Patterns of Strain in Nanocrystals

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Diamond Light Source

JAEA Symposium on X-Ray and High Magnetic Field
6 March 2009

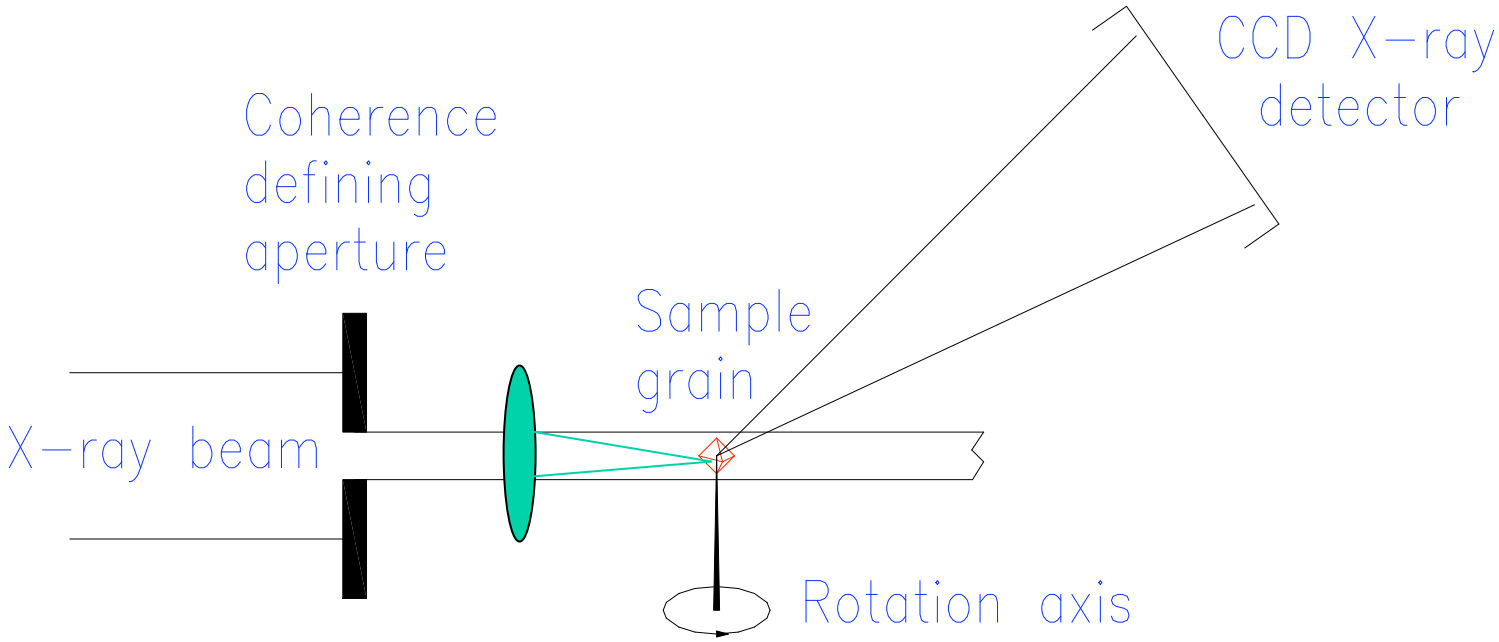
Outline

- Coherent X-ray Diffraction
- Imaging of small crystals and strain fields
- Domain speckle patterns
- X-ray Ptychography
- Pulsed field experiments

