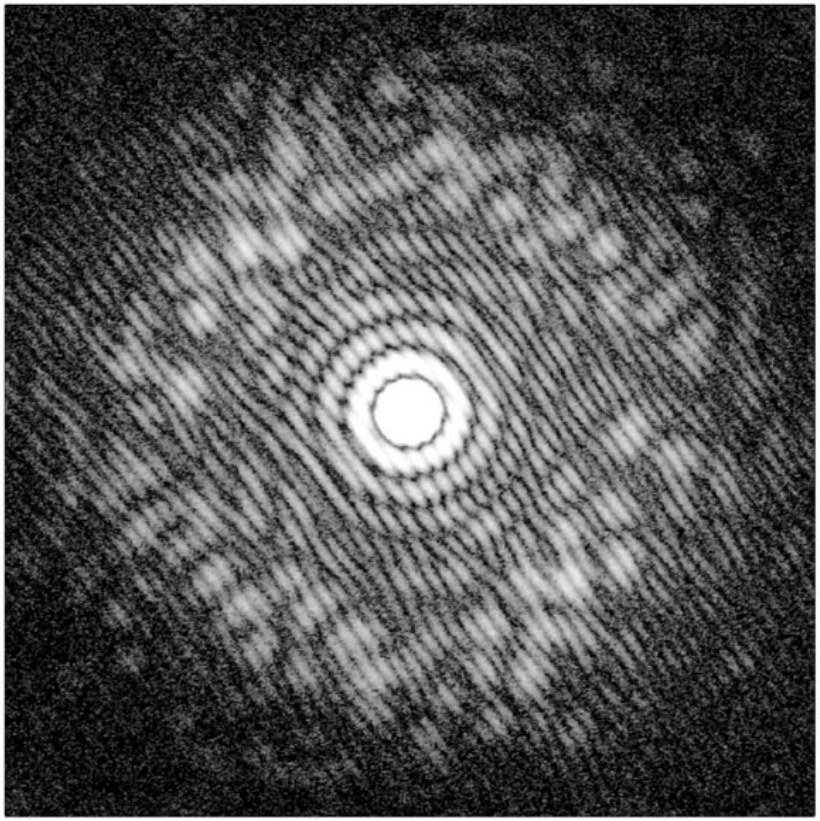


Direct Holographic Inversion

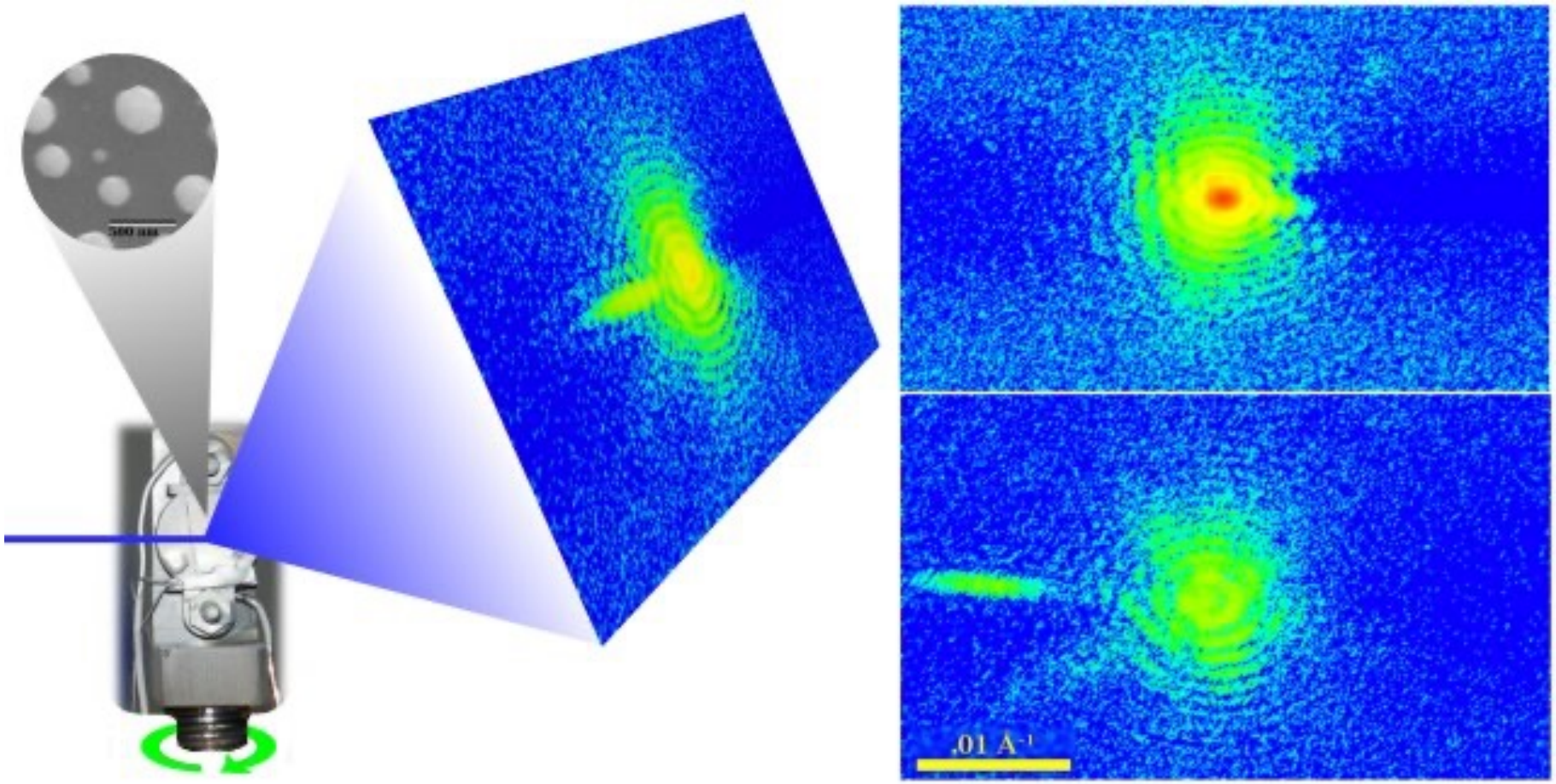
1.59nm RCP diffraction from magnetised film and pinhole

