Phase Structure due to Refraction in Coherent X-ray Diffraction

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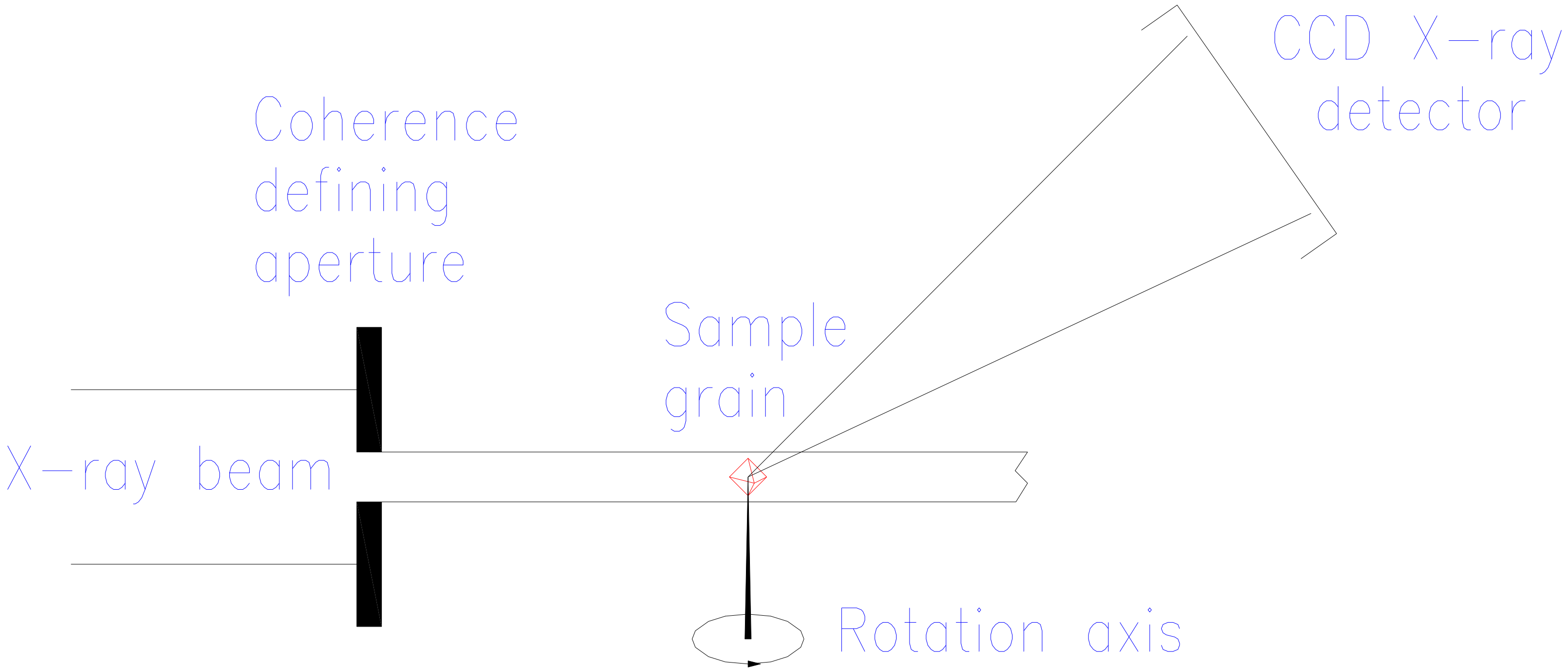
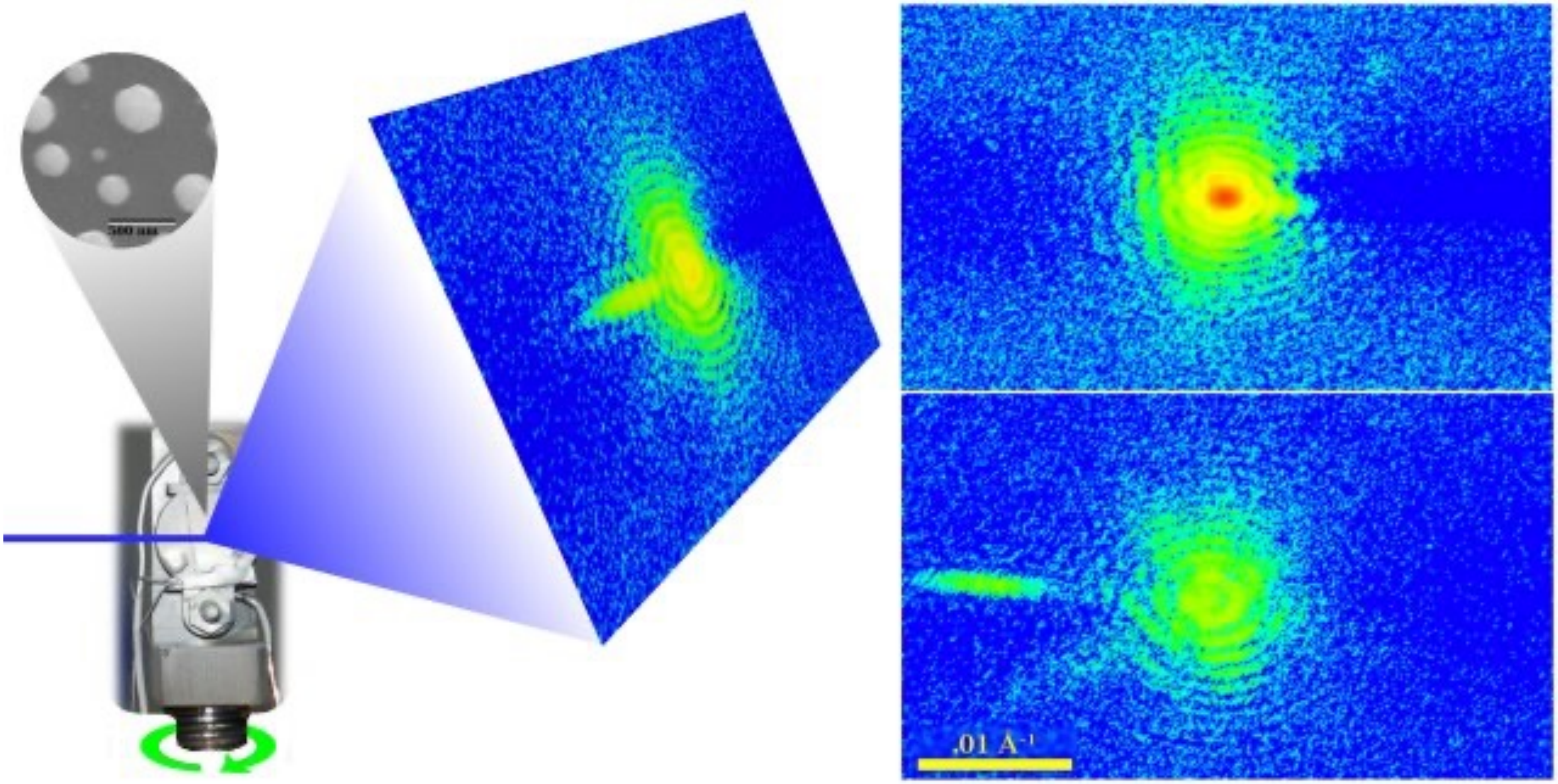
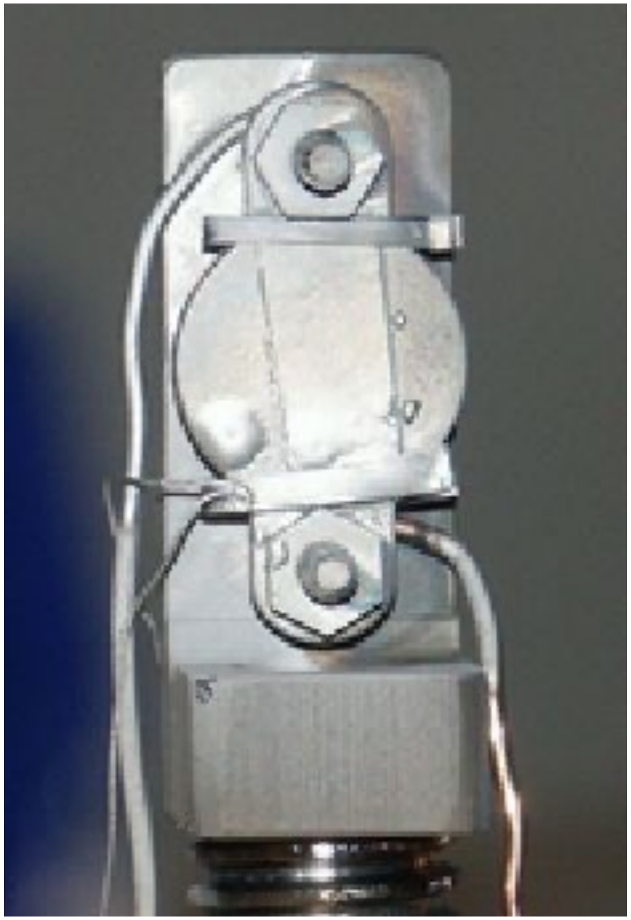
Lensless X-ray Microscope