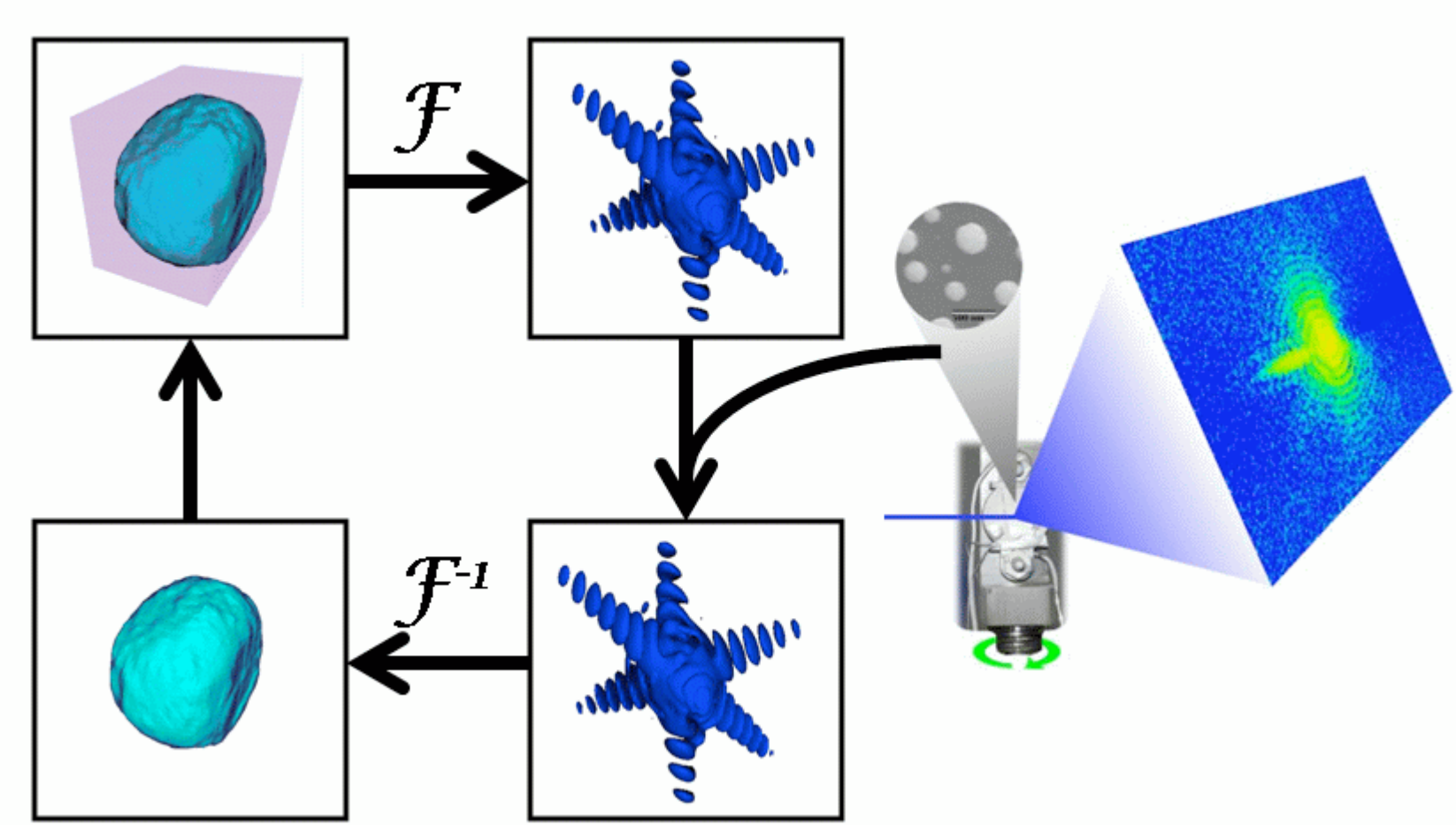
Coherent X-ray Diffraction Imaging

APS ξ_{HOR}= 20μm, focus to 1μm

XFEL ξ_{HOR}> 500μm, focus to 0.1μm

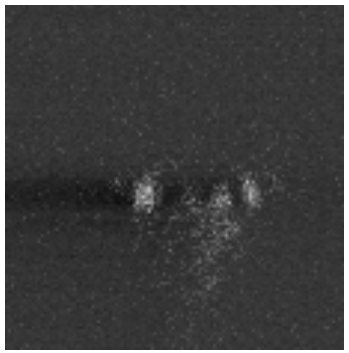


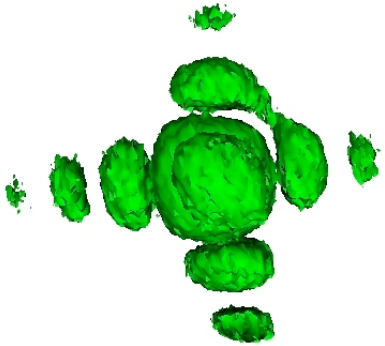
Generic "Error Reduction" method

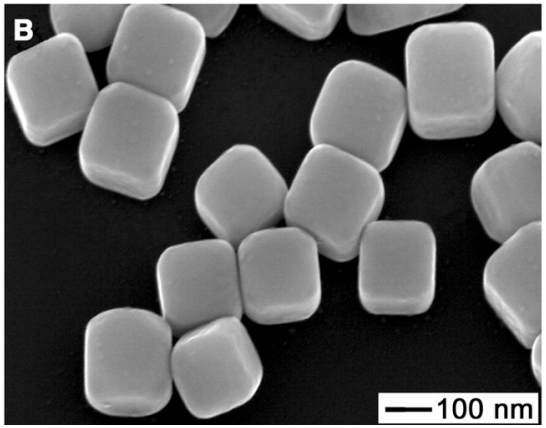


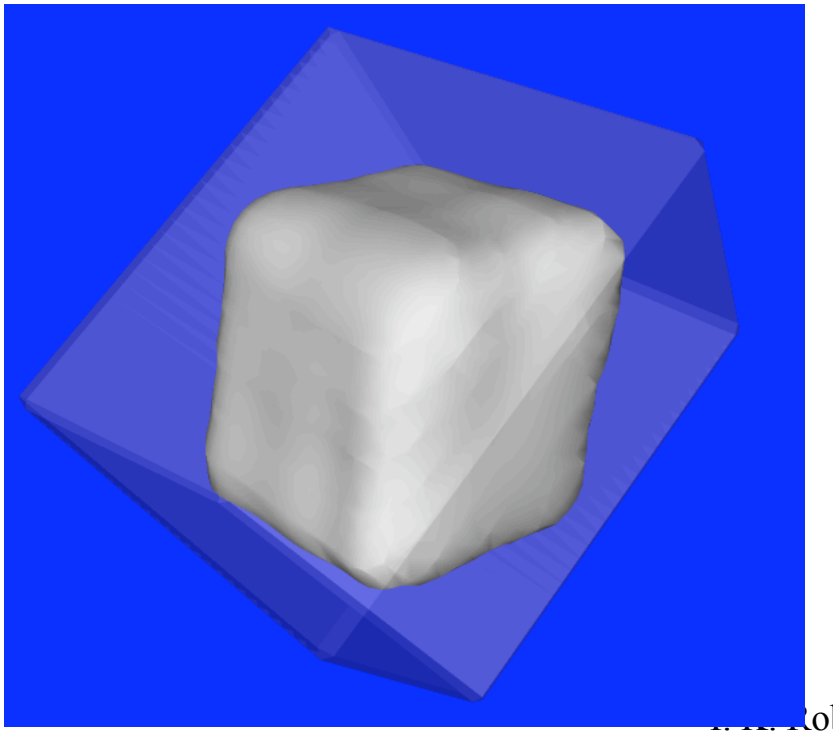
J. R. Fienup Appl. Opt. 21 2758 (1982)
R. W. Gerchberg and W. O. Saxton Optik 35 237 (1972)