S. Eisebitt, J. Lüning, W. Schlotter, M. Lörgen, O. Hellwig, W. Eberhardt and J. Stöhr, Nature 432, 885-888 (2004)

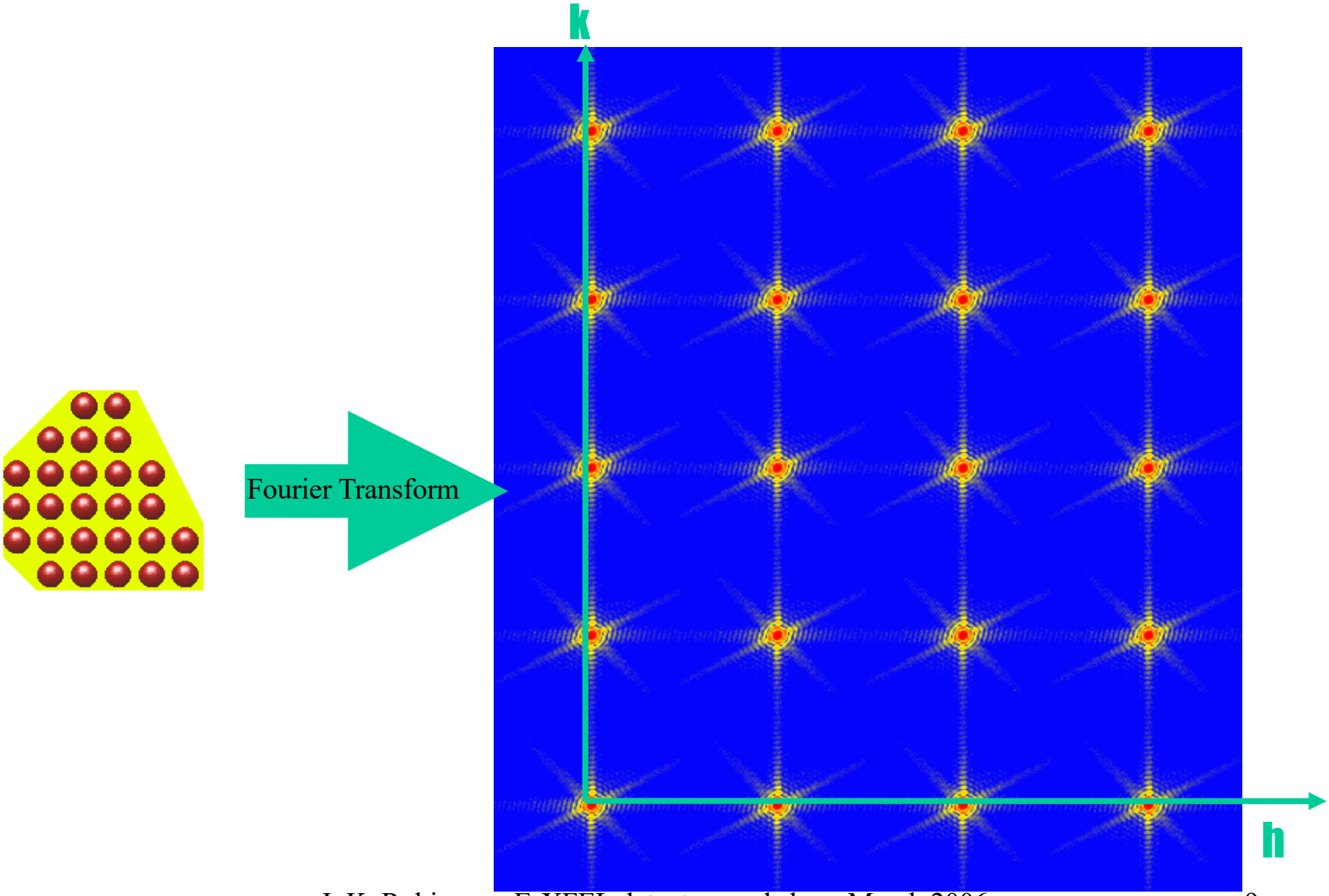




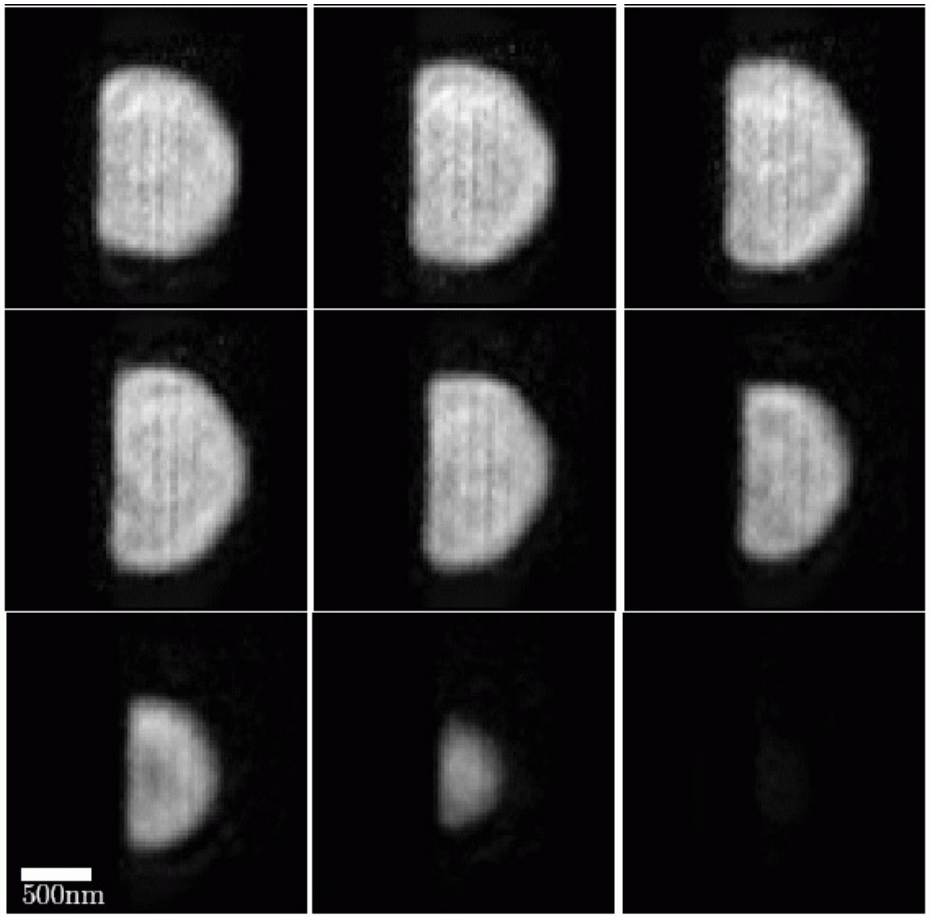
Lensless Imaging setup in UHV

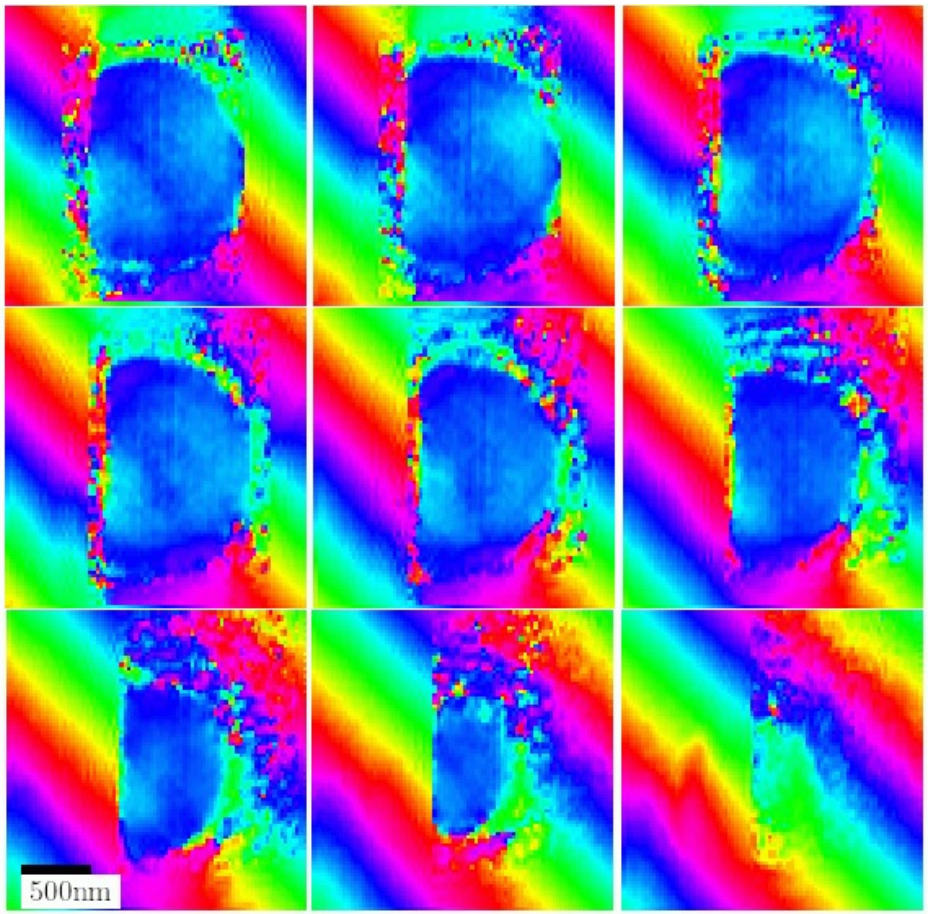