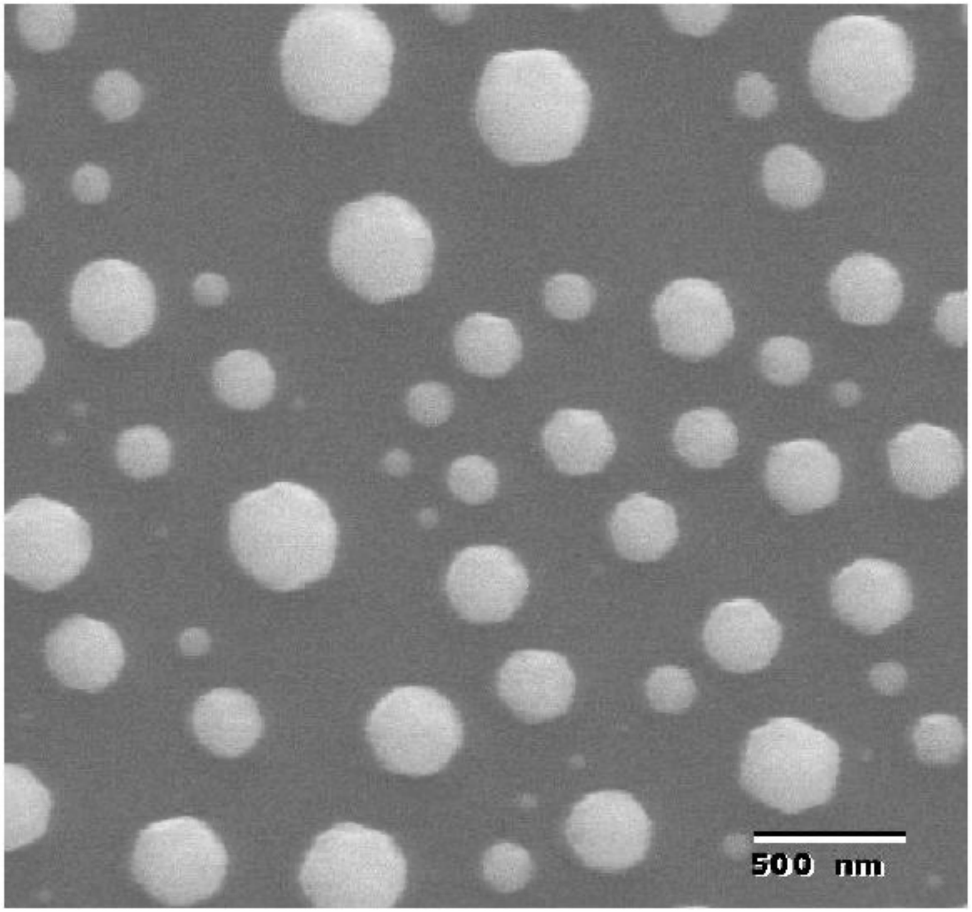


Lensless Imaging setup in UHV

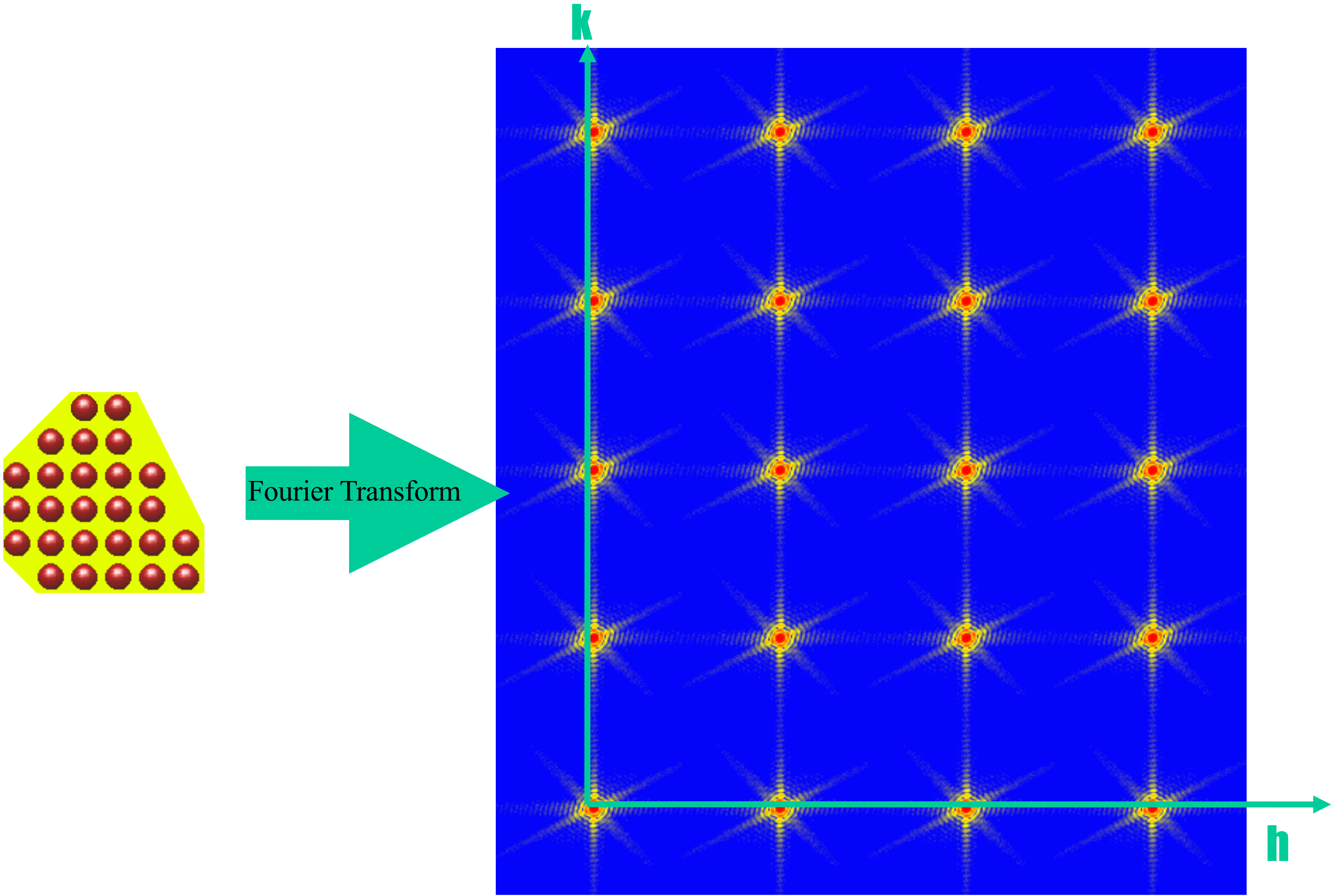


In situ growth of Pb crystals





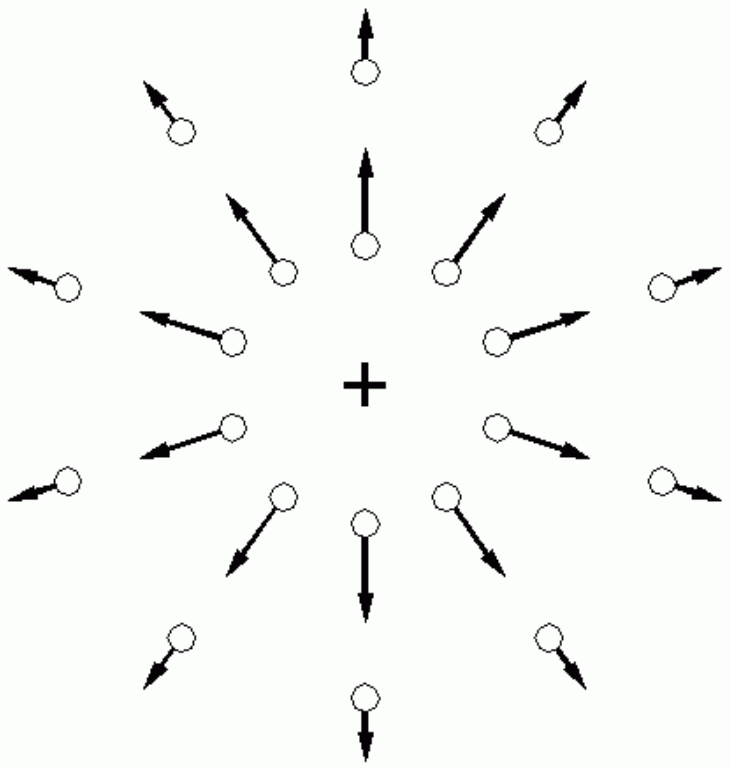
Coherent Diffraction from Crystals

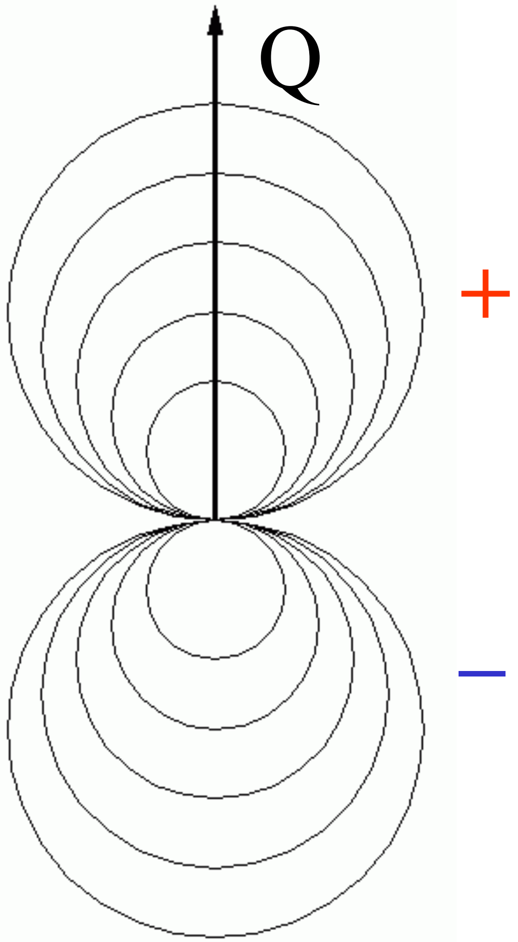

Fourier Transform

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





Good statistics, 3D diffraction data

Mark Pfeifer, Garth Williams, Ivan Vartaniants, Ross Harder

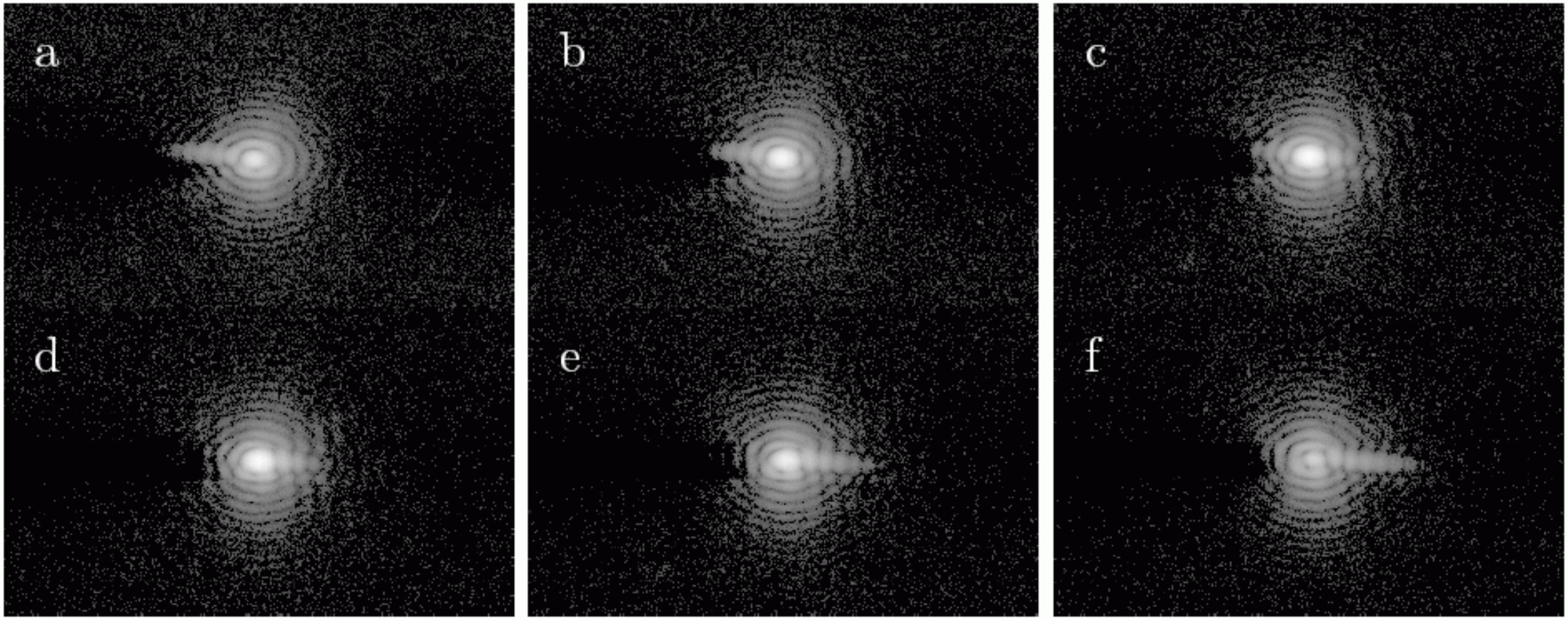
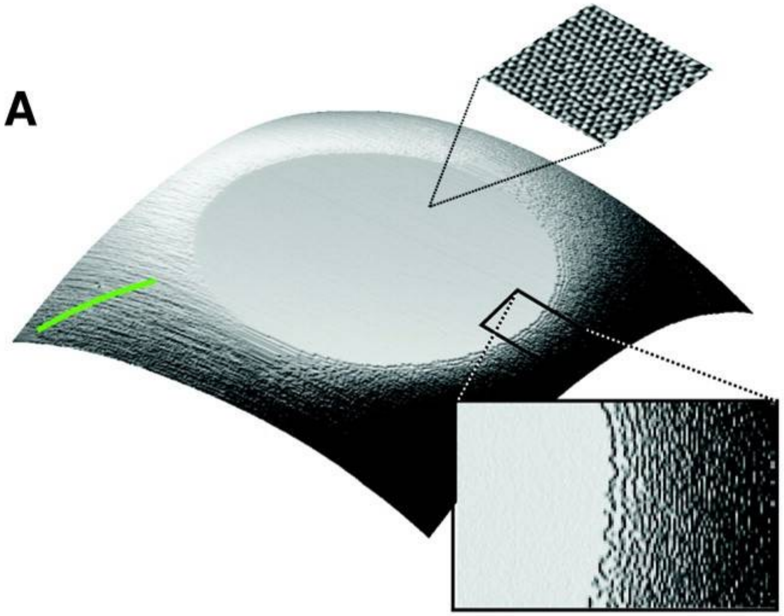


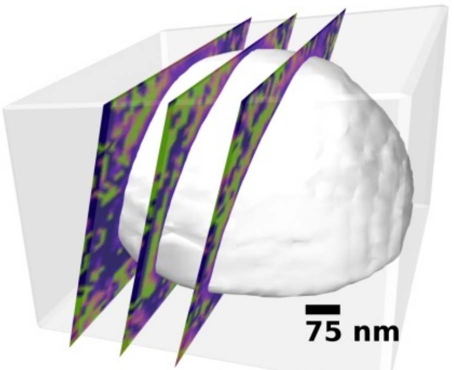
Figure 4.12: Center slices from 3D CXD pattern from Pb sample, on a log scale. Data file 296 from 10/03.