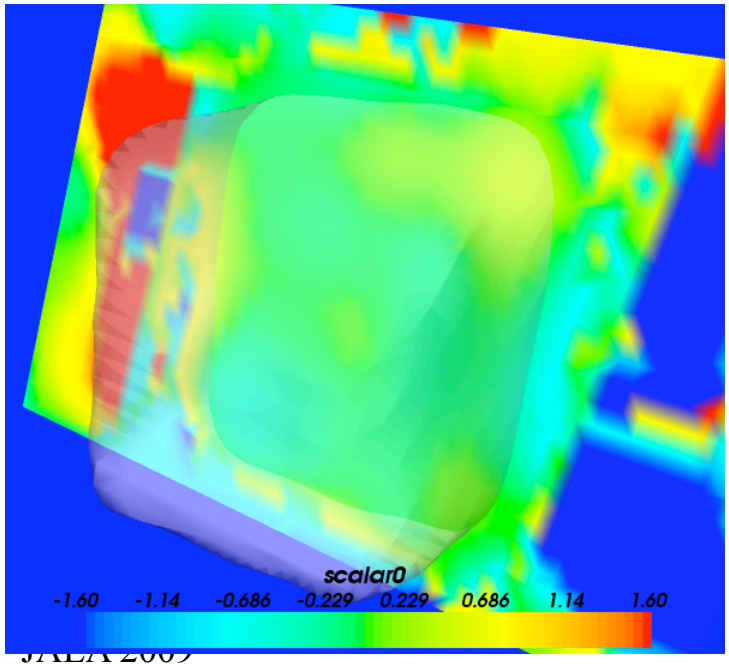
3D Ag Nano Cube



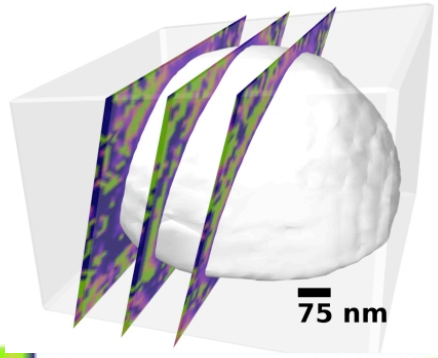


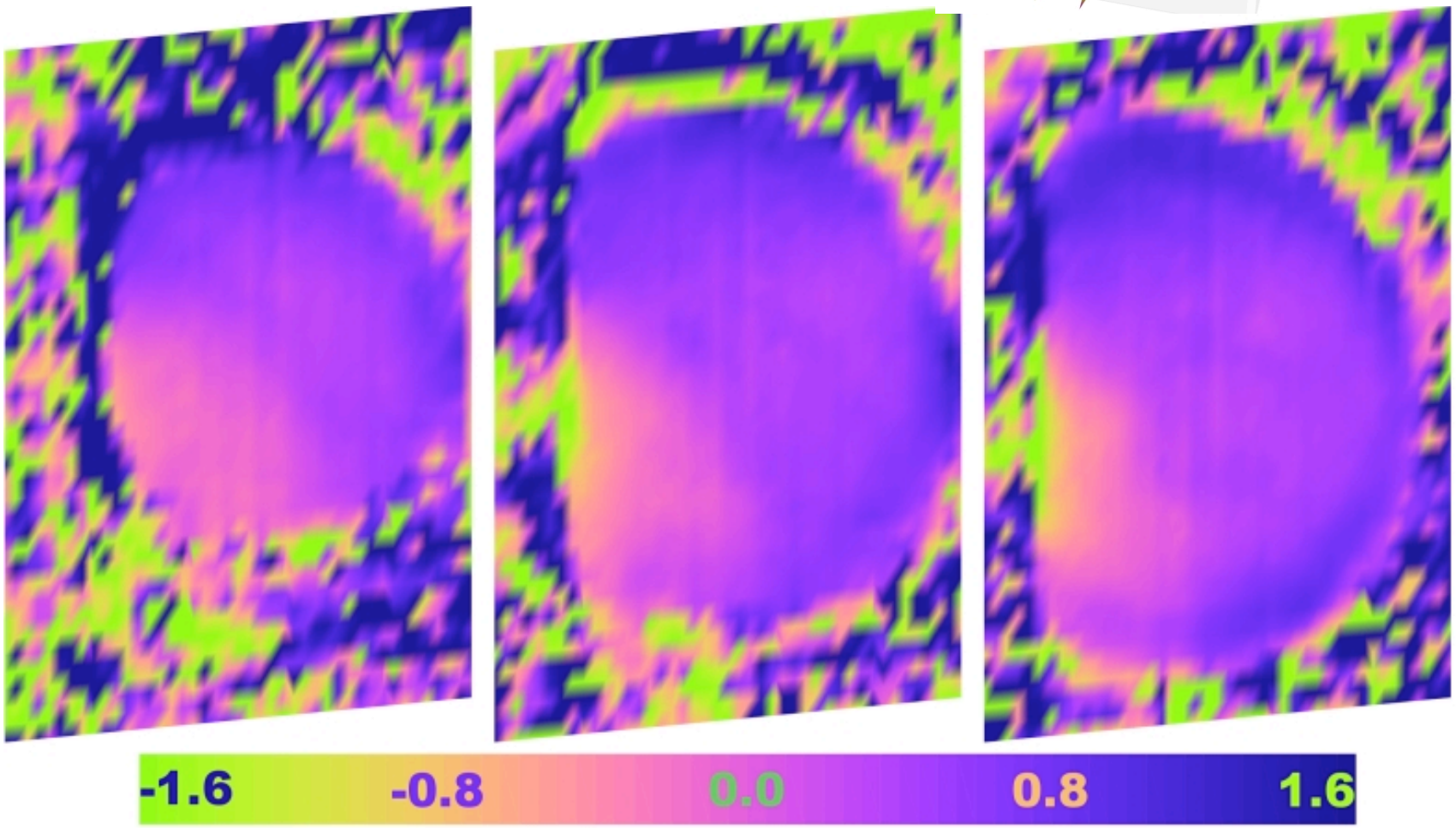






3D phase map sections





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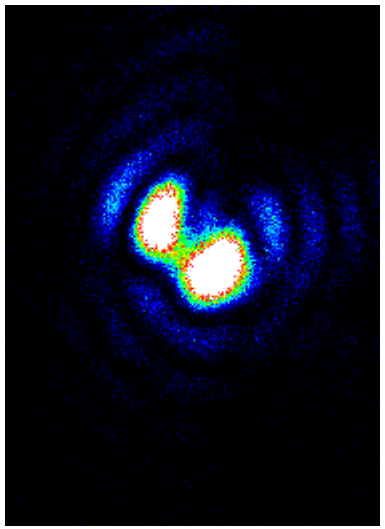
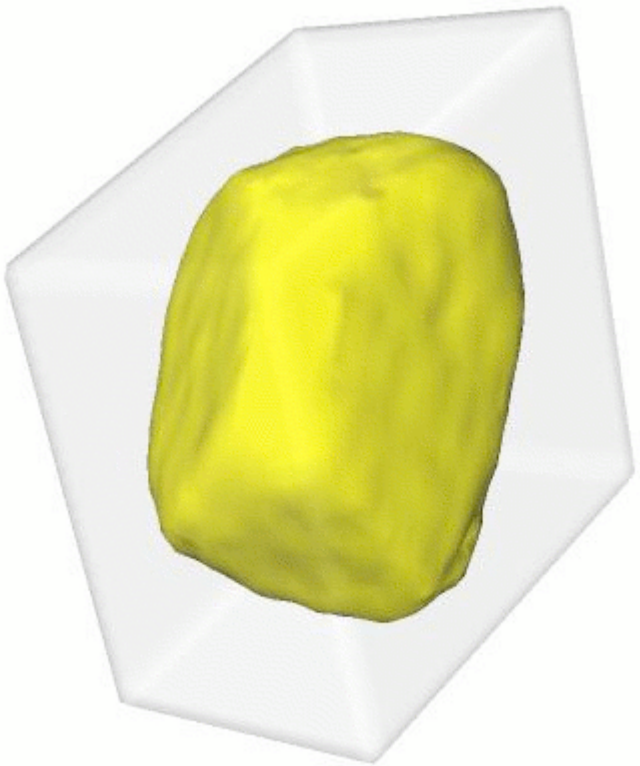
Gold nanocrystal reconstruction

showing support used for 20 HIO followed by 10 ER





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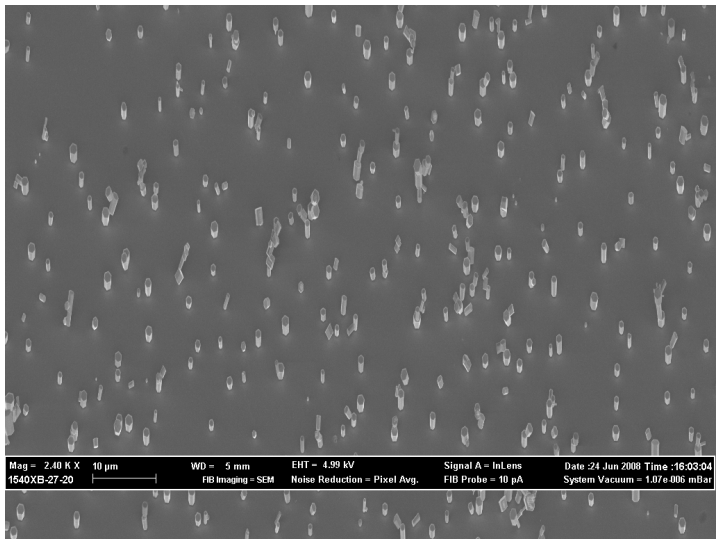
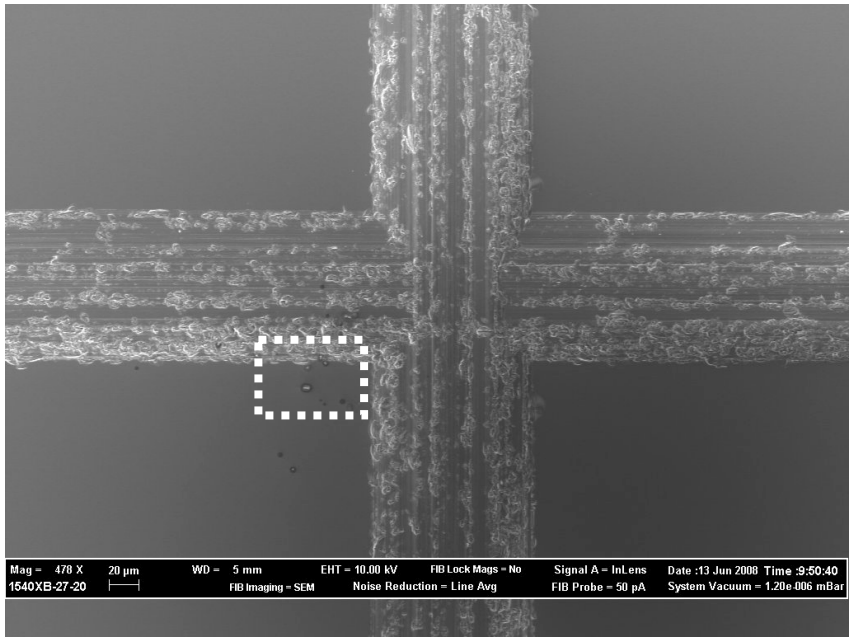
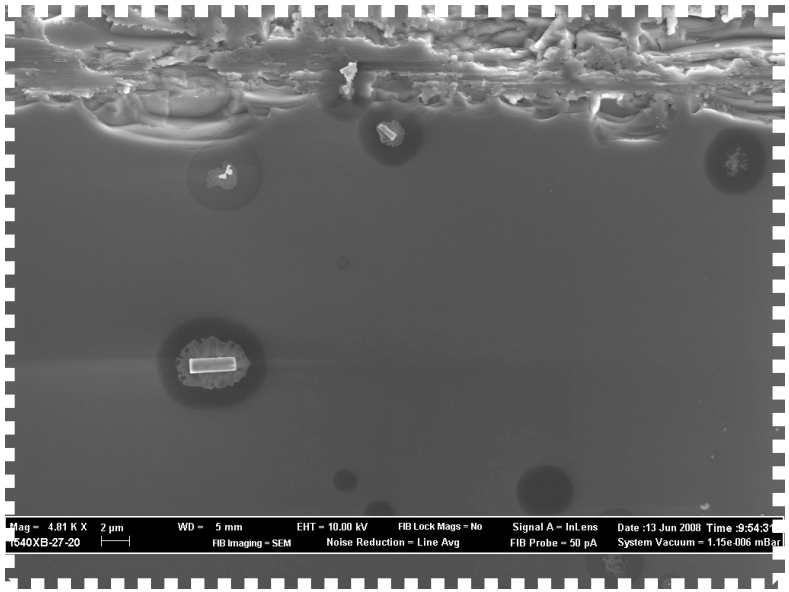
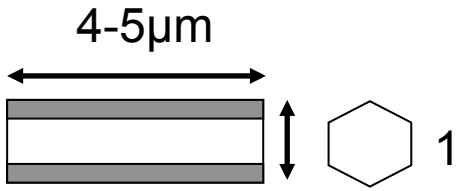
ZnO Sample Preparation