Coherent Diffraction from Crystals

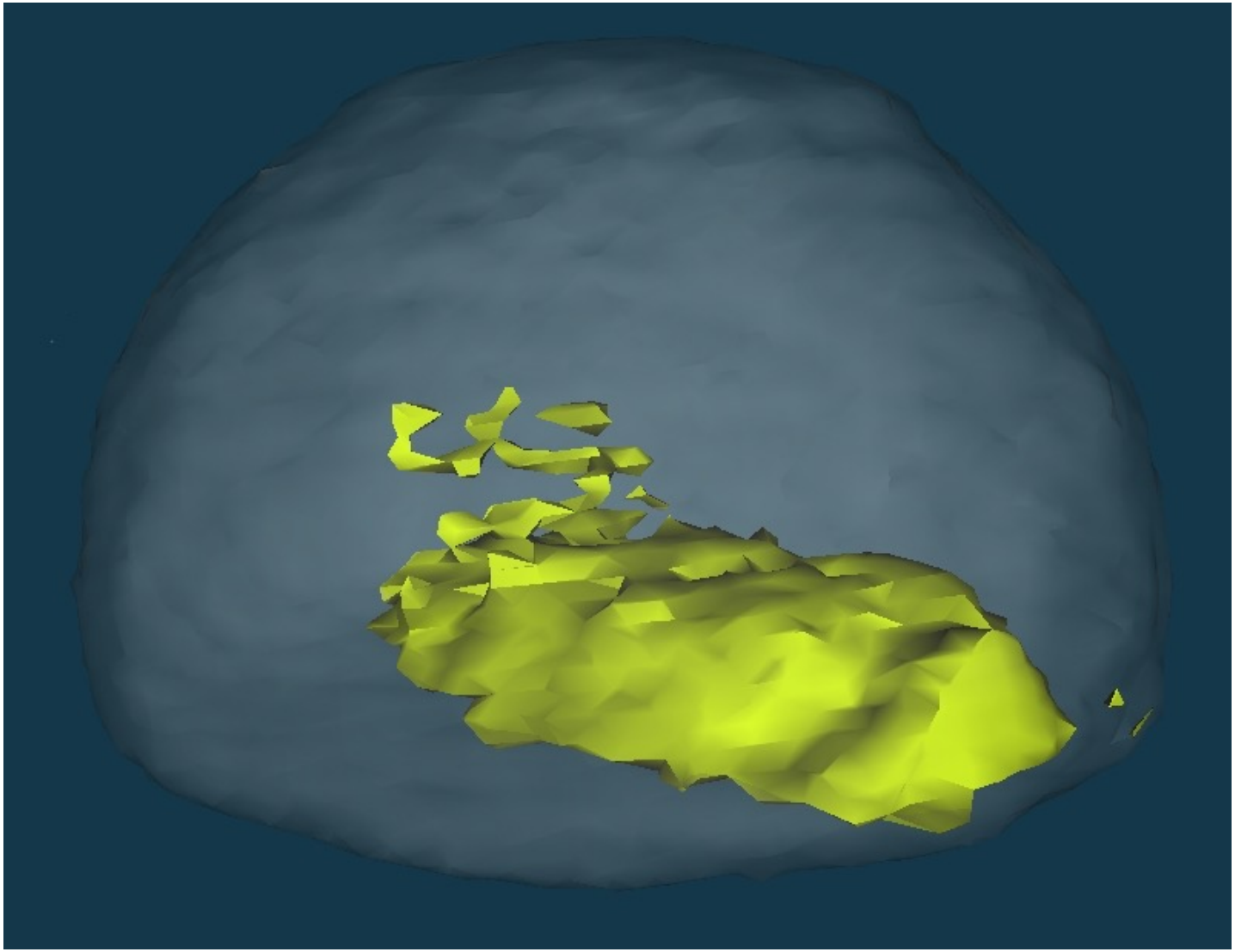


Then refine amplitude *and* phase

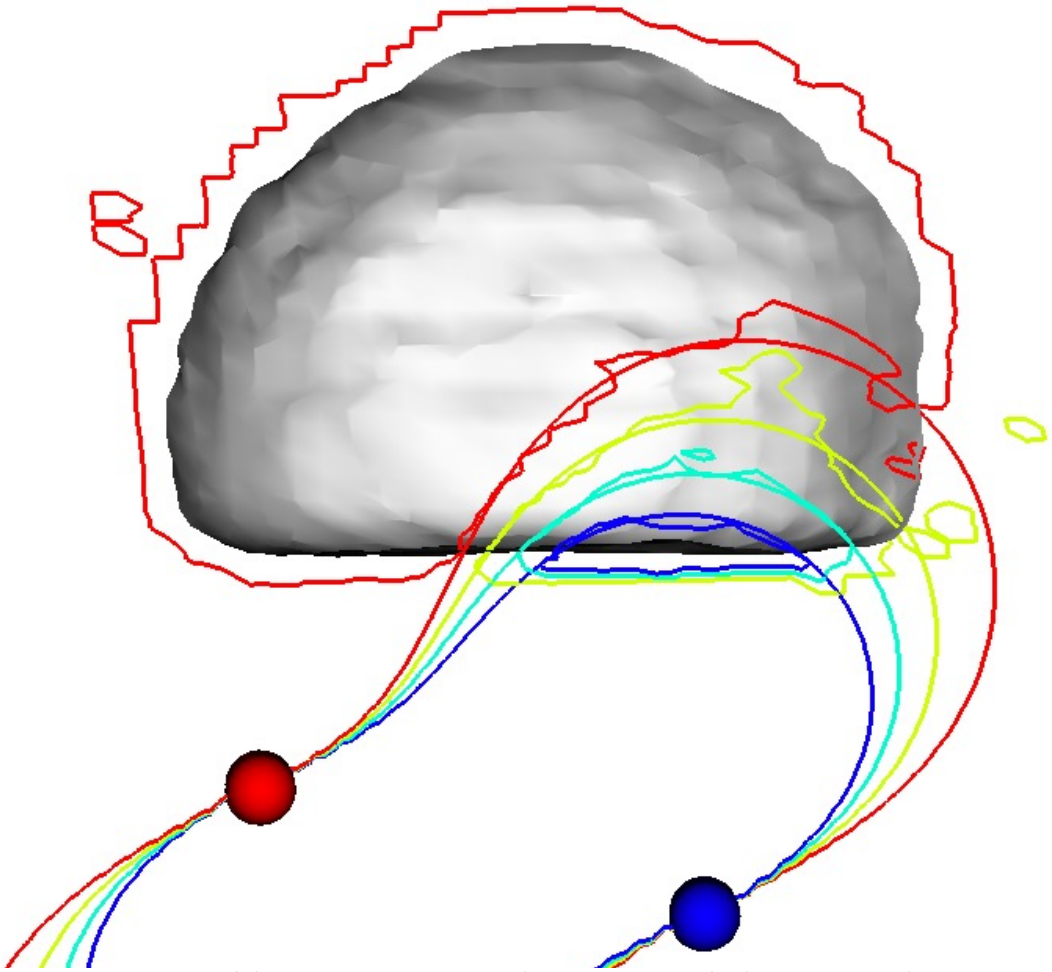




Modeling of 3D Phase Bump



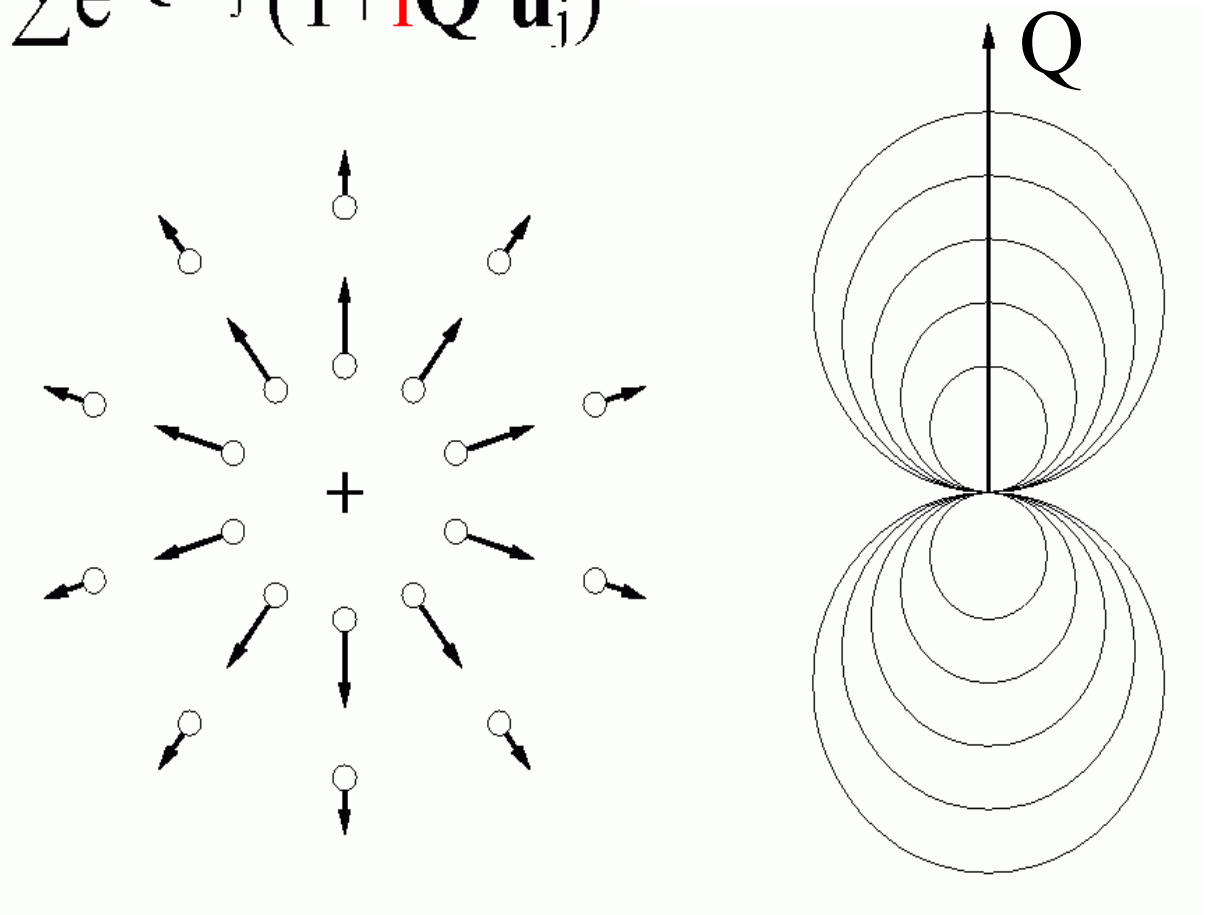