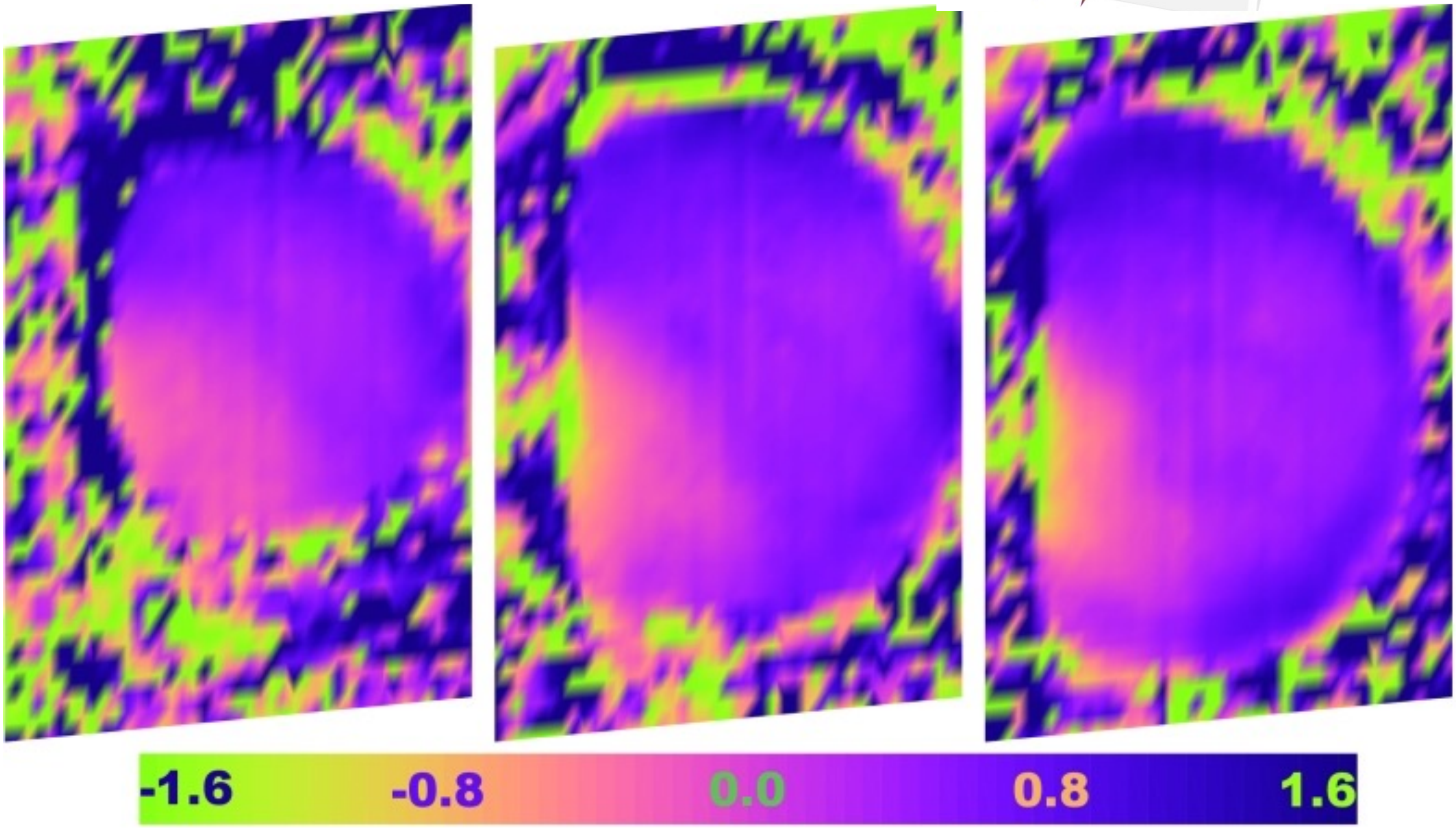
Facets of Equilibrium Crystal Shape

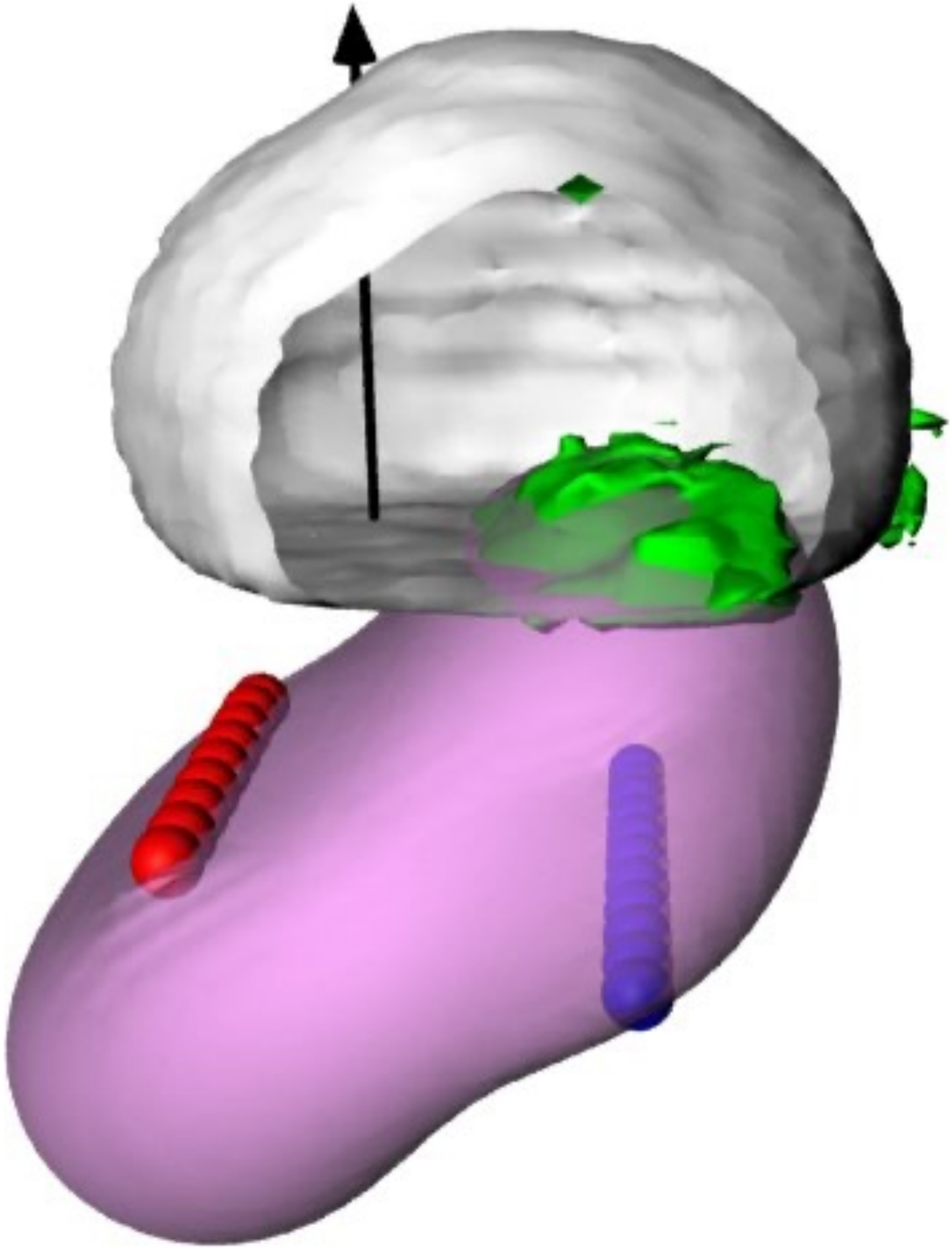


Thurmer K, Williams E, Reutt-Robey J
Science **297** 2033 (2002)

3D phase map sections







Refraction effects in Lead at 8.9keV

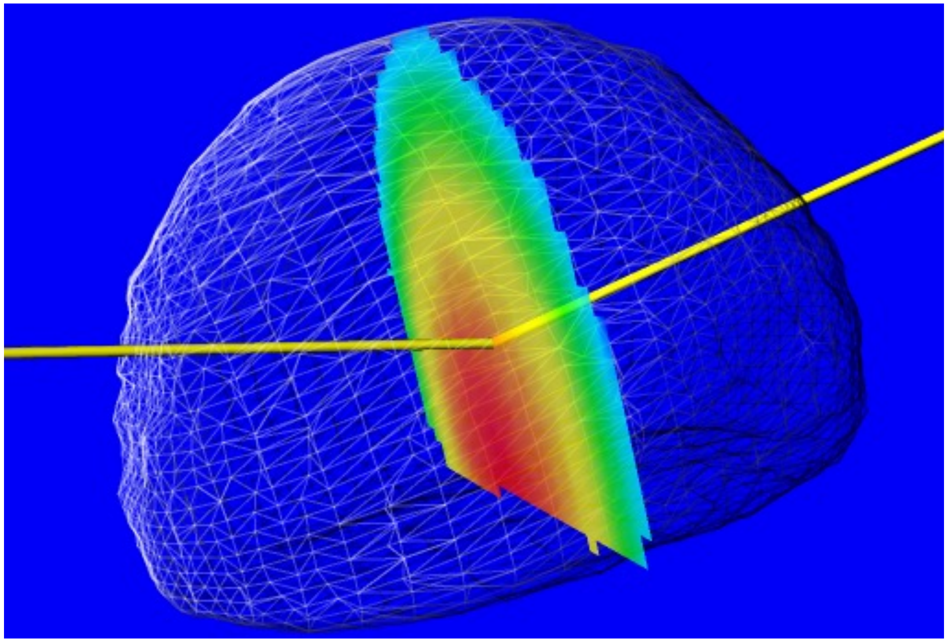
Phase accumulation due to refraction along scattering path