Dimensions:



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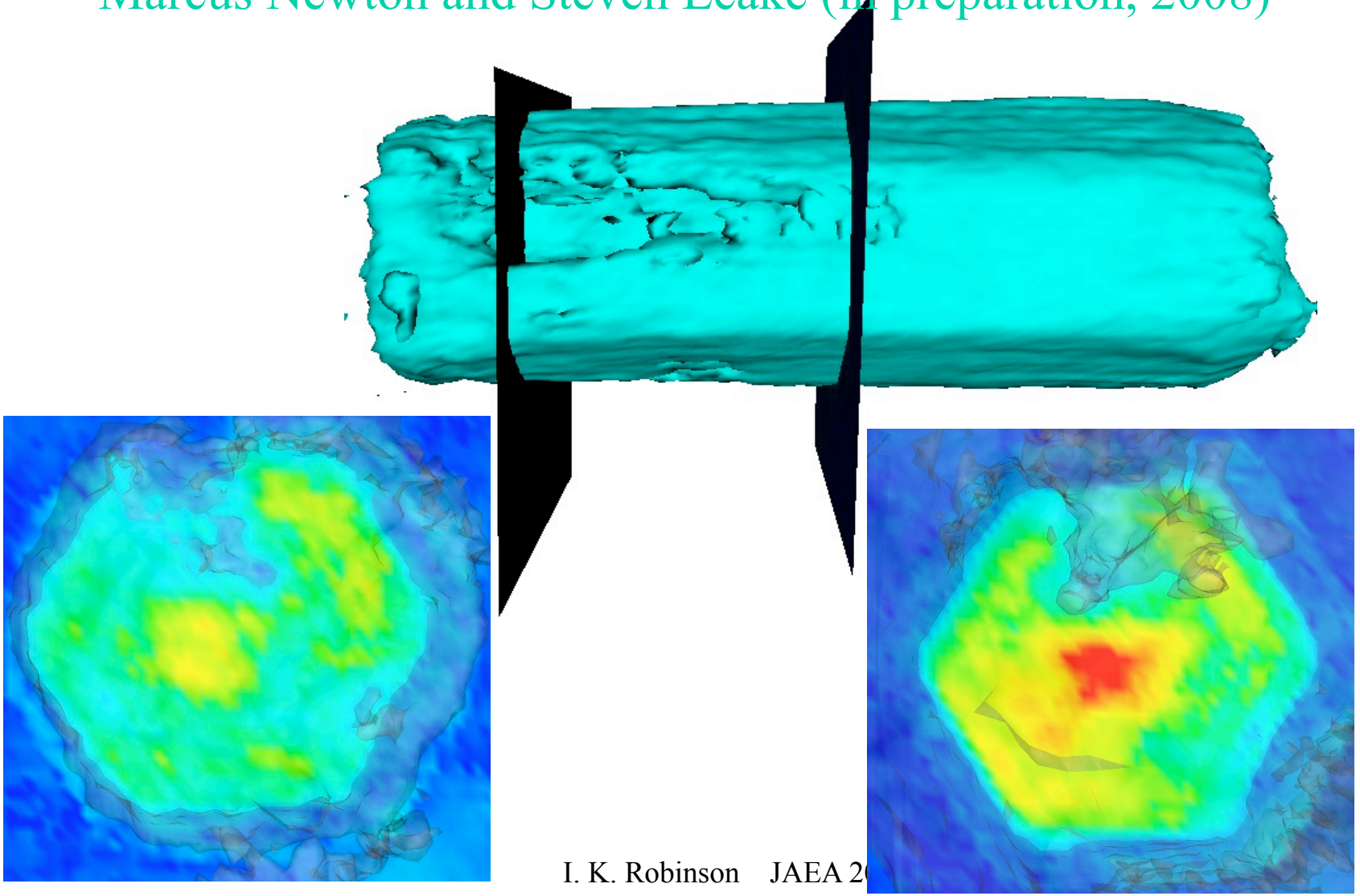
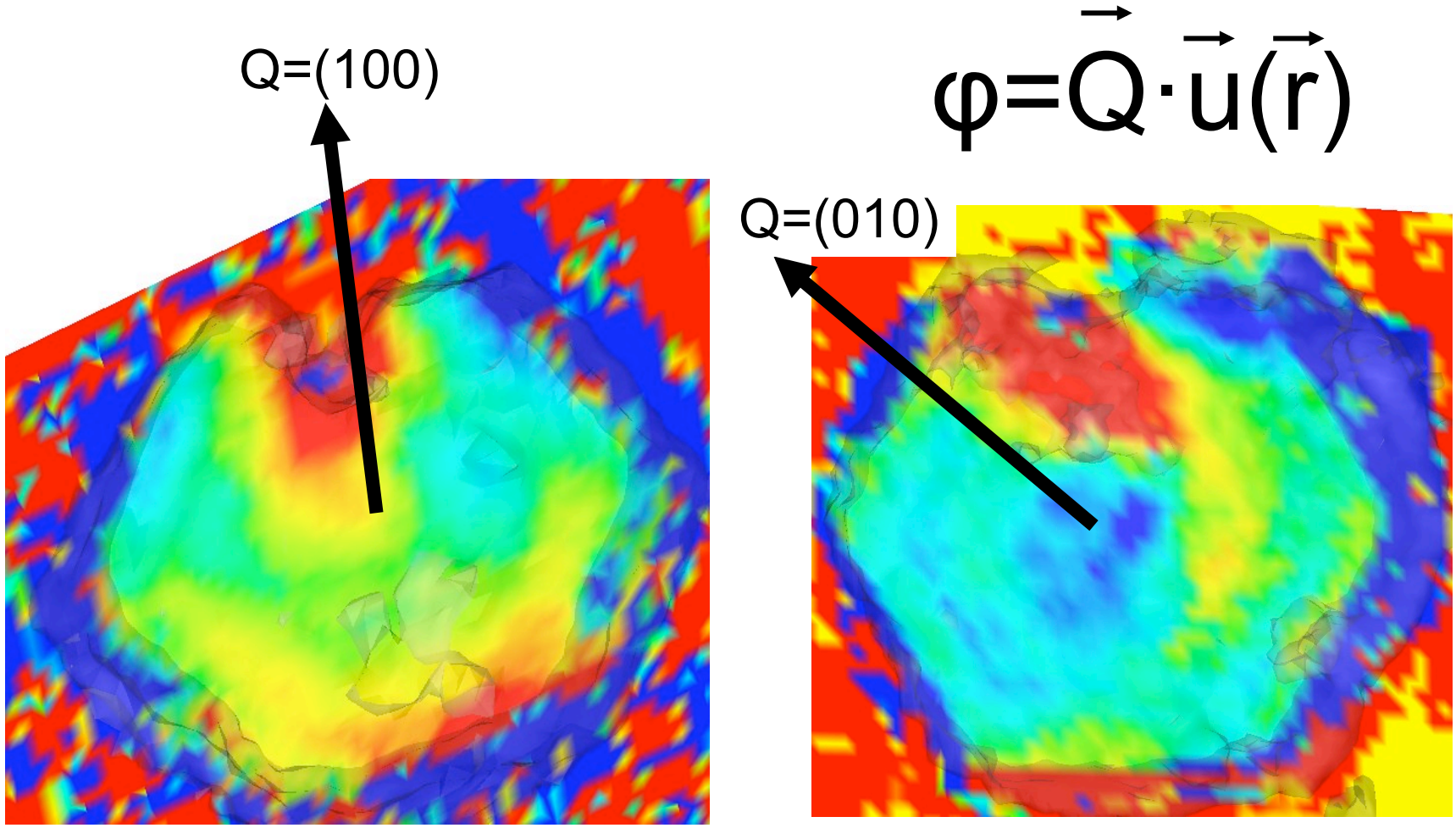
Density sections ZnO-39 (010)