Field lines of Point Charges

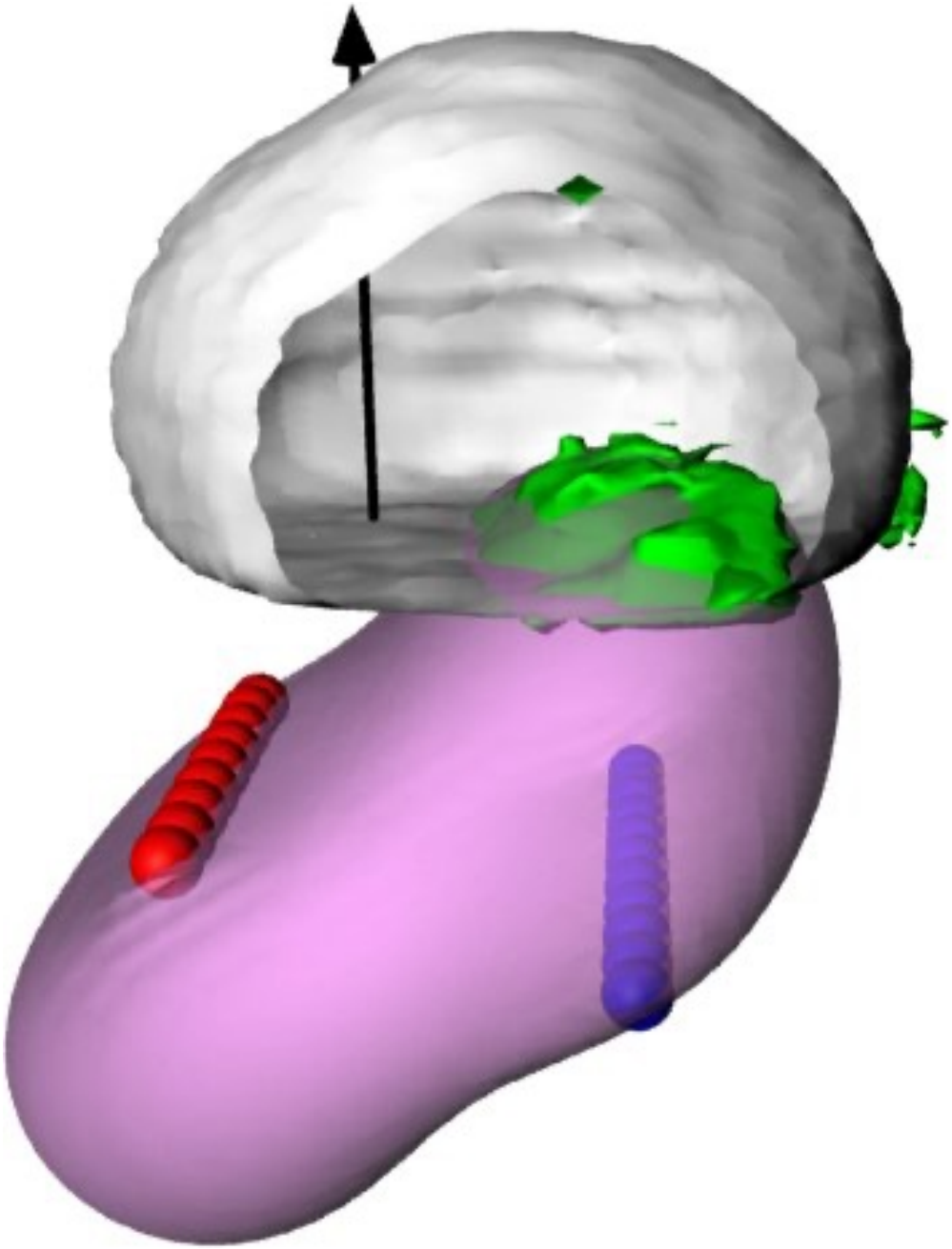


Diffraction by Strain of Point Defect

$$A \sim \sum e^{i\mathbf{Q}\cdot(\mathbf{R}_j+\mathbf{u}_j)}$$
$$\approx \sum e^{i\mathbf{Q}\cdot\mathbf{R}_j}(1+i\mathbf{Q}\cdot\mathbf{u}_j)$$