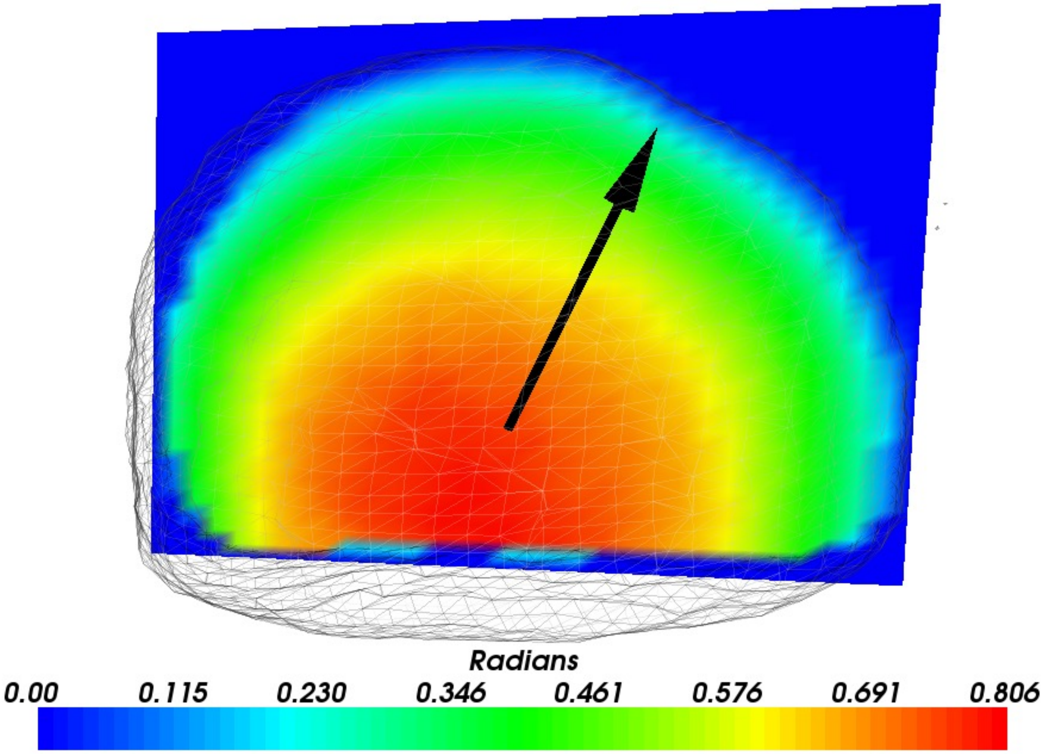
d=750nm: $kd\delta = 0.76$rad

$kd\beta = 0.07$

$\delta = 2.23\text{x}10^{-5}$

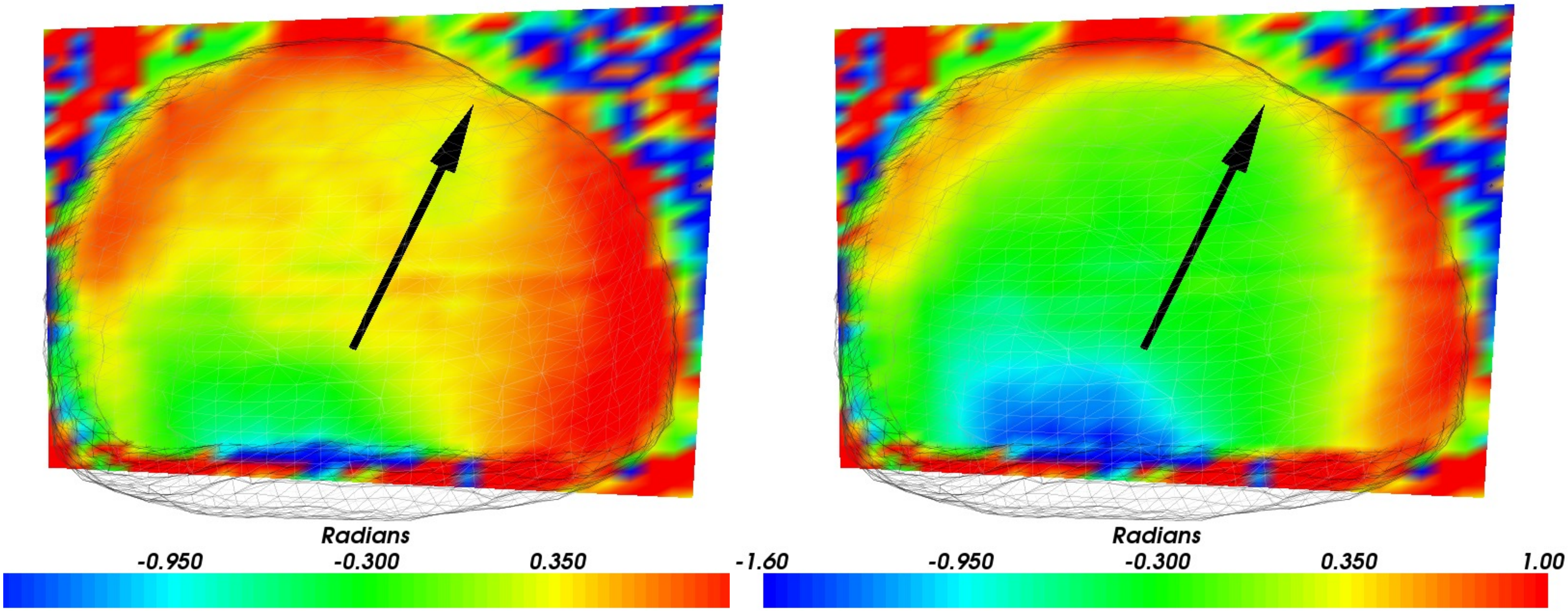
$\beta = 2.19\text{x}10^{-6}$





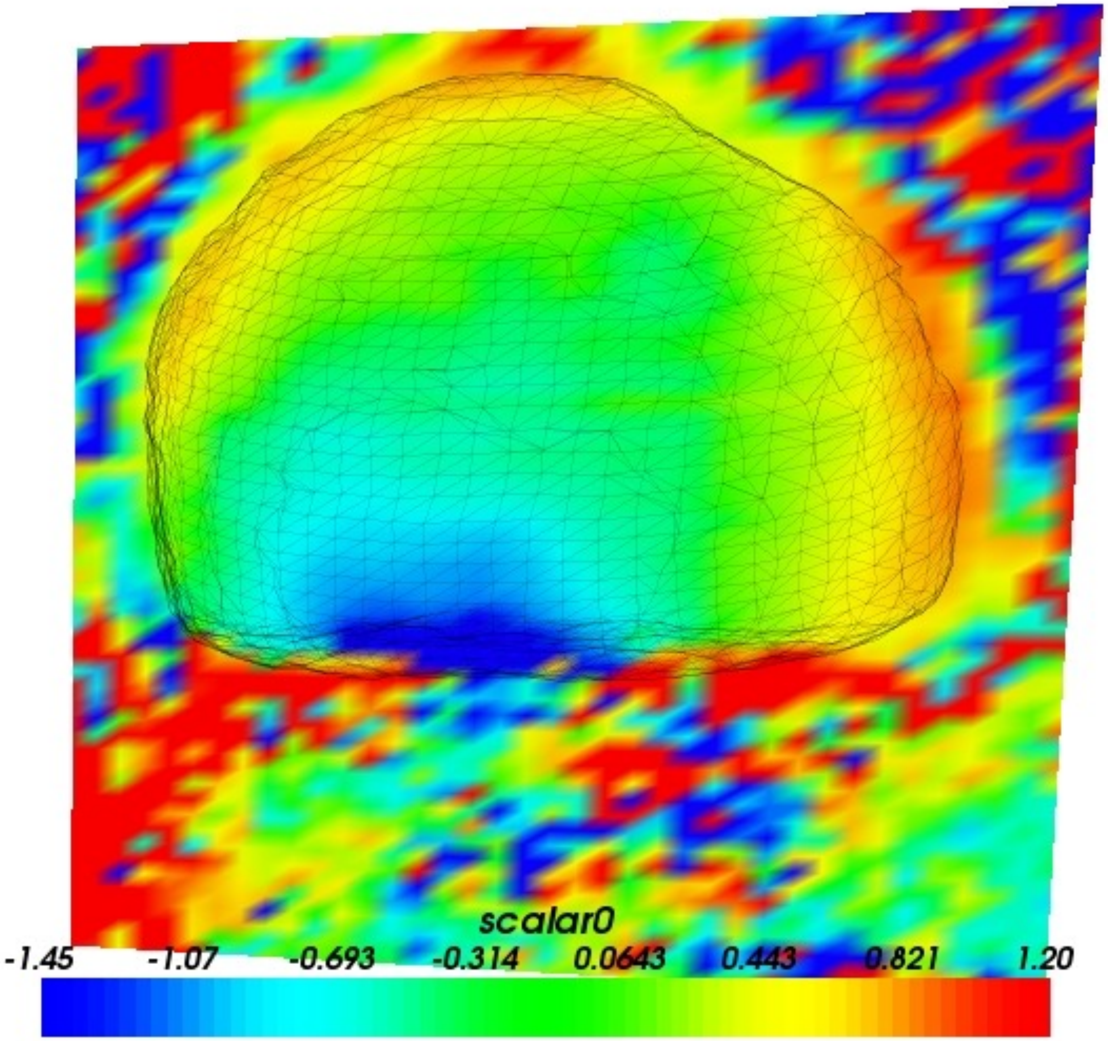
I. K. Robinson

Phase Maps before and after Correction



Positive Phase is Surface Expansion

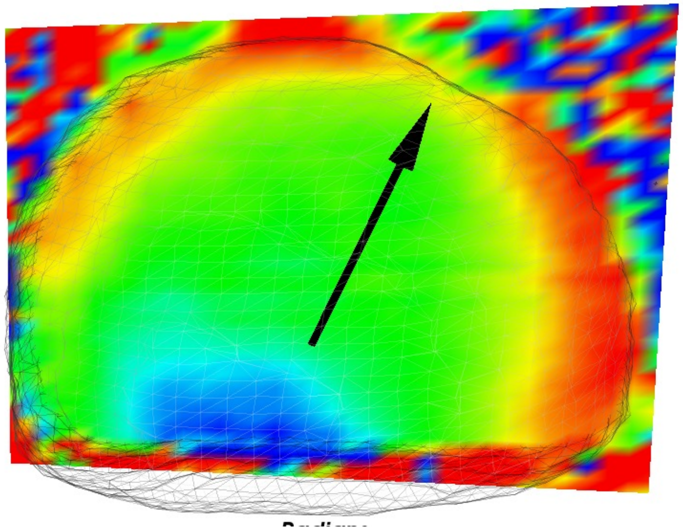
including correction for refraction by crystal

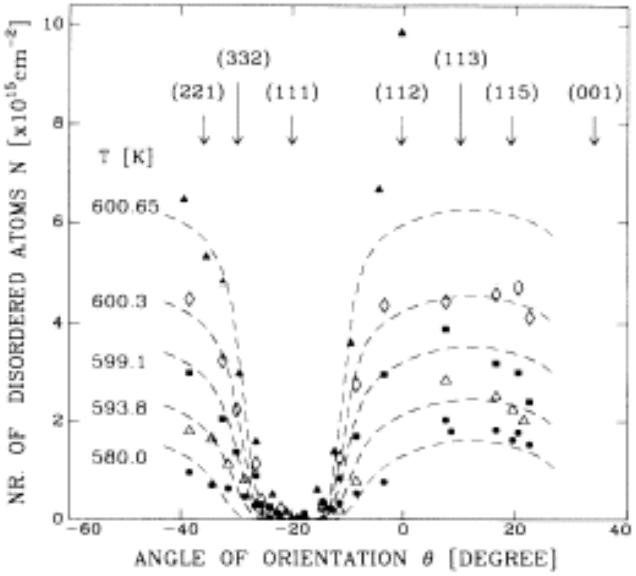


Max phase = 1.15rad
= 0.052nm

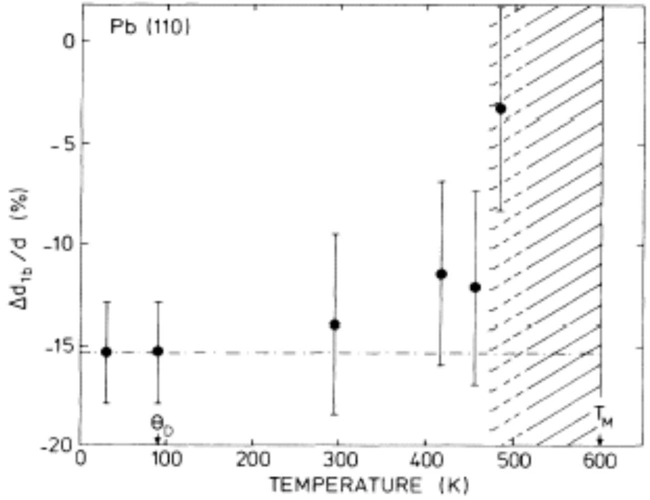
Phase on (111) facet:
= 0.47 rad
= 0.02nm

Surface Thermal Expansion: ion channeling + theory

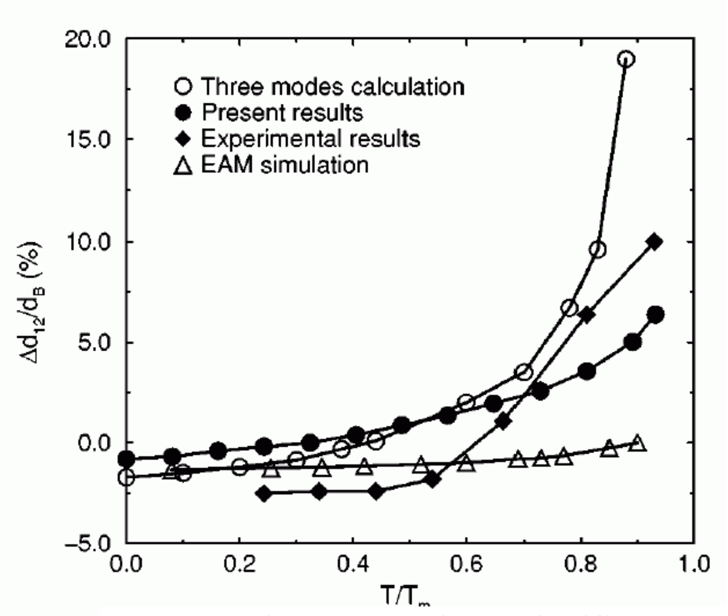




Pluis, van der Gon, Frenken, van der Veen
PRL 59 401(1987)



Frenken, Huusen, van der Veen
PRL 58 (1987)

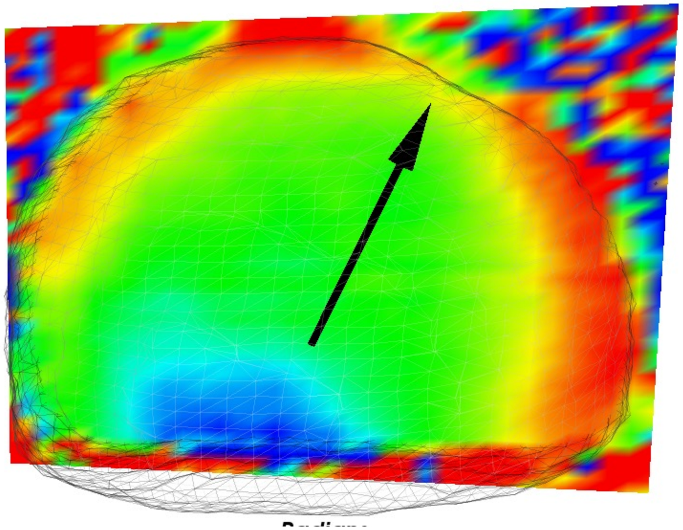


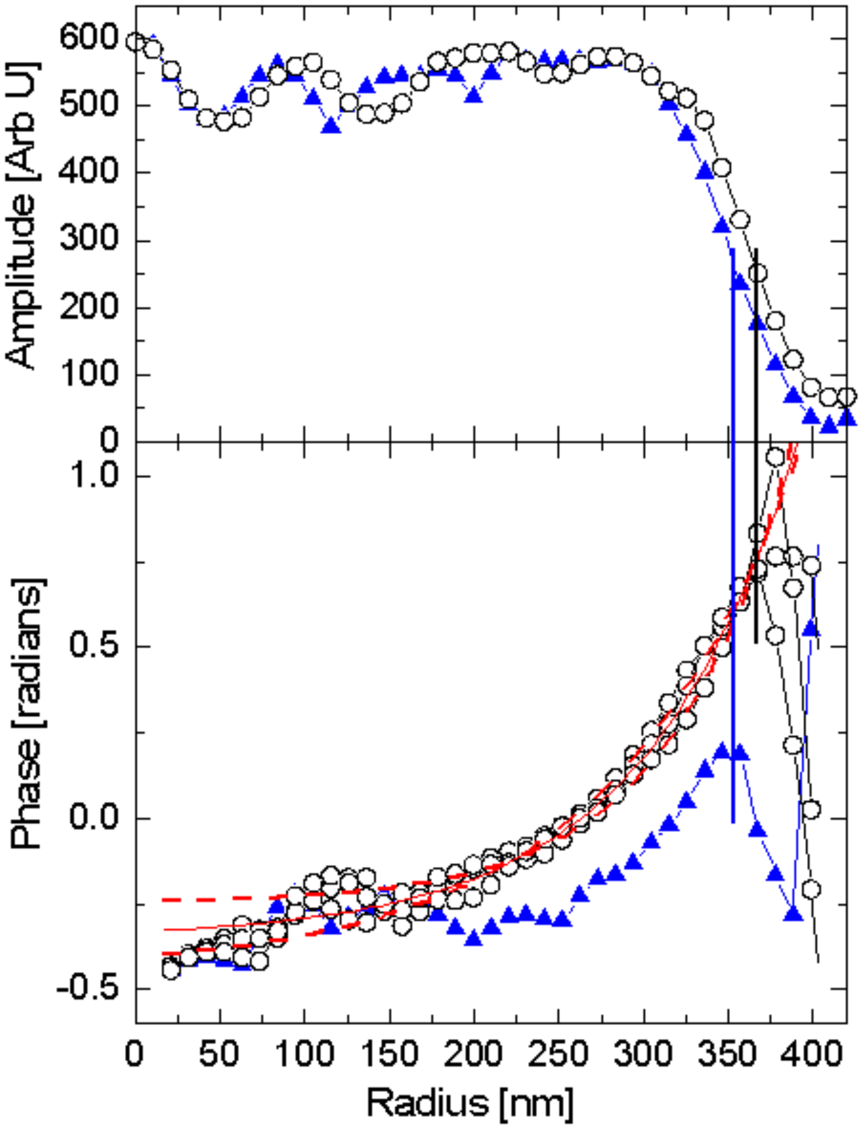
Ag(111) theory J. Xie (Scheffler group)
PRB 59 970 (1999)