Marcus Newton and Steven Leake (in preparation, 2008)



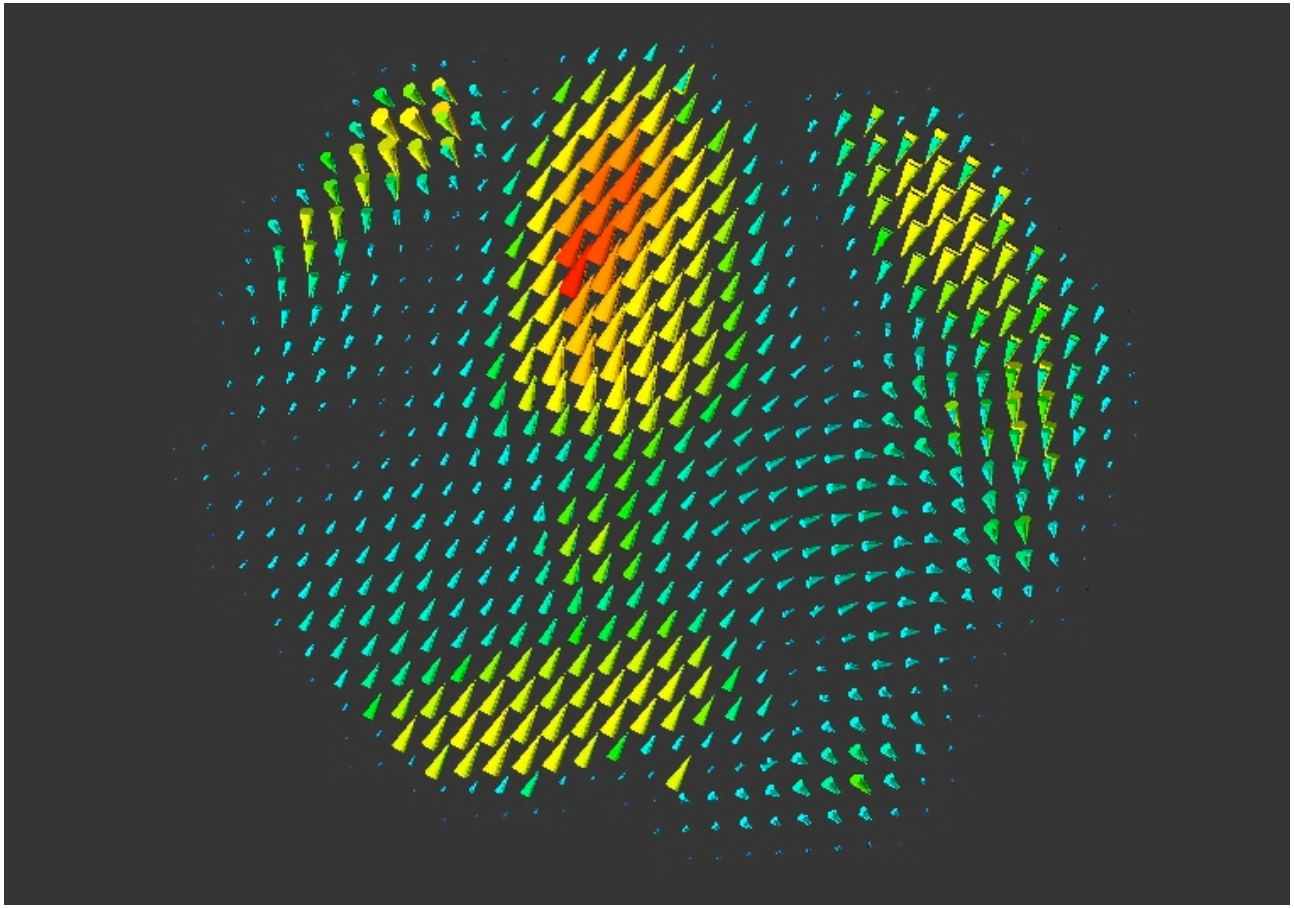
Phase maps from 2 Bragg peaks

Blue-Red is +2 radians. Slice at -1500nm from centre ZnO-5 -39



2D vector field of displacements

Marcus Newton, UCL, Jan 2009



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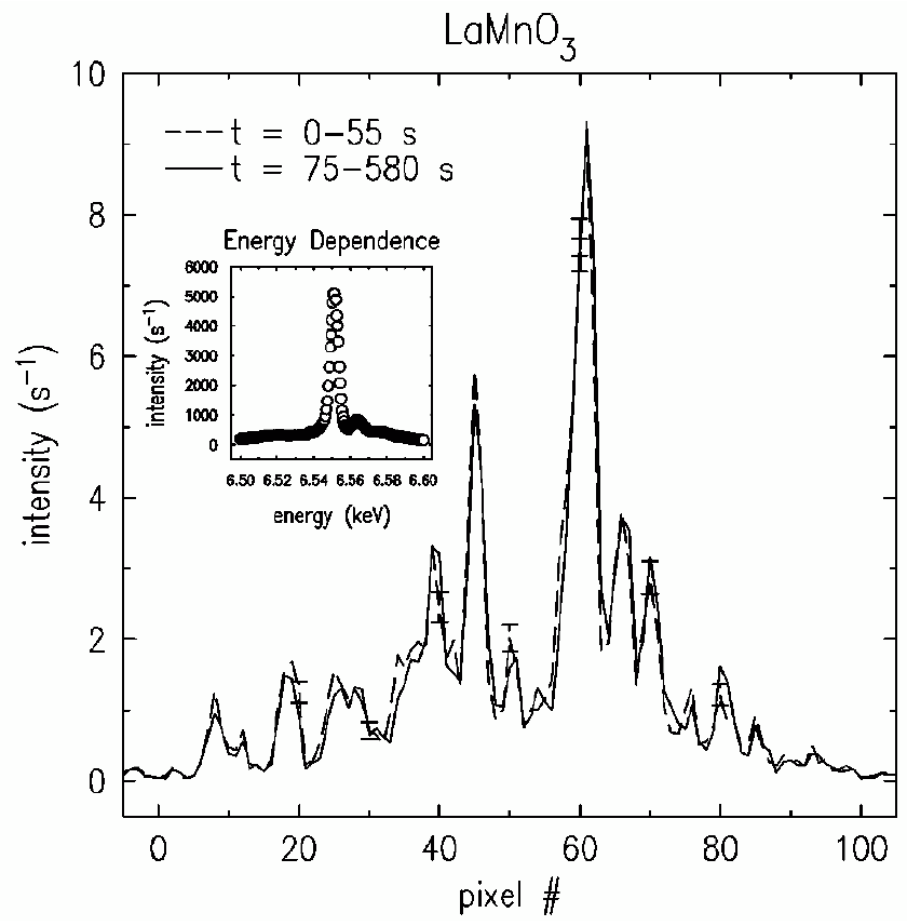
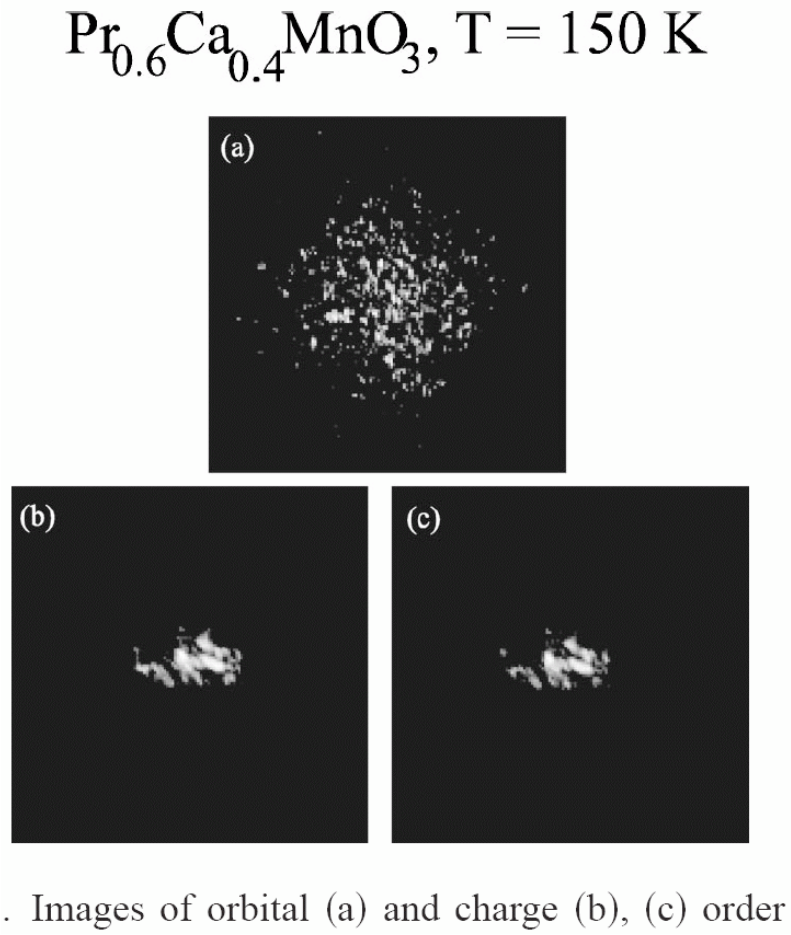
$LaMnO_3$ and $Pr_{0.6}Ca_{0.4}MnO_3$ speckle