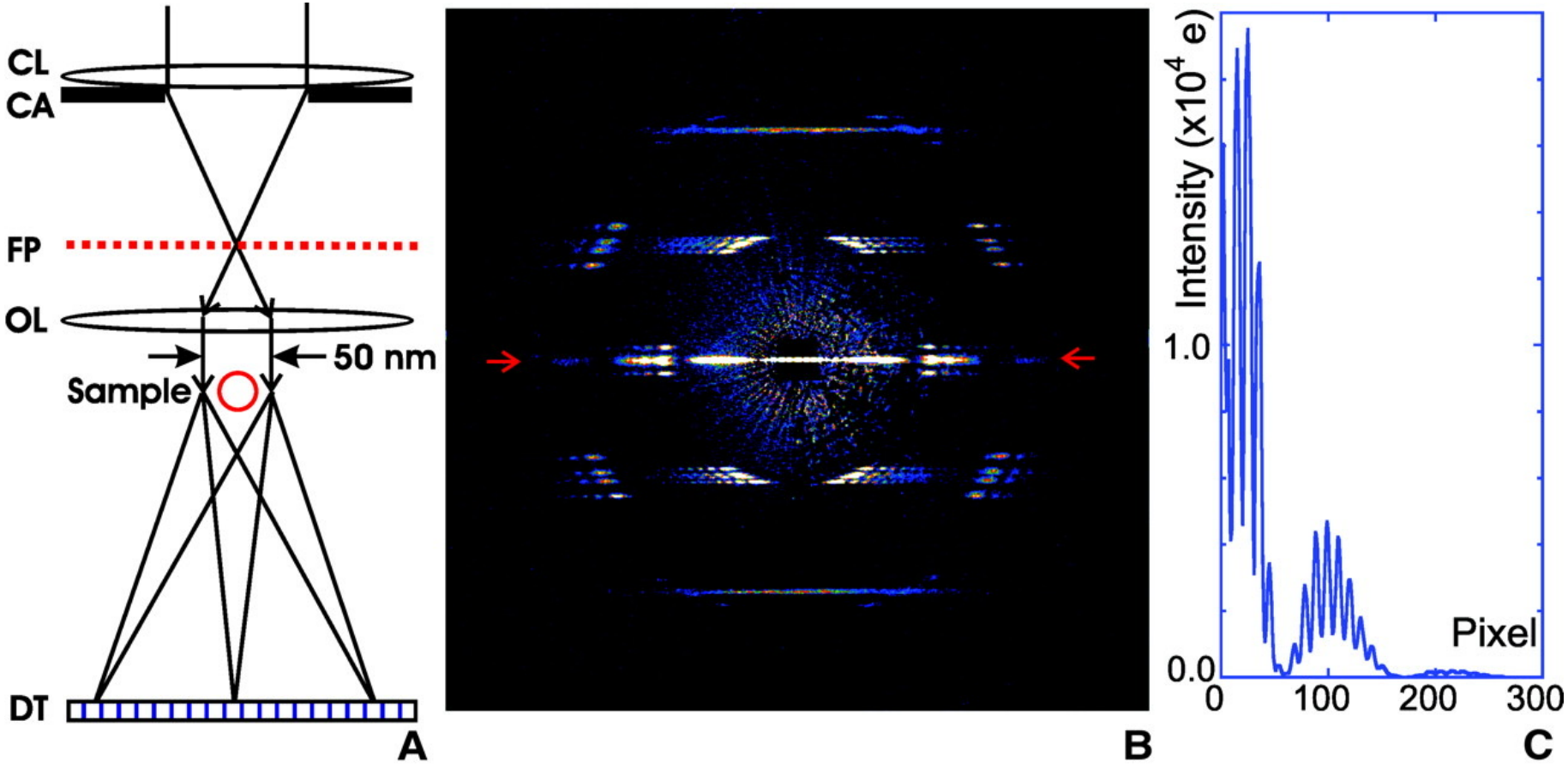
Imaginary density





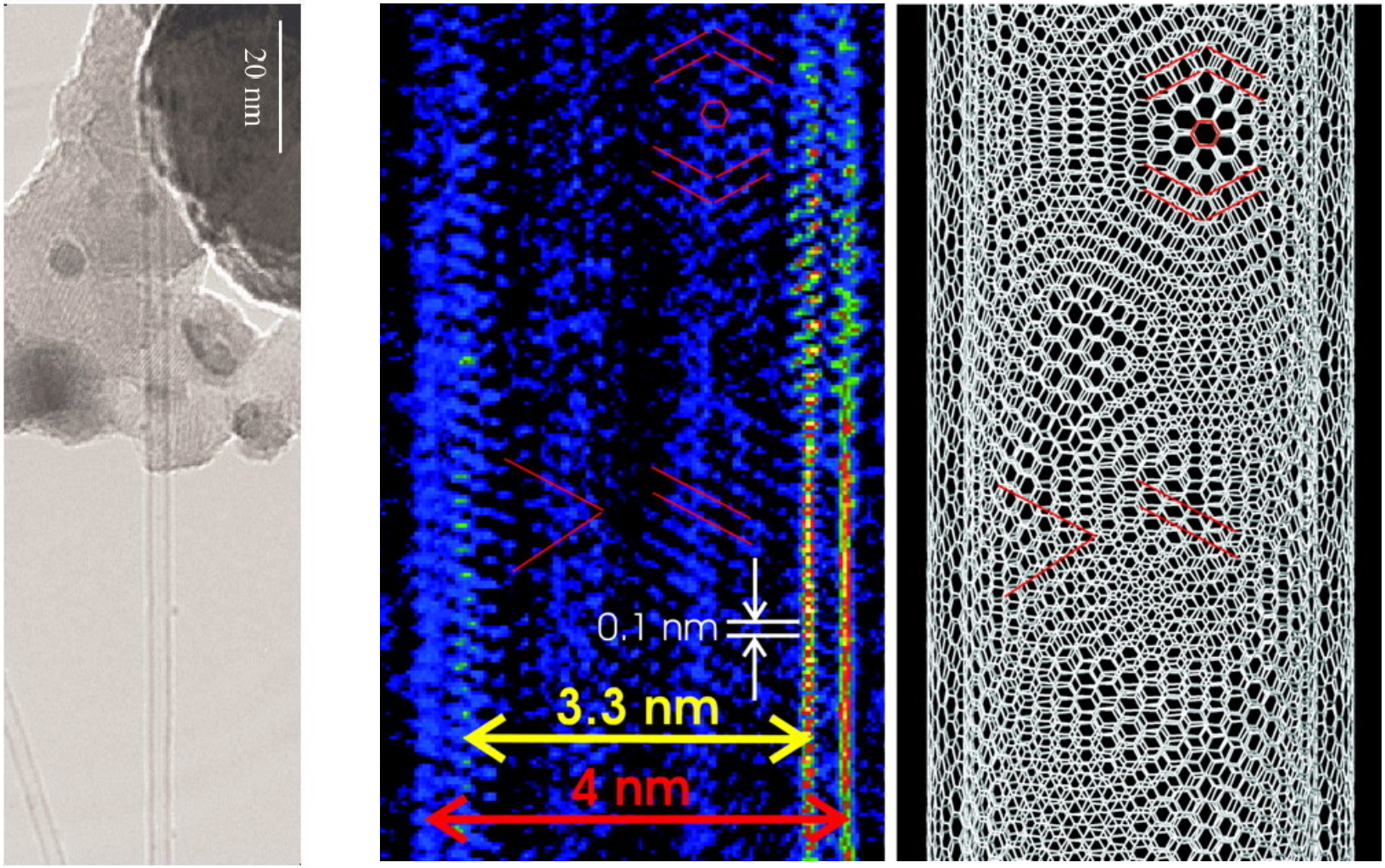
Electron Diffraction from C-nanotube

Jim Zuo et. al. Science 300 1419 (2003)



Images of DW C-nanotube

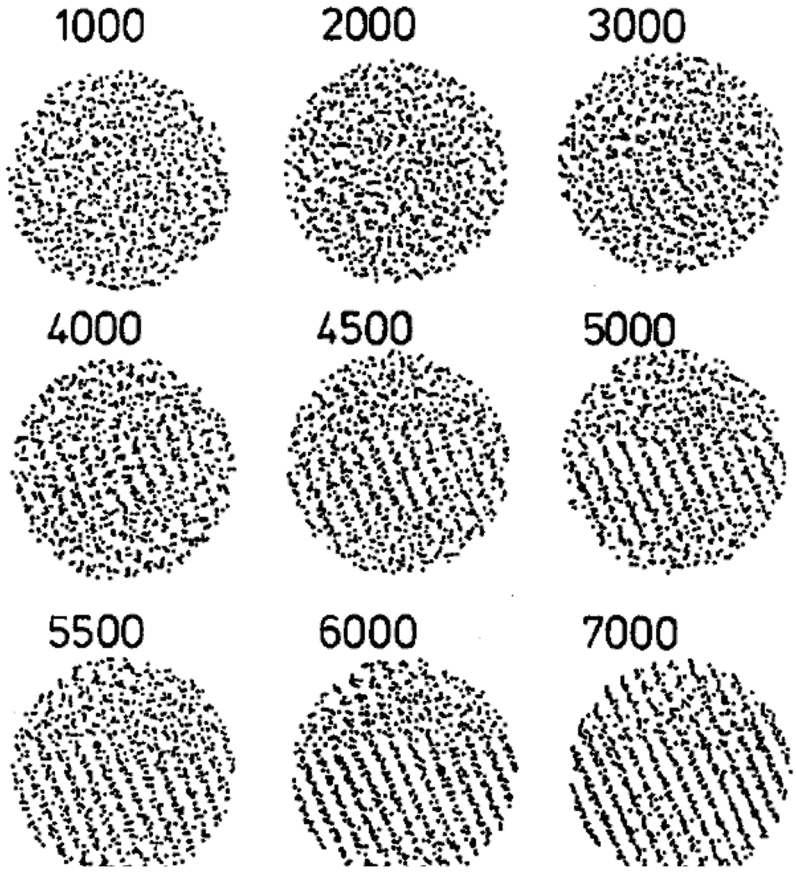
Jim Zuo et. al. Science 300 1419 (2003)