Depth Variation of Distortion

Facets subtend 18.6 ±2.6°
ECS predicts 14°

Depth measured 90 ± 20nm
Theory says 75nm





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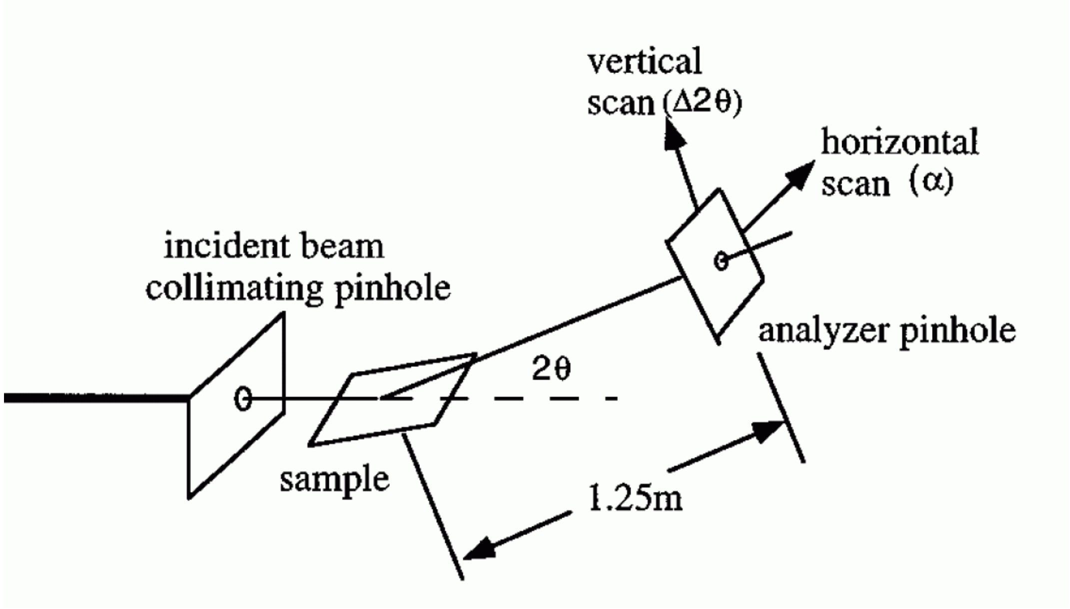
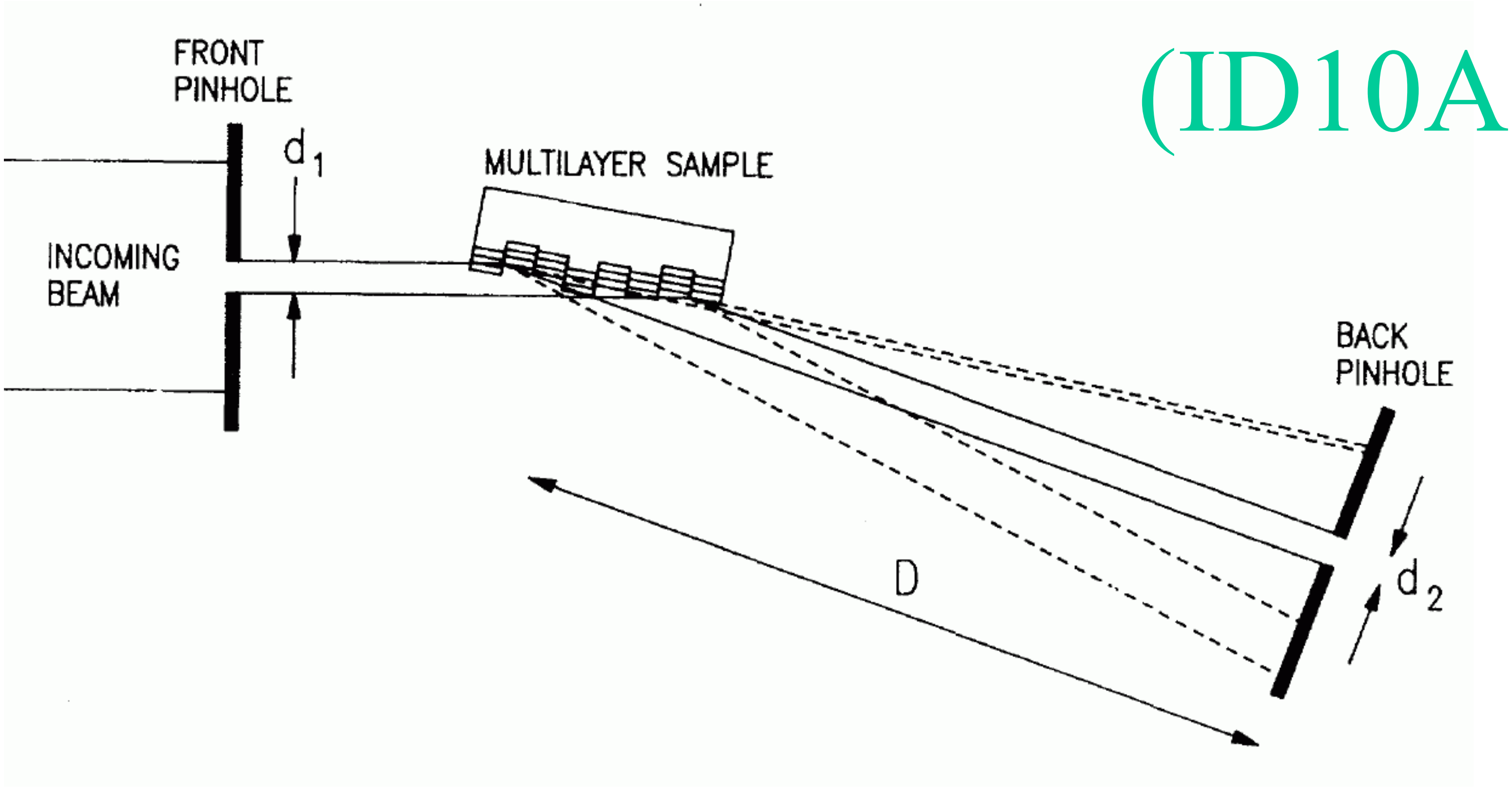
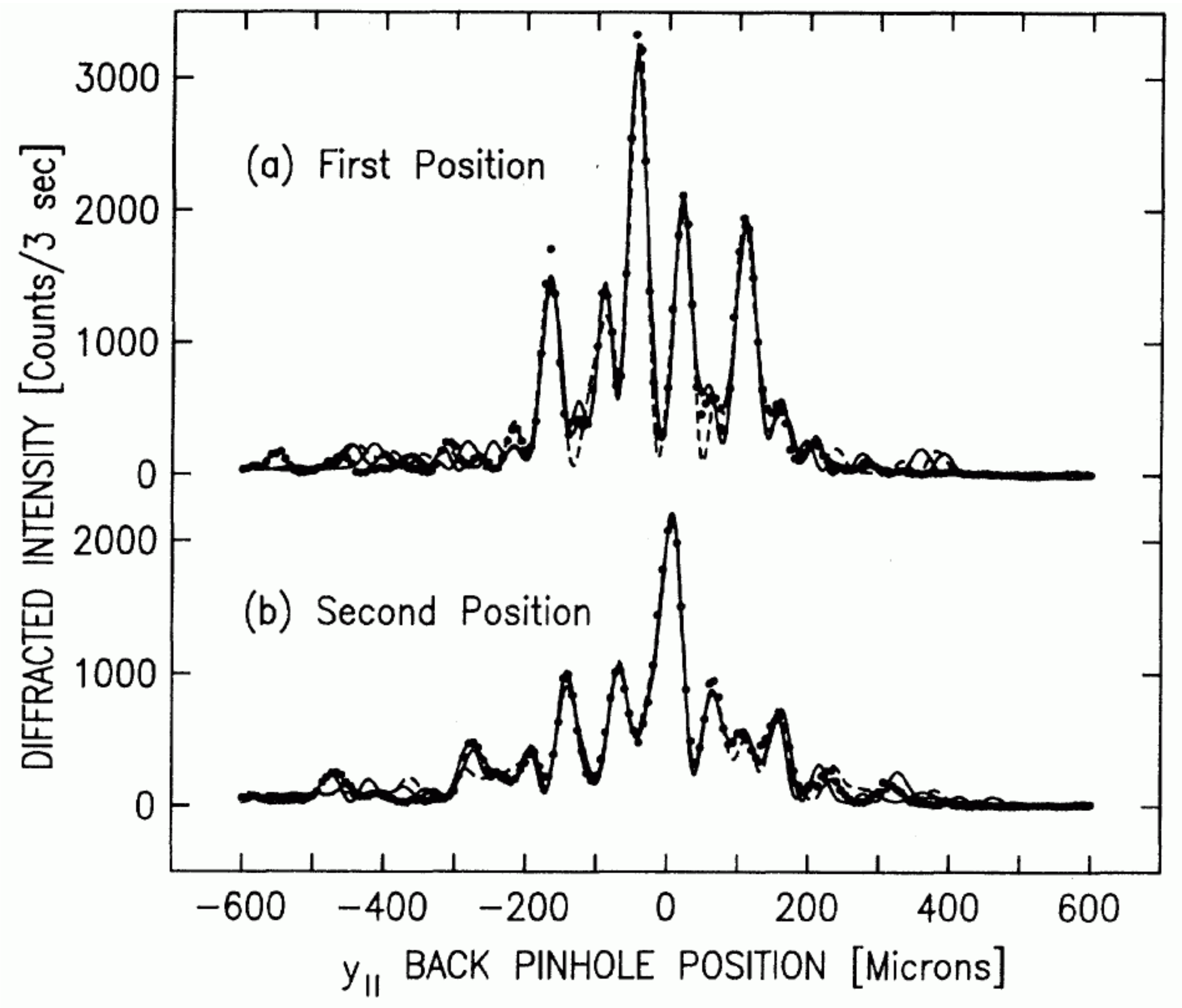
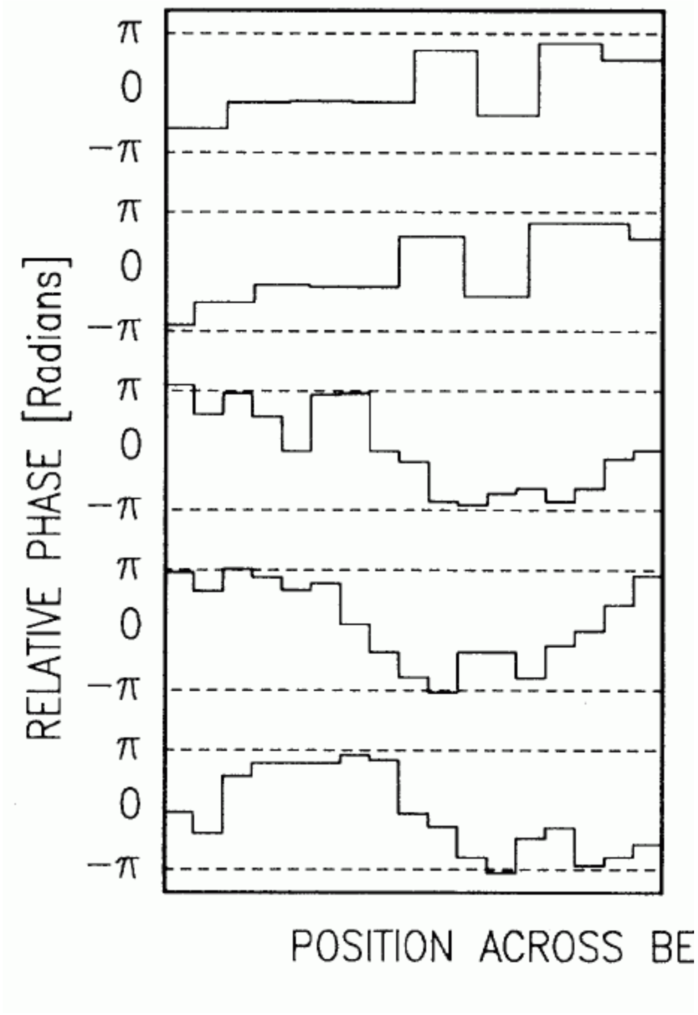
Pinhole Speckle Experiments at “Troika” (ID10A)





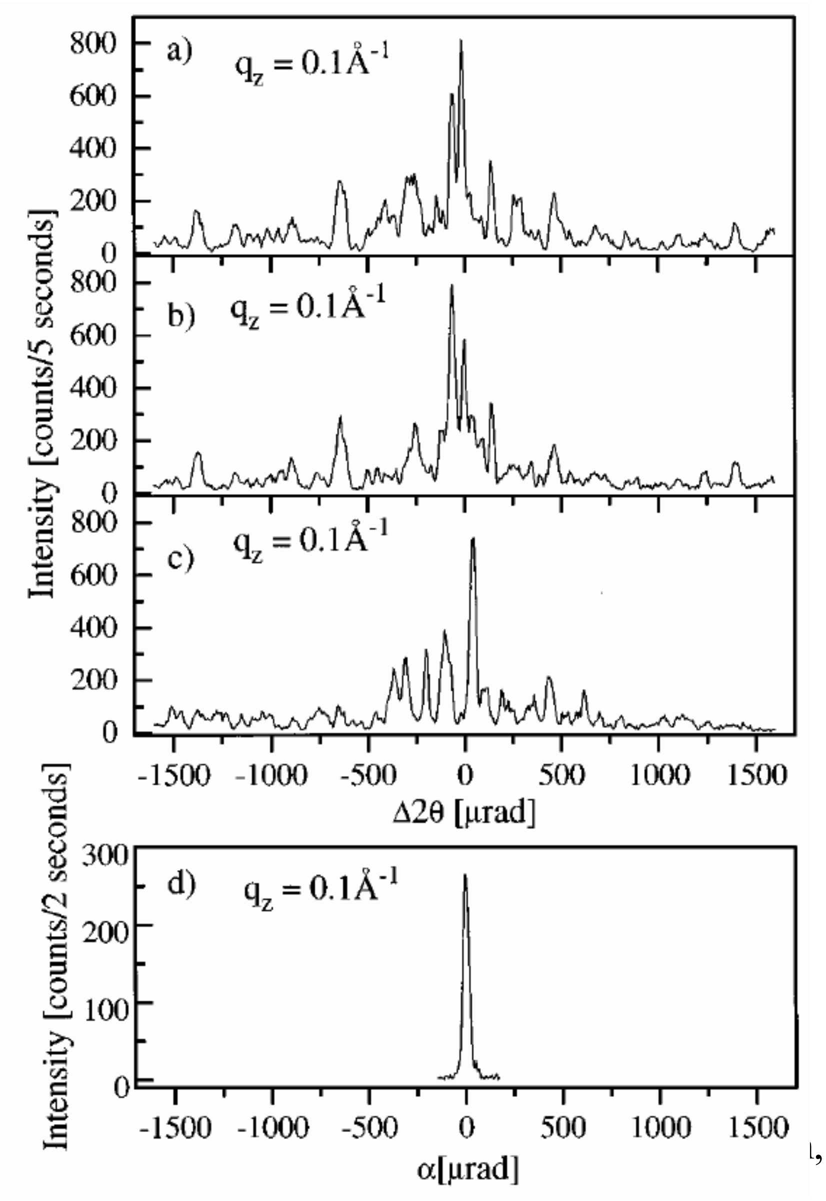
Fitting of speckle with block phase model