C. S. Nelson, J. P. Hill, Doon Gibbs, F. Yakhou, F. Livet, Y. Tomioka, T. Kimura and Y. Tokura, PRB 66, 134412 (2002)

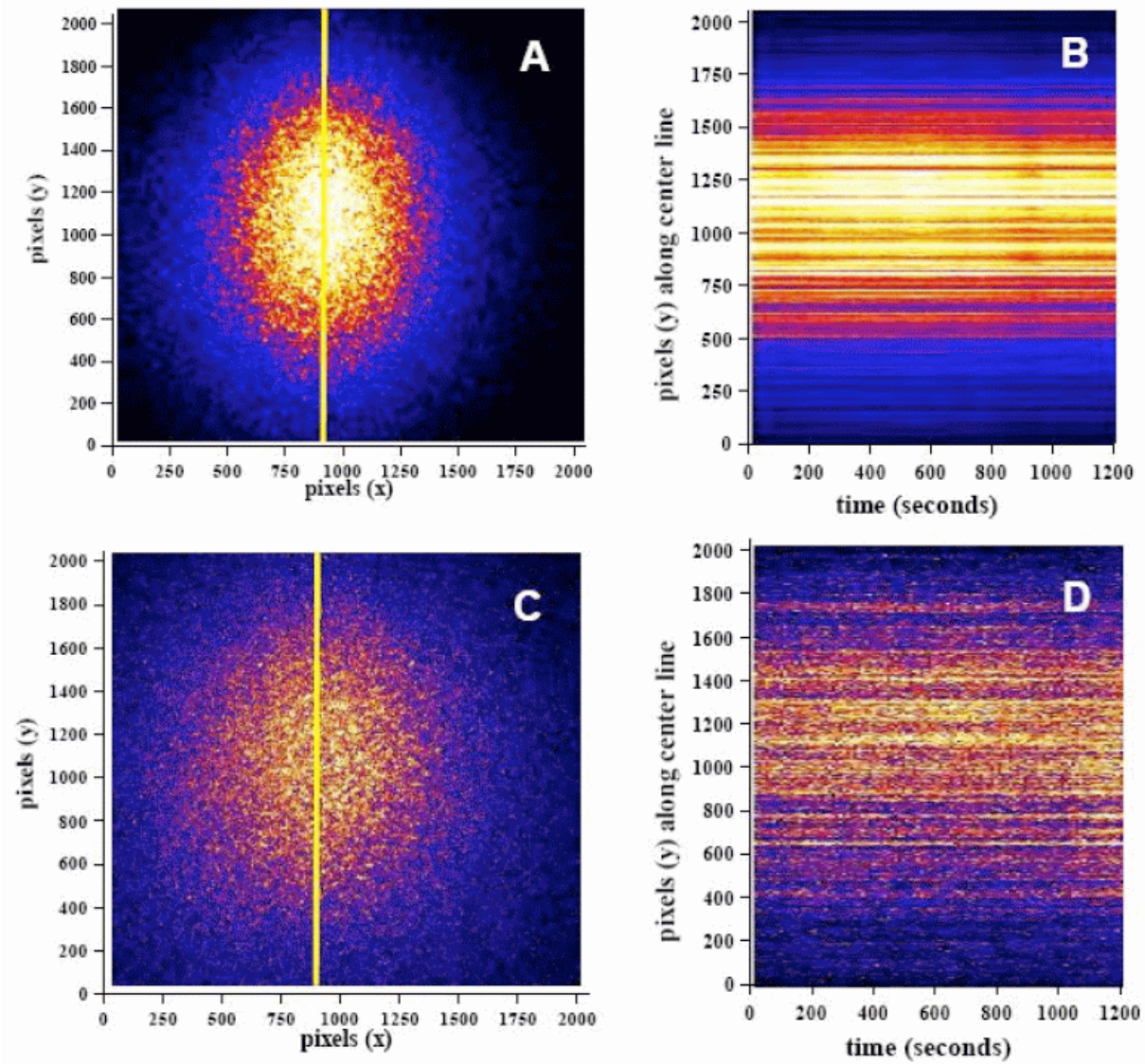




. Images of orbital (a) and charge (b), (c) order

$Pr_{0.5}Ca_{0.5}MnO_3$ at MnL_{III} edge (650 eV)