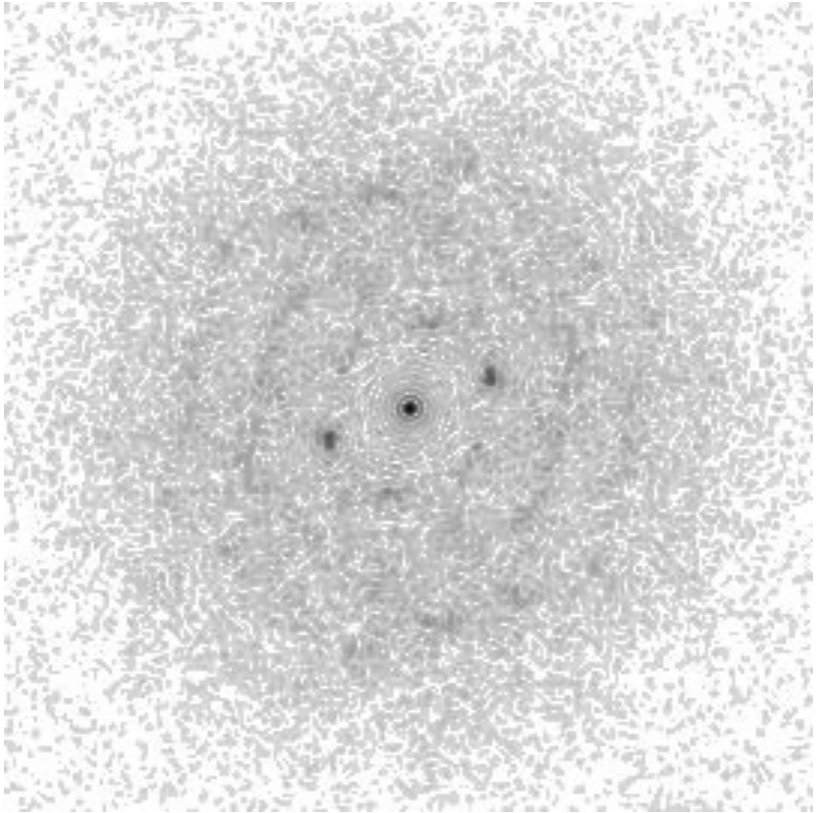


MD simulation of freezing

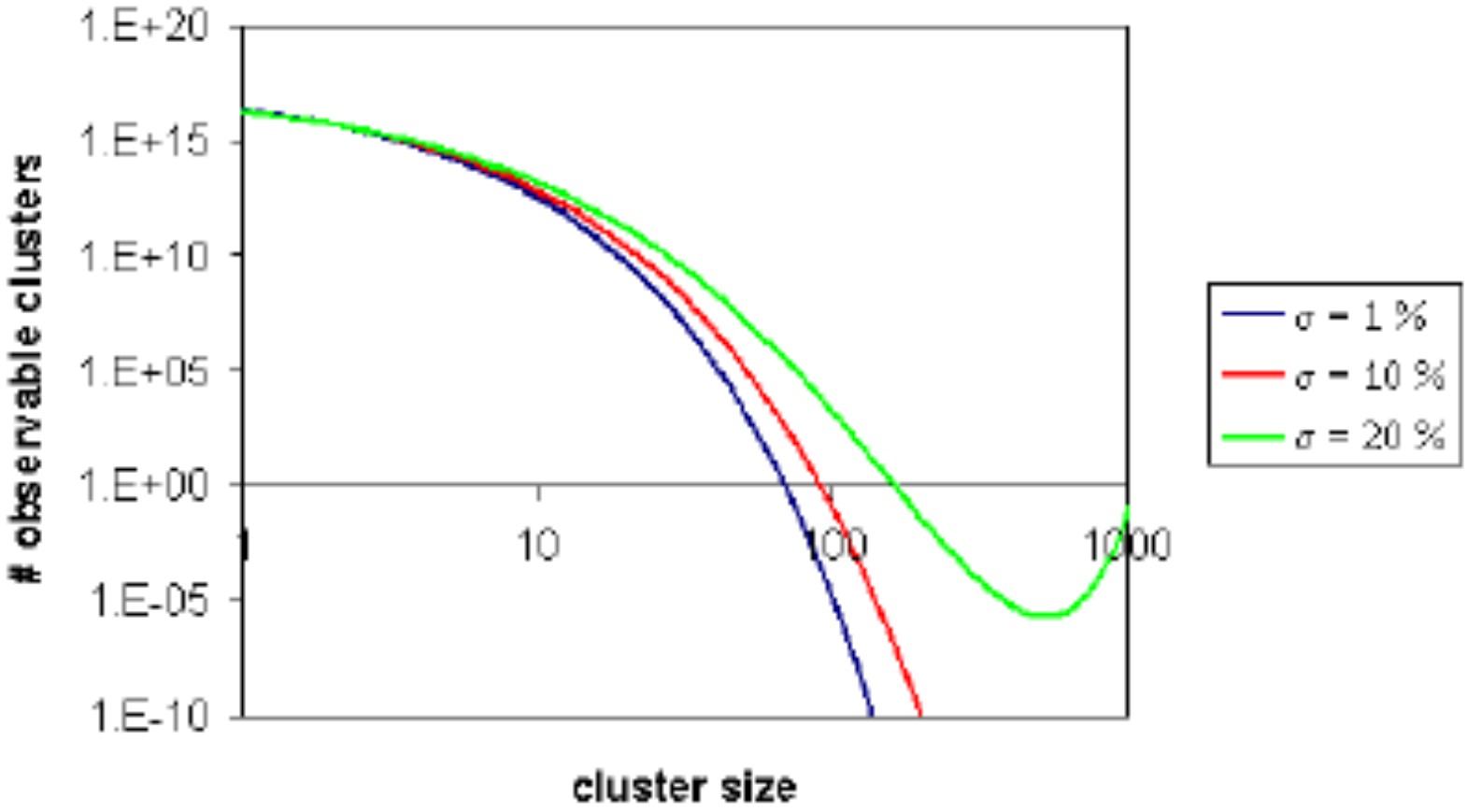
LJ liquid of 864 atoms. Time steps after T-Jump