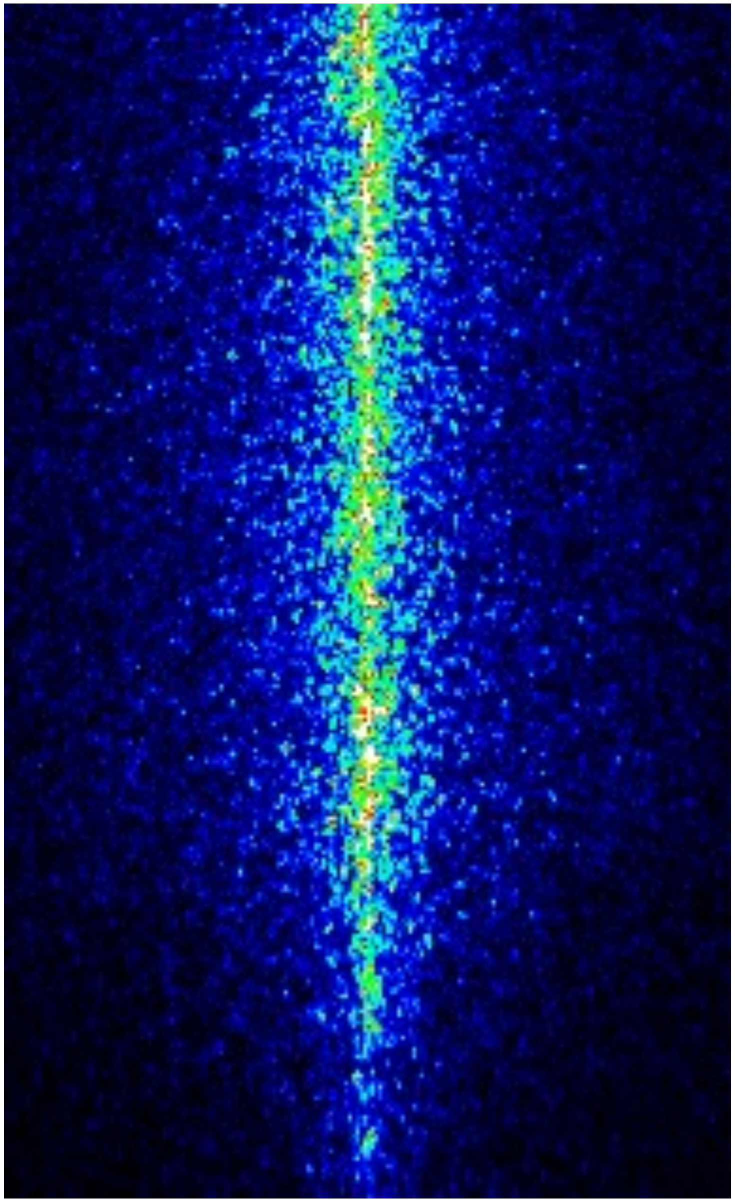




Speckle in Reflectivity from Si

J. L. Libbert et al Phys. Rev. B 56 6454 (1997)

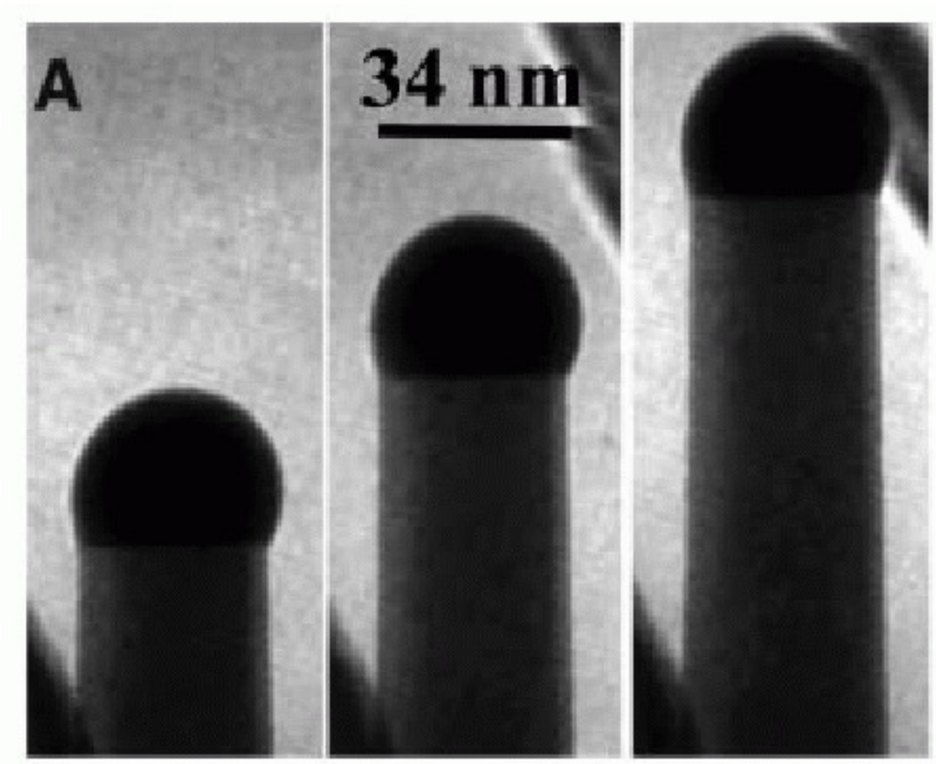


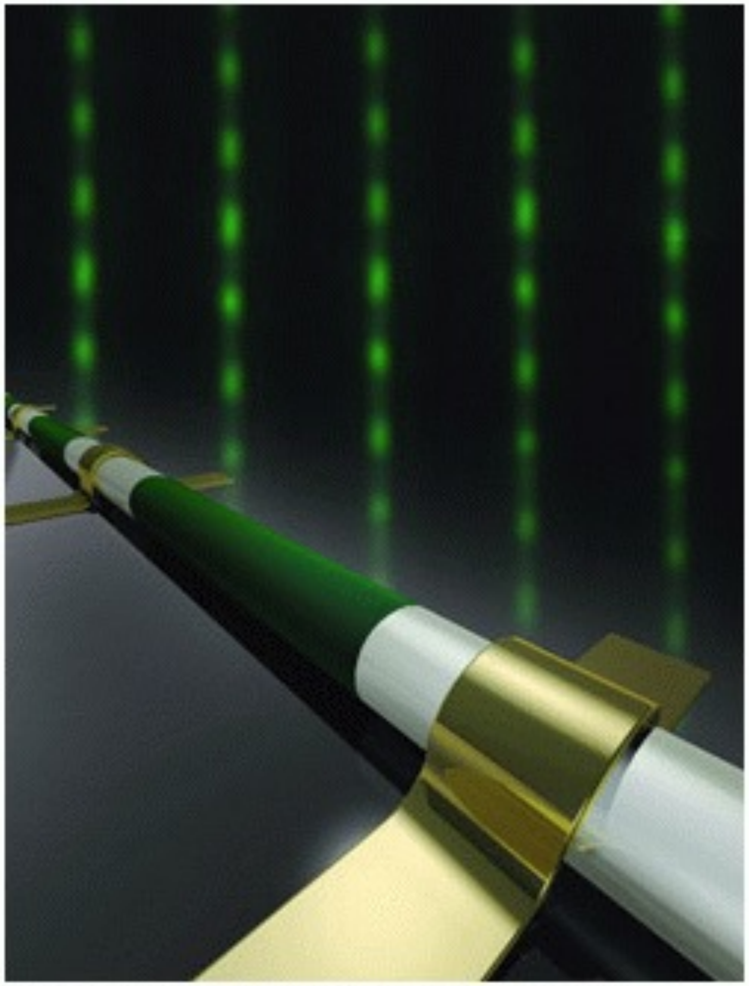


fe1103-24.spe 1x1 20 micron 20s x 31acc

VLS growth of nanowires

S. Kodambaka et al., Science 316 729 (2007)

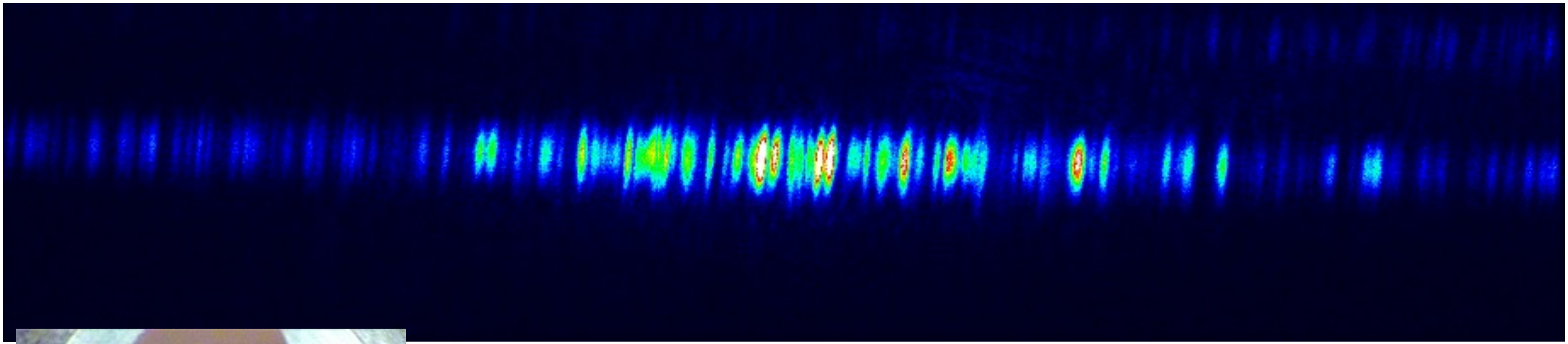


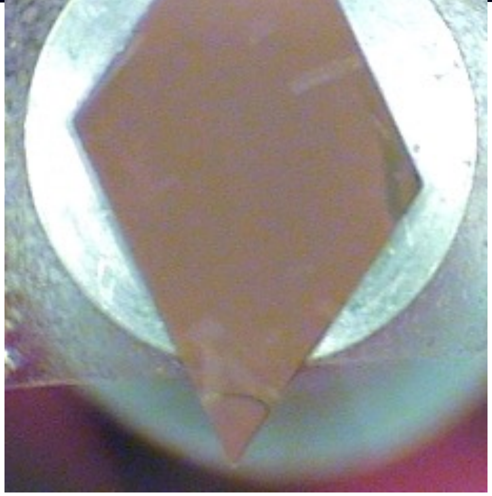


NiSi/Si nanowire heterostructure devices. *Nature* **430**, 61 (2004).

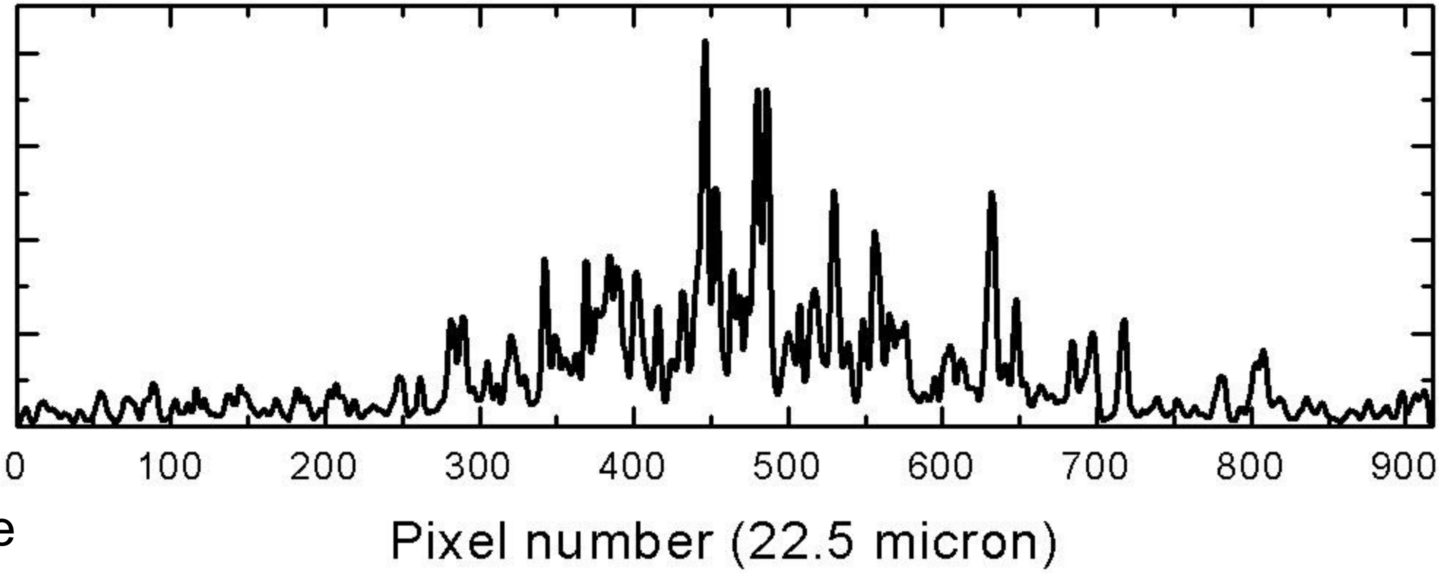
GaAs Nanowire "Barcode"