J. J. Turner et al, New Journal of Physics 10 053023 (2008)

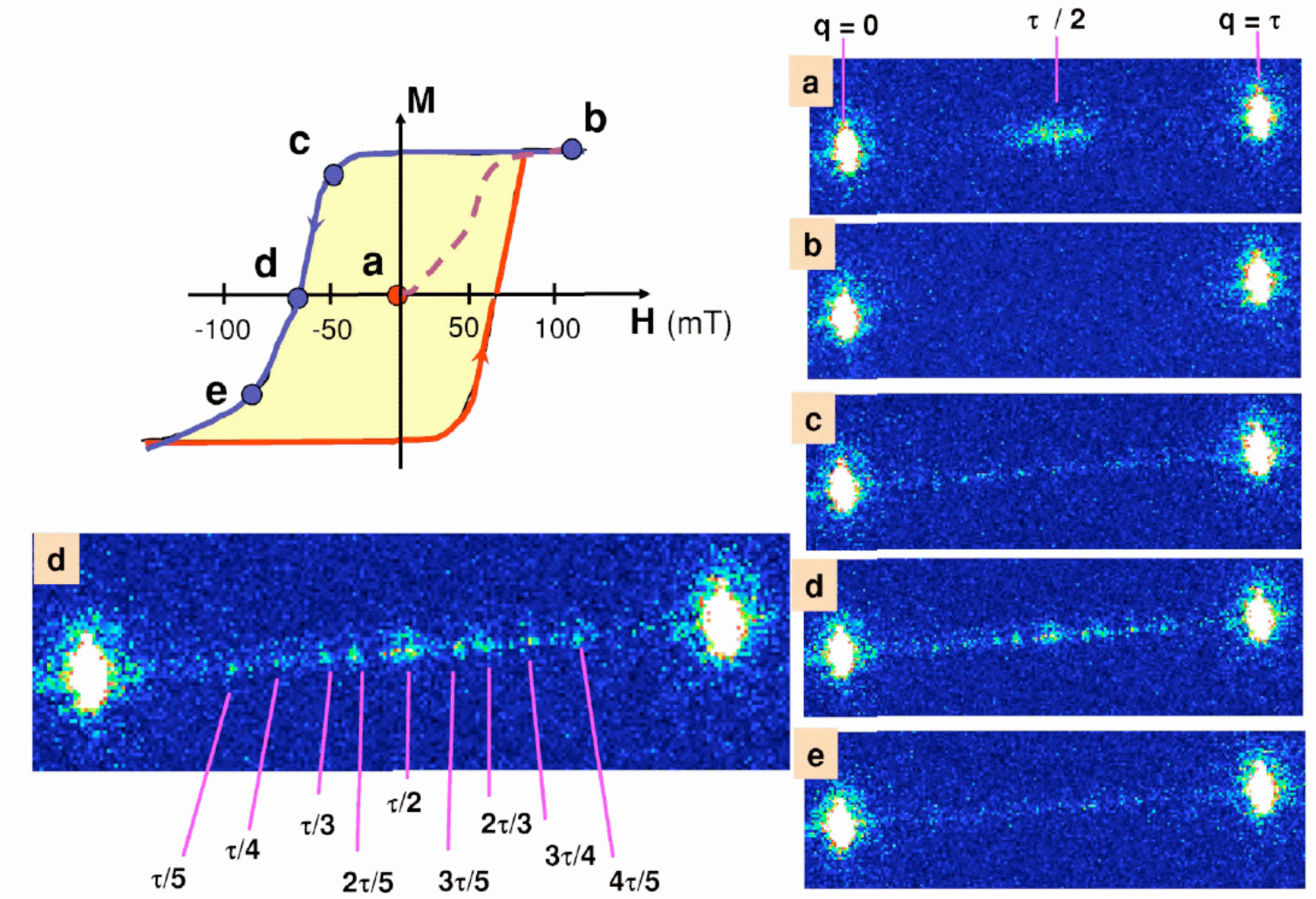


(0, ½ , 0)
Orbital ordered
T=205K

(0, ½ , 0)
Near phase transition
T=232K

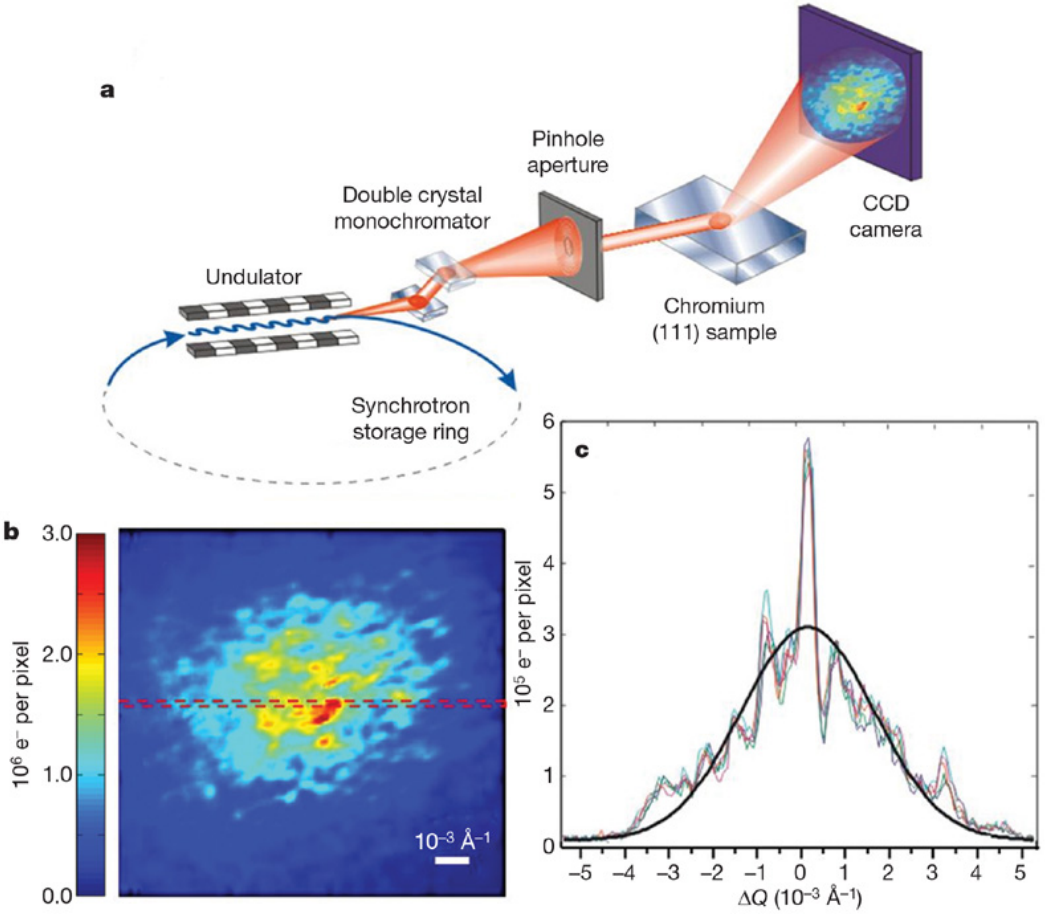
Co/ Pt multilayer line grating at 780eV

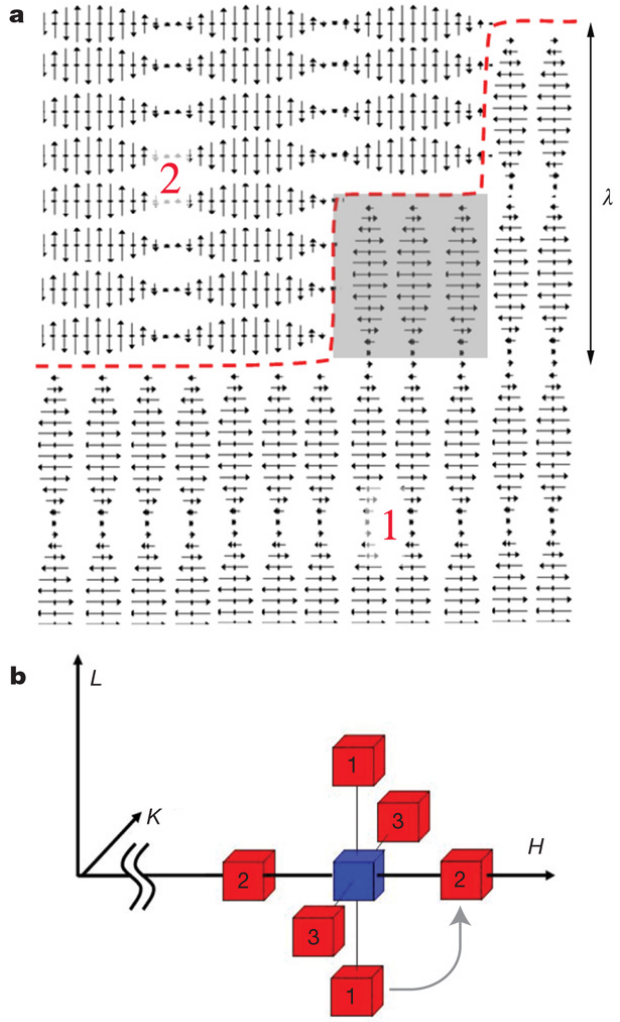
K. Chesnel et al, PRB 70 180402 (2004)



Antiferromagnetic Domains in Cr

O. Shpyrko et al, Nature 447 68 (2007)





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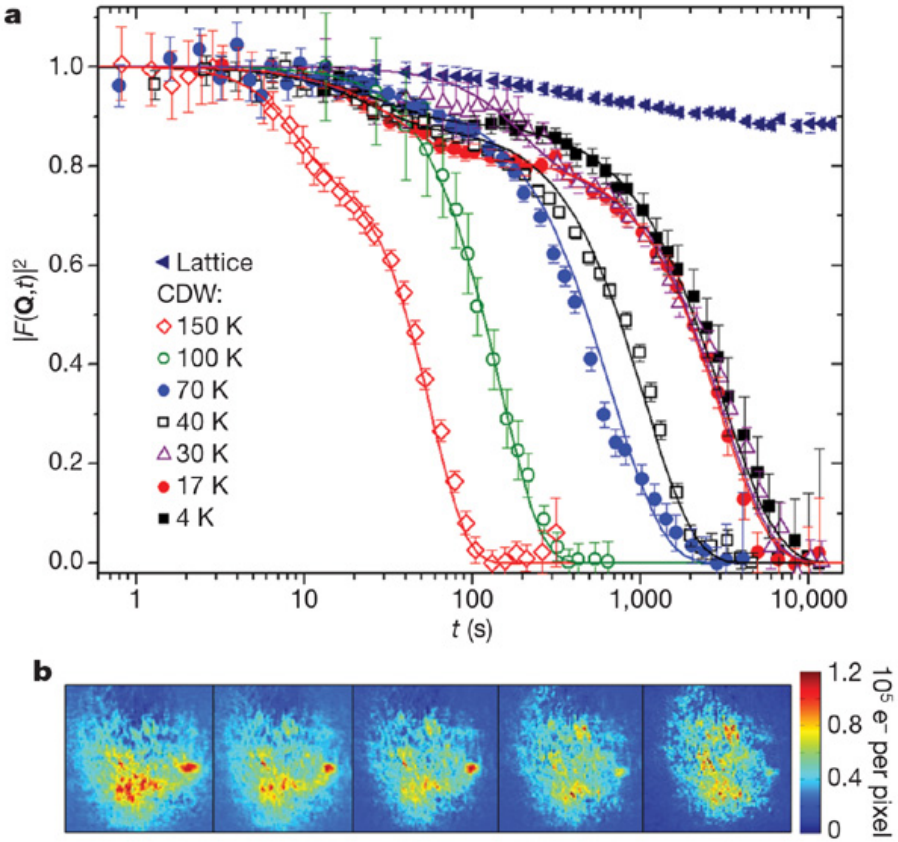
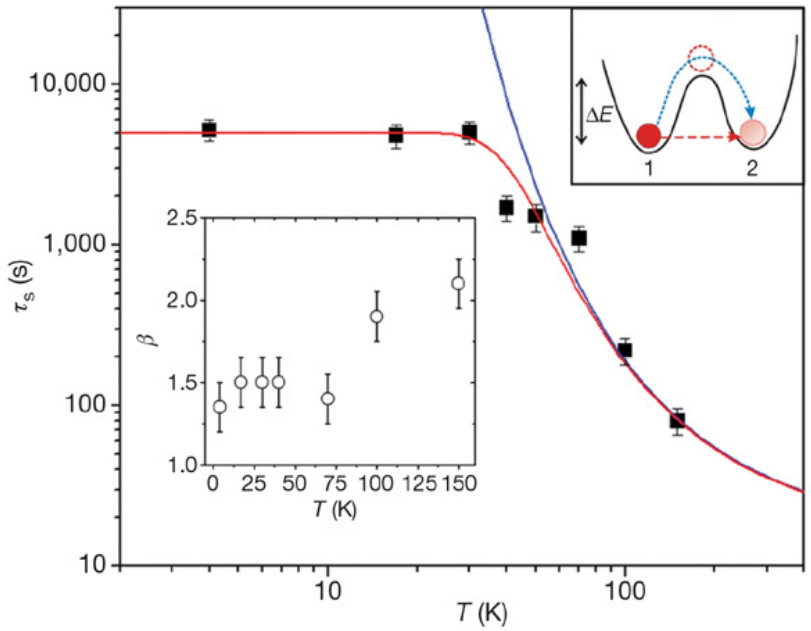
XPCS of Domain Fluctuations in Cr

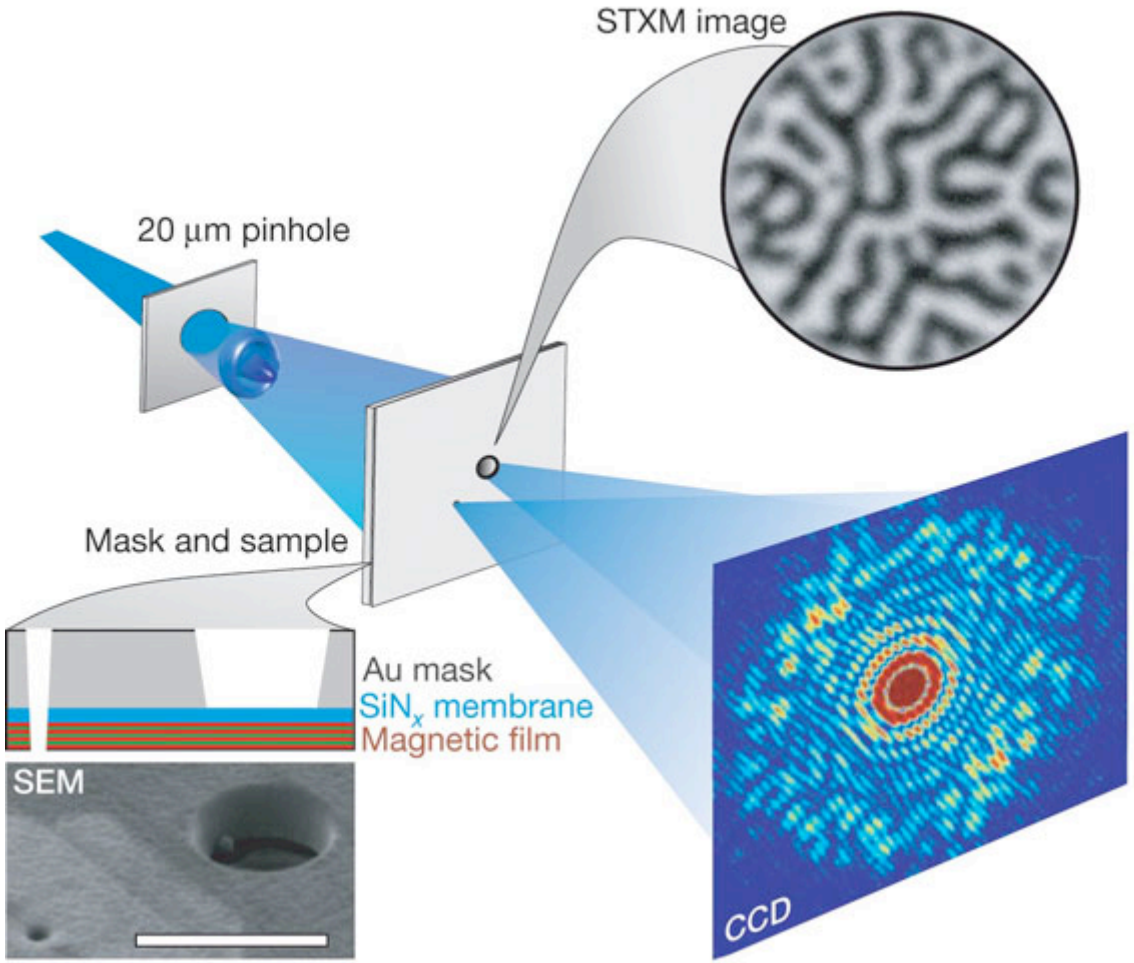
O. Shpyrko et al, Nature 447 68 (2007)





X-ray Holography of Pt/CoML Domains