S. Nose and F. Yonezawa, JCP 84 1893 (1986)





Nucleation cluster size distribution

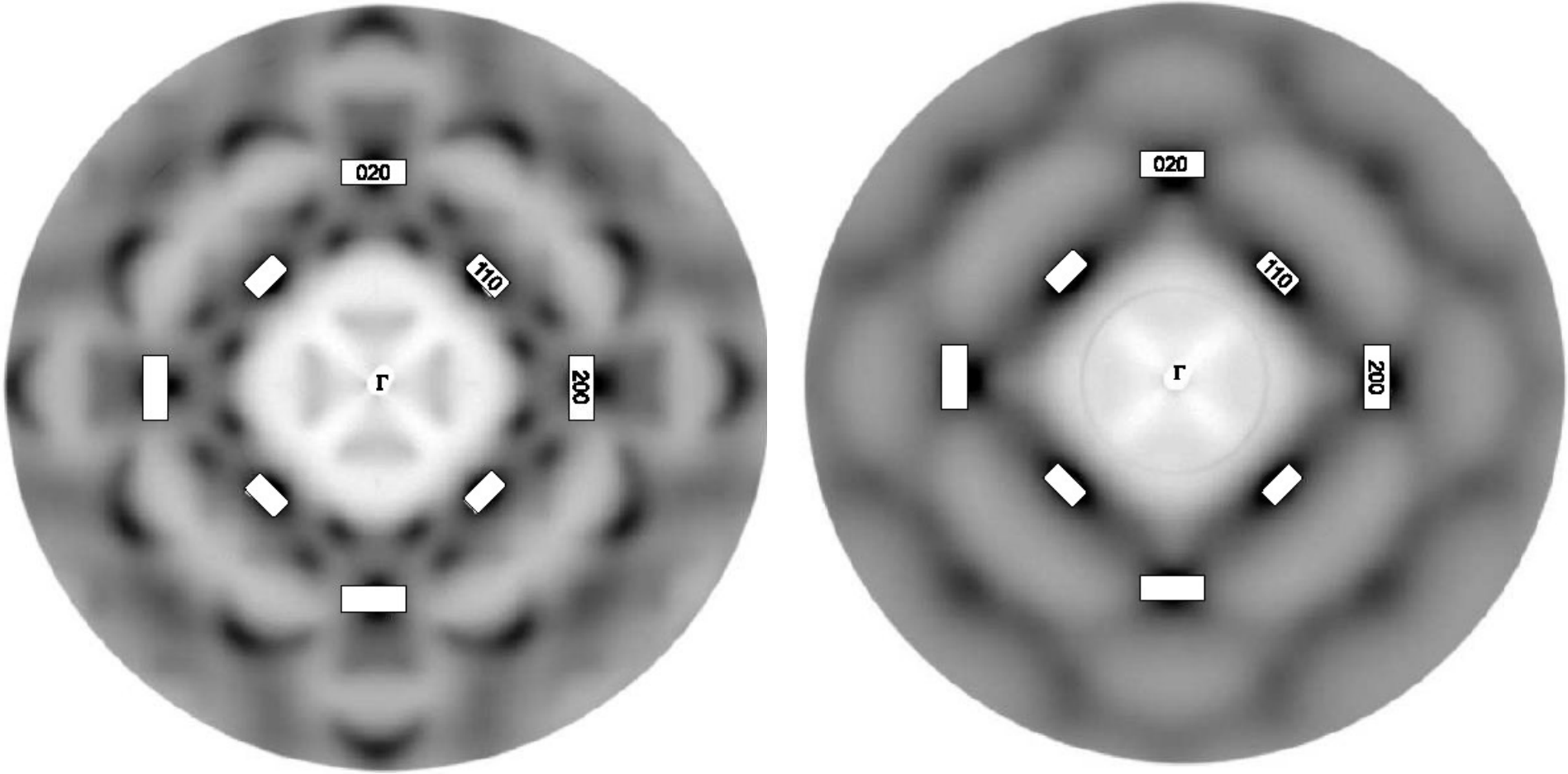


High-energy diffuse scattering

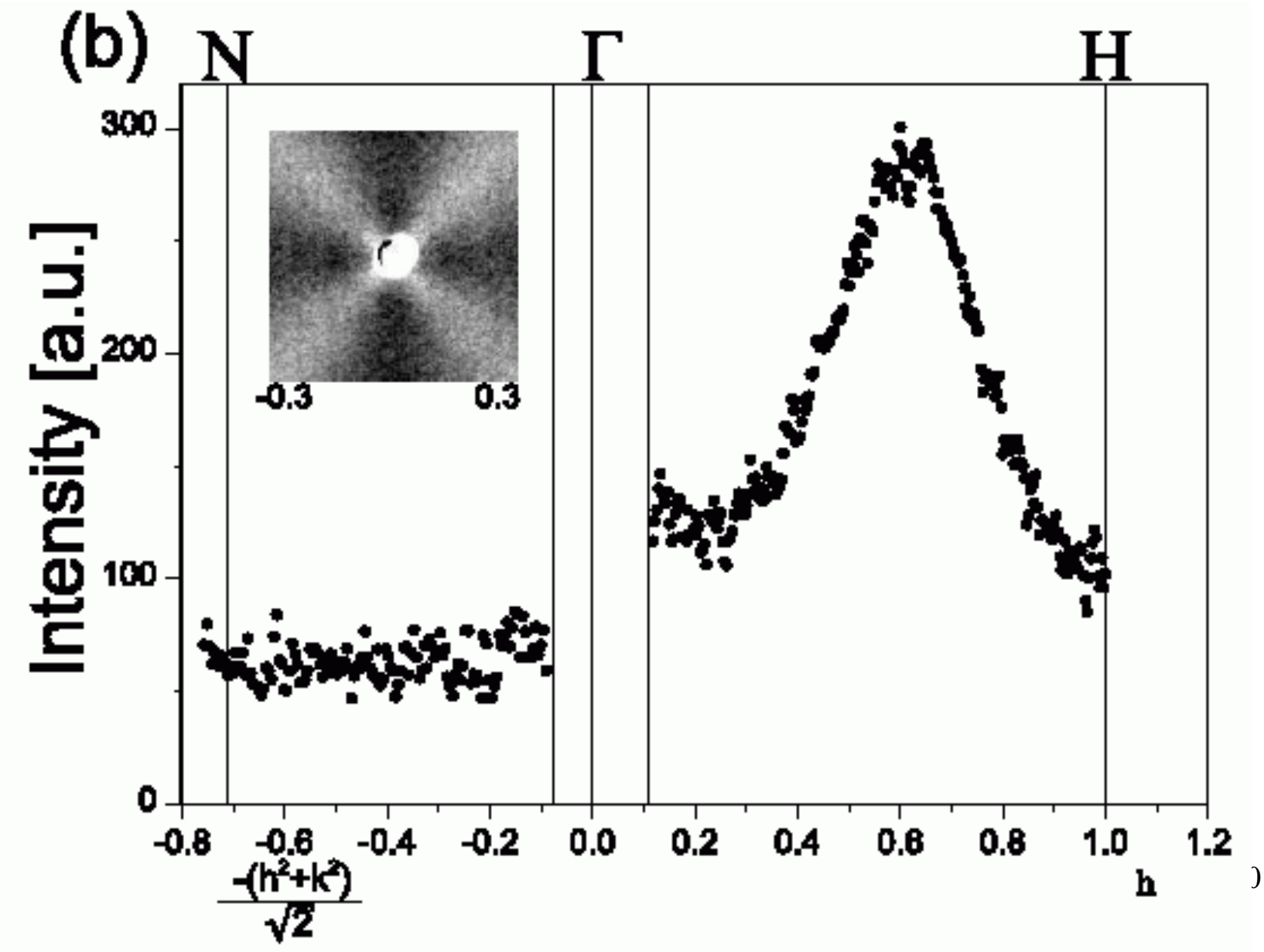
could use spontaneous radiation from U2

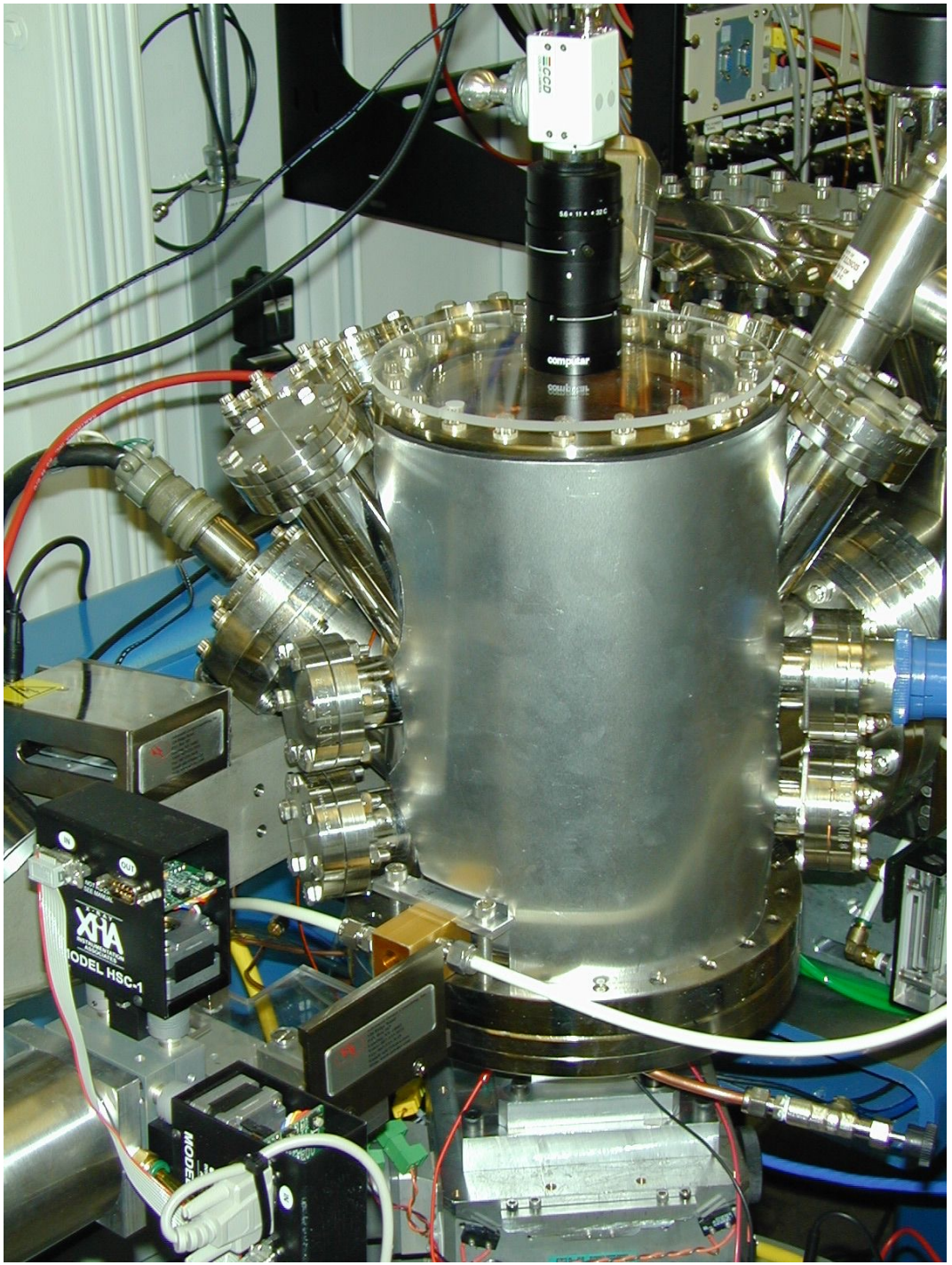
Imgo Ramsteiner PhD Thesis, Stuttgart 2005

$Ti_{60}V_{40}$ at 300K and 1170K, along [001]