Vincent Favre-Nicolin, Joel Eymery (CEA), Rienk Algra (Philips), Ross Harder



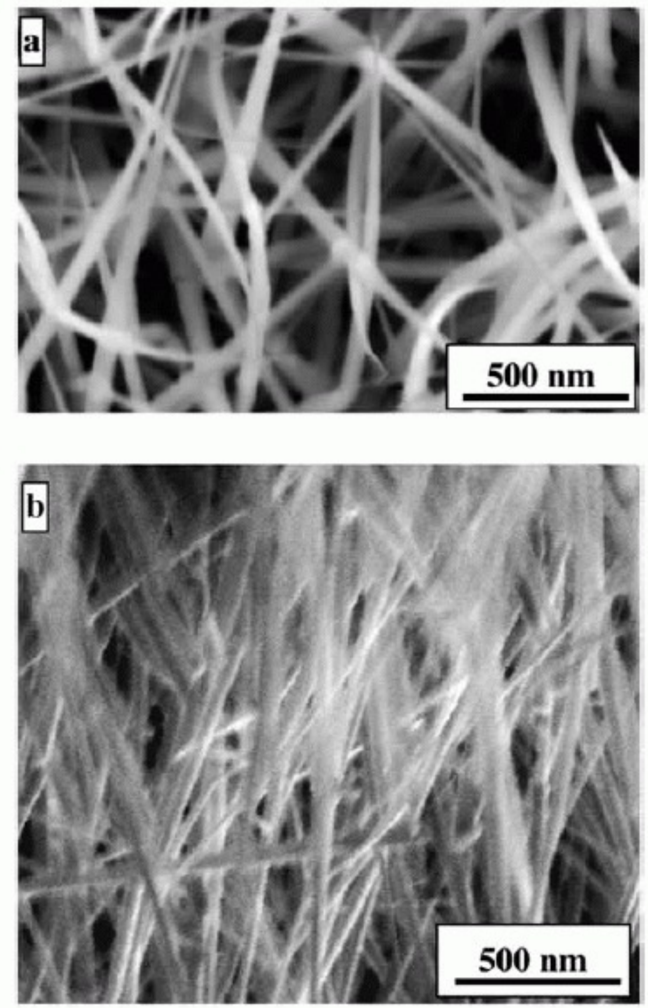


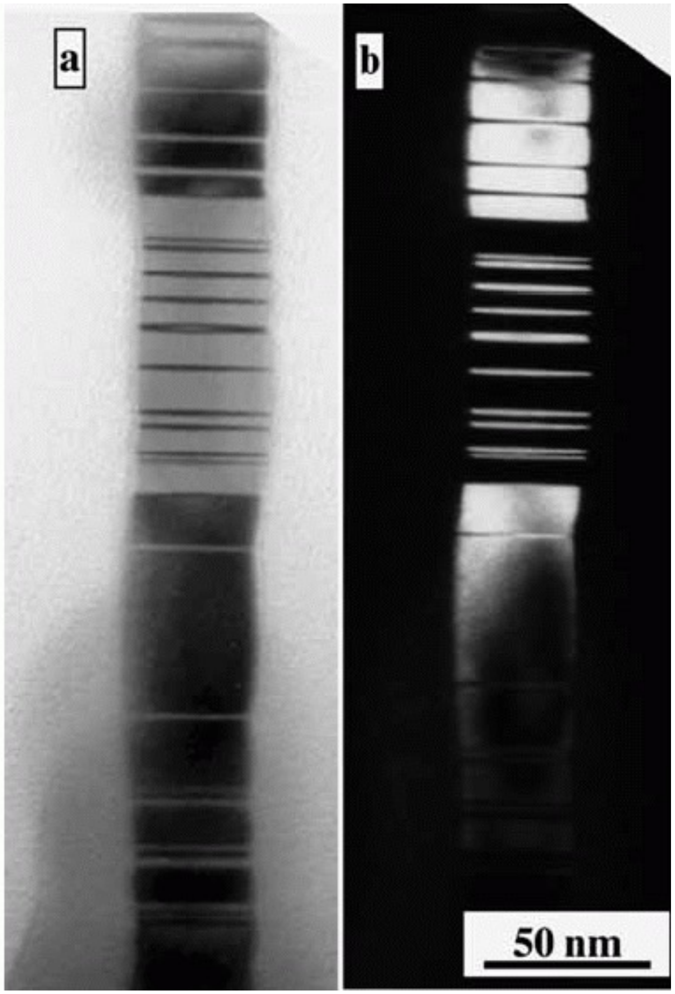
GaAsNW1106-22.spe
B9348 from Philips



Dark Field TEM of GaAs Nanowires

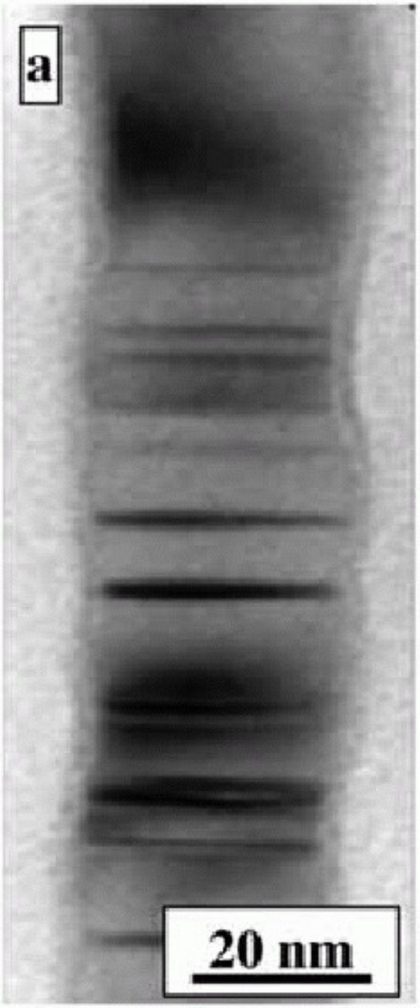
R. Banerjee et al, Phil. Mag. Lett. 86 807 (2006)