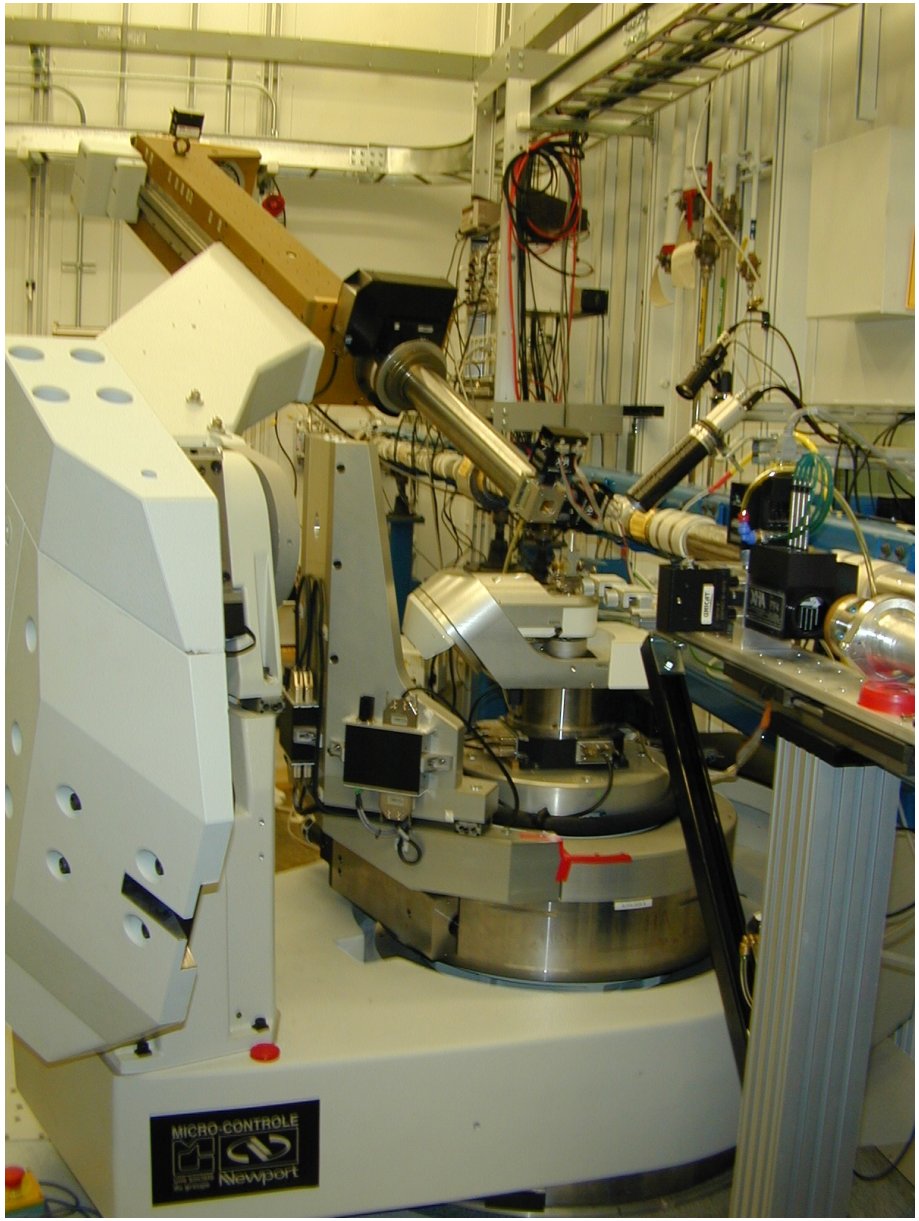
Non-analyticity at Zone Centre

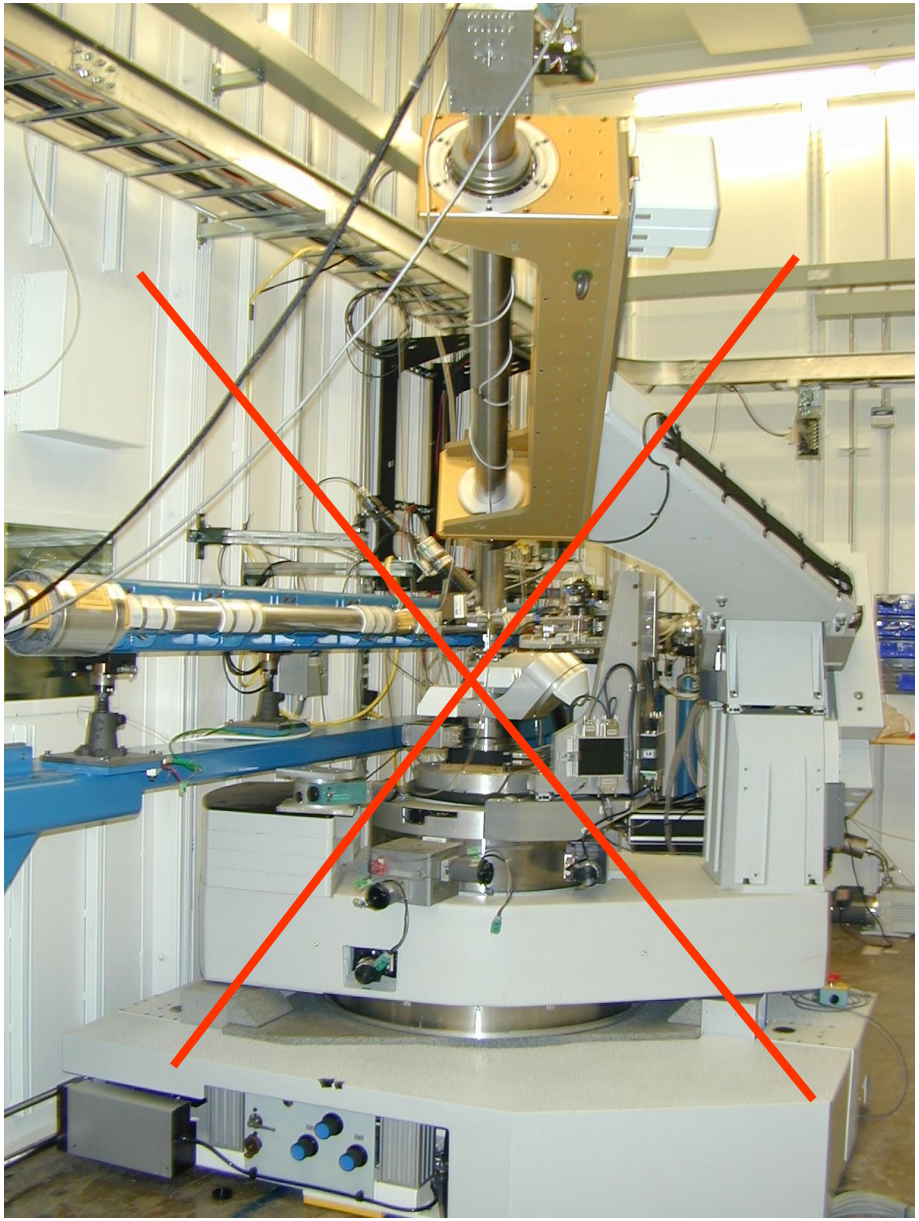



MODEL HSC-1

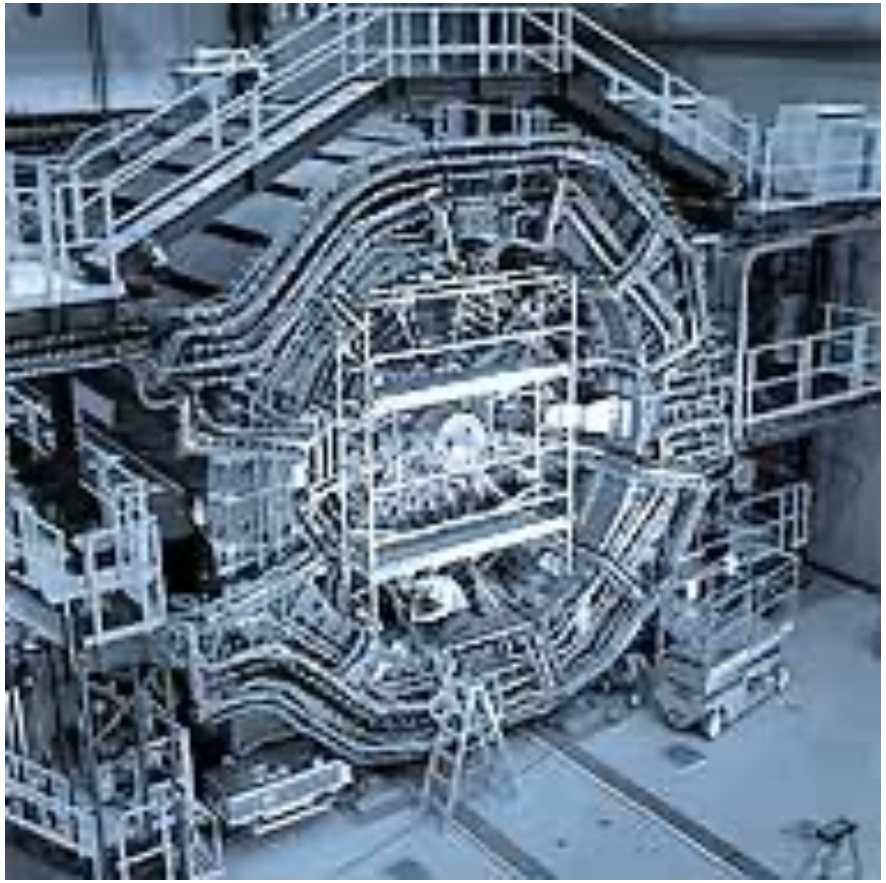
Sample Handling

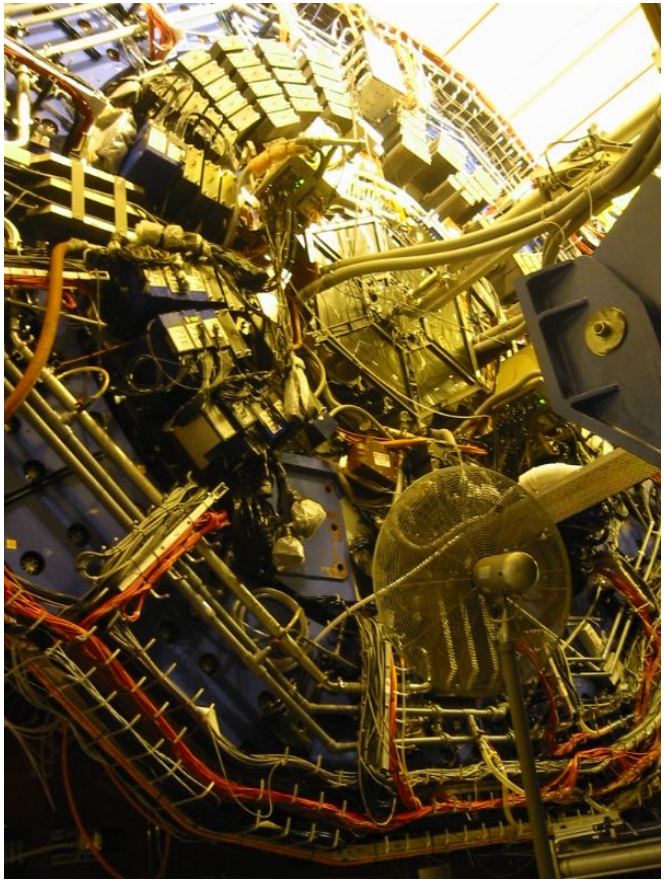
- Optics will achieve 0.1μm focus
- Continuous film sliding through beam
  - 0.1μm in 200ns is 0.5m/s
  - Raster $(10mm)^2$ sample in 30 minutes
- Liquid jet sprayed into UHV
- Optical tweezer array under water


MICRO-CONTROLE
Newport



The HEP approach: detectors drive the science





Detector Requirements

- Fluctuations should 'live' for nanoseconds
  - 50fs pulses might beat radiation damage
  - 5MHz frame rate is 'interesting'
- Parallel detector bank, covering ~πSr
- Pixel size ~100μm at D=1-2m
- 0.1nm, 0.02nm and 1nm wavelength ranges
- Large dynamic range, $>10^6$ at small angle
  - Nested detector banks
- Intelligent, subjective event 'trigger'

Conclusions and Outlook

- Coherent X-ray Diffraction Imaging
- X-ray Holography
- Extension to Phase Objects
- Single molecule imaging with Electrons
- High Energy Diffuse Scattering
- Detector Requirements