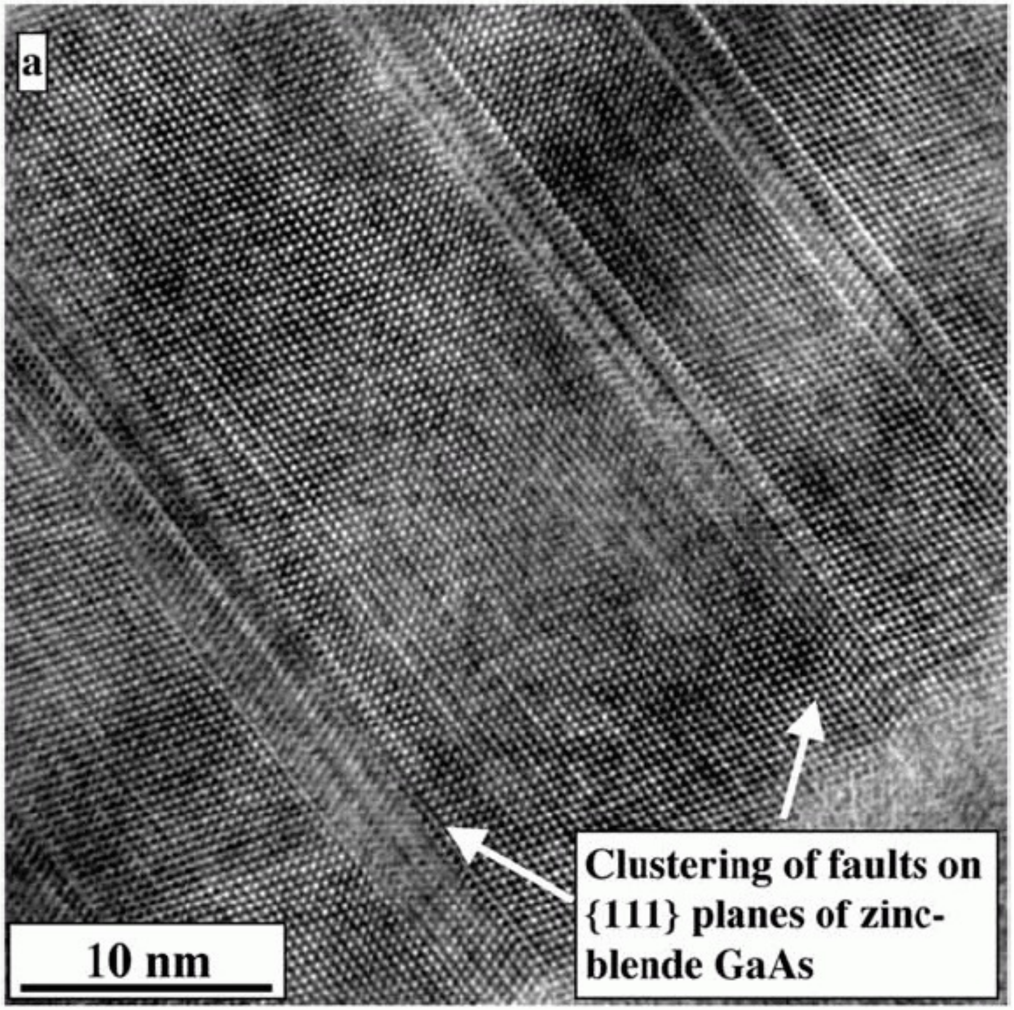




Dark Field TEM of GaAs Nanowires

R. Banerjee et al, Phil. Mag. Lett. 86 807 (2006)

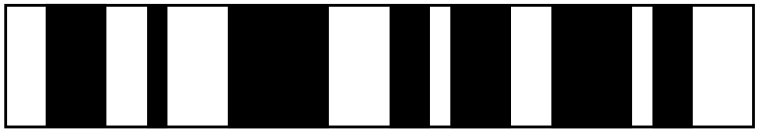




Clustering of faults on {111} planes of zinc-blende GaAs

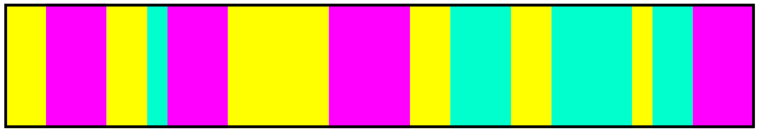
Models of Barcode Diffraction

(111) wires at (11-1) reflection

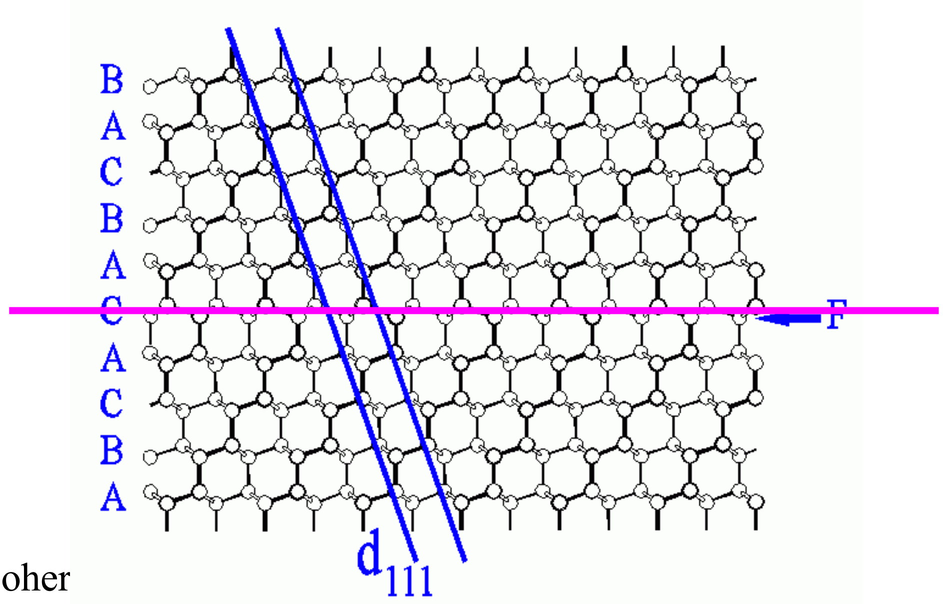


0 123456 789005

- Twinned stacking sequence

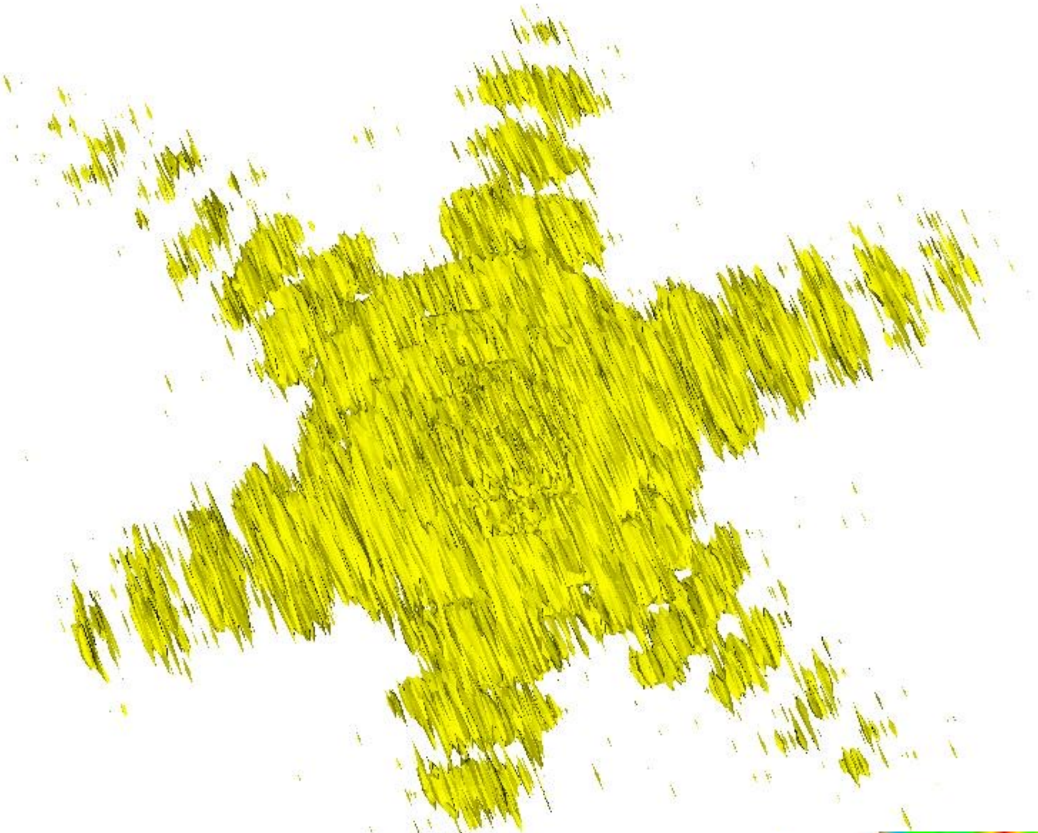


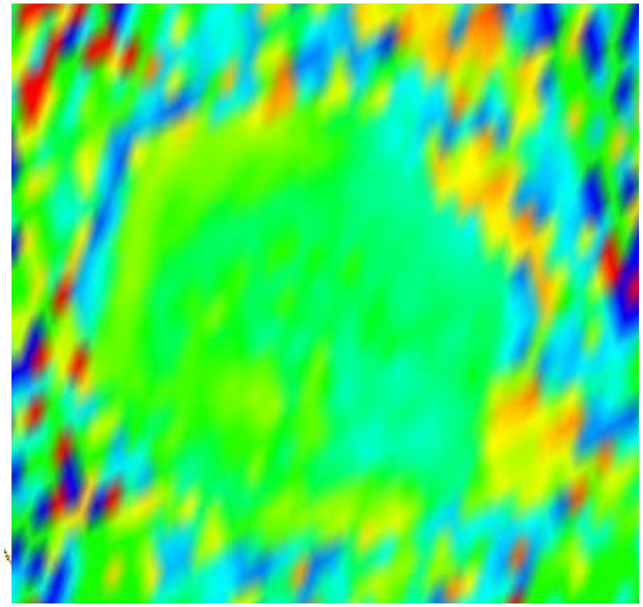
- Deformation faults

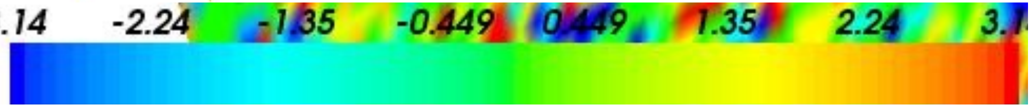


ZnO Nanowire Reconstruction

Ross Harder, Steven Leake, PhD project at UCL



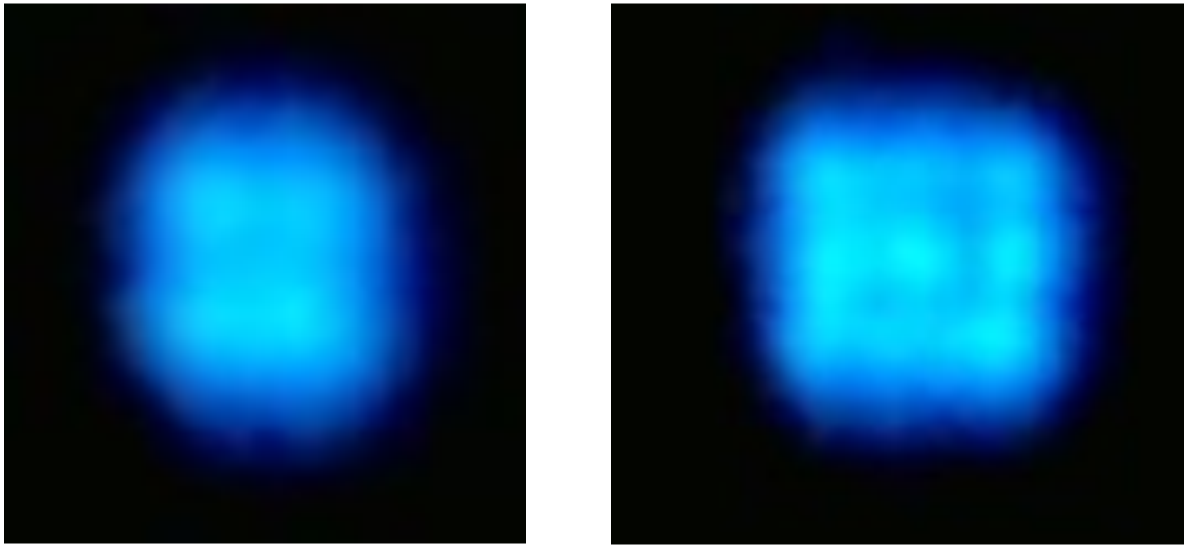




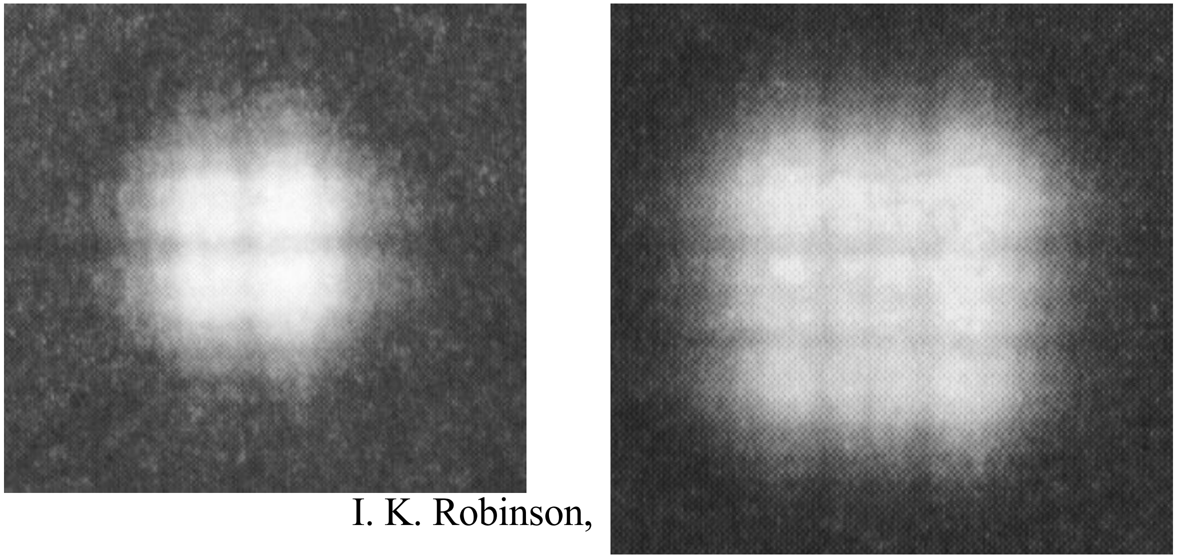
Phase Images using CXD

- Strain, displacements along **Q**-vector
- Chemical contrast (especially at resonance)
- Lattice shifts due to stacking faults
- Height of a reflecting surface
- Antiphase domain structures
- Refraction along path through object
- Illuminating wavefront, resulting from slits, focussing optics

Fresnel Diffraction when $d^2 \sim \lambda D$

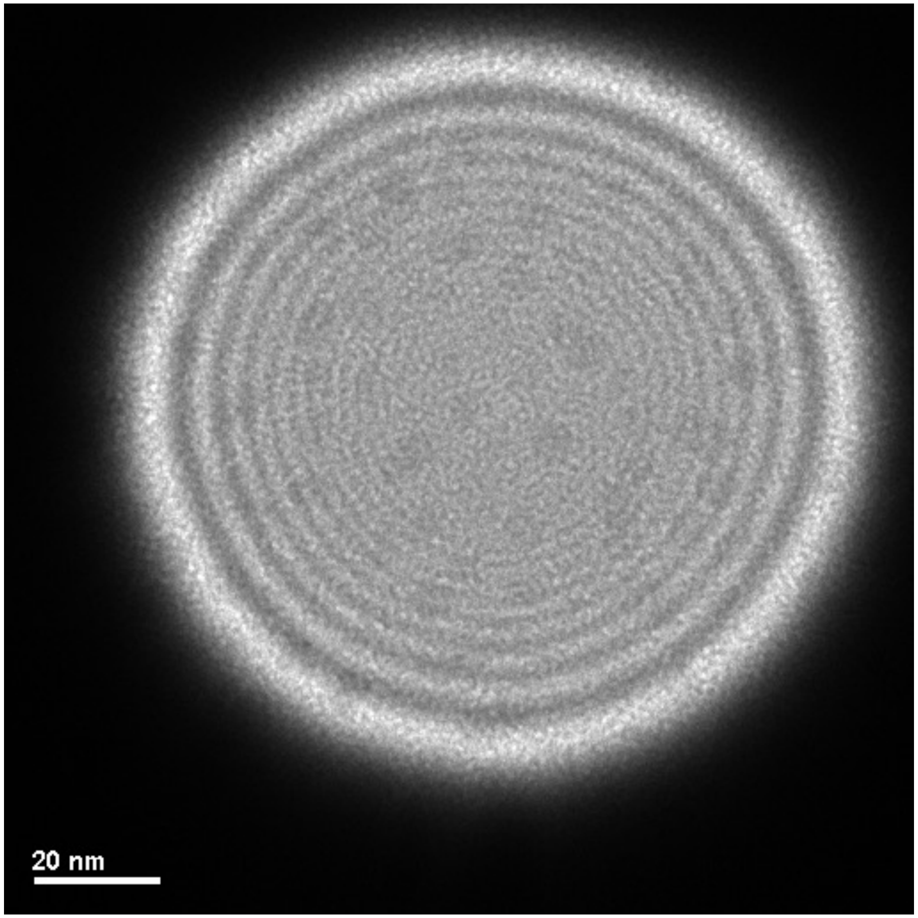


X-ray beam defined by RB slits 5um



Visible Fresnel diffraction from Hecht “Optics”

100nm Electron Microscope probe



FeAl antiphase domains (001)

Lorenz Stadler, PhD dissertation, TU Wien (2005)

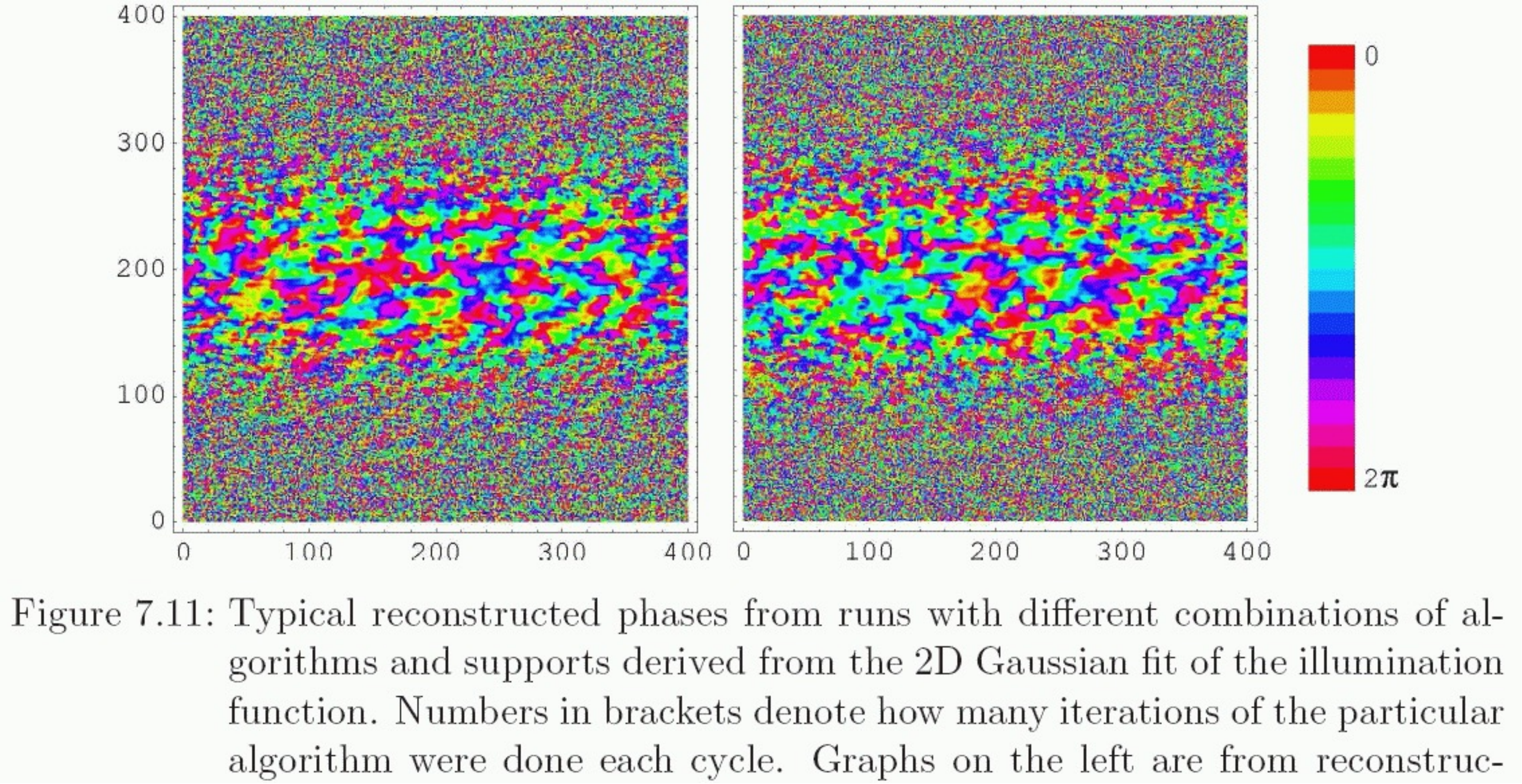
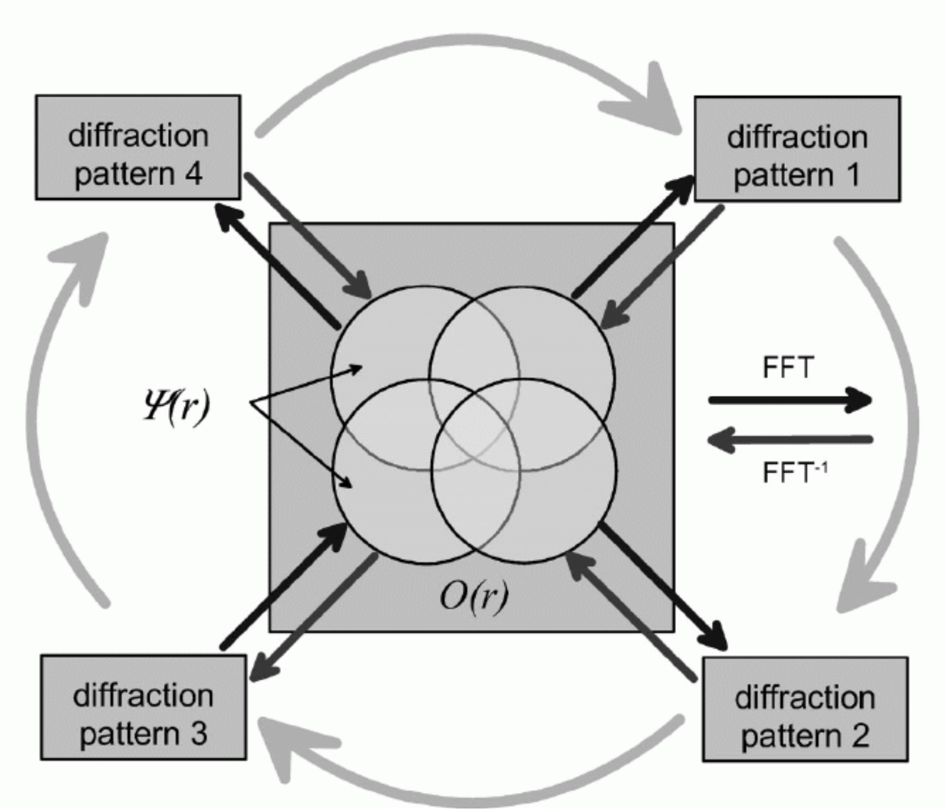
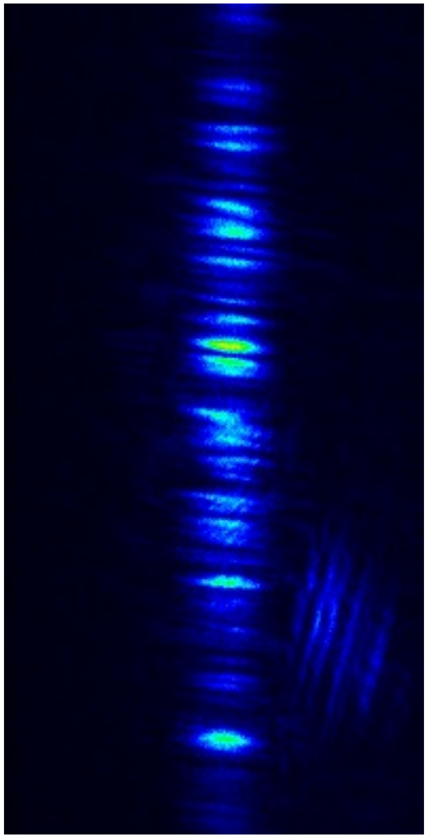


Figure 7.11: Typical reconstructed phases from runs with different combinations of algorithms and supports derived from the 2D Gaussian fit of the illumination function. Numbers in brackets denote how many iterations of the particular algorithm were done each cycle. Graphs on the left are from reconstruc-

Future of CXD: Ptychography

Rodenburg & Pfeiffer, PRL (2007)





Conclusions

- Strain fields imaged from asymmetric patterns
- Surface strain has orientation dependence
- Coherent diffraction from rough surfaces
- Nanowire "barcode" from stacking faults
- Wire cross sections show strain
- Refraction effects can be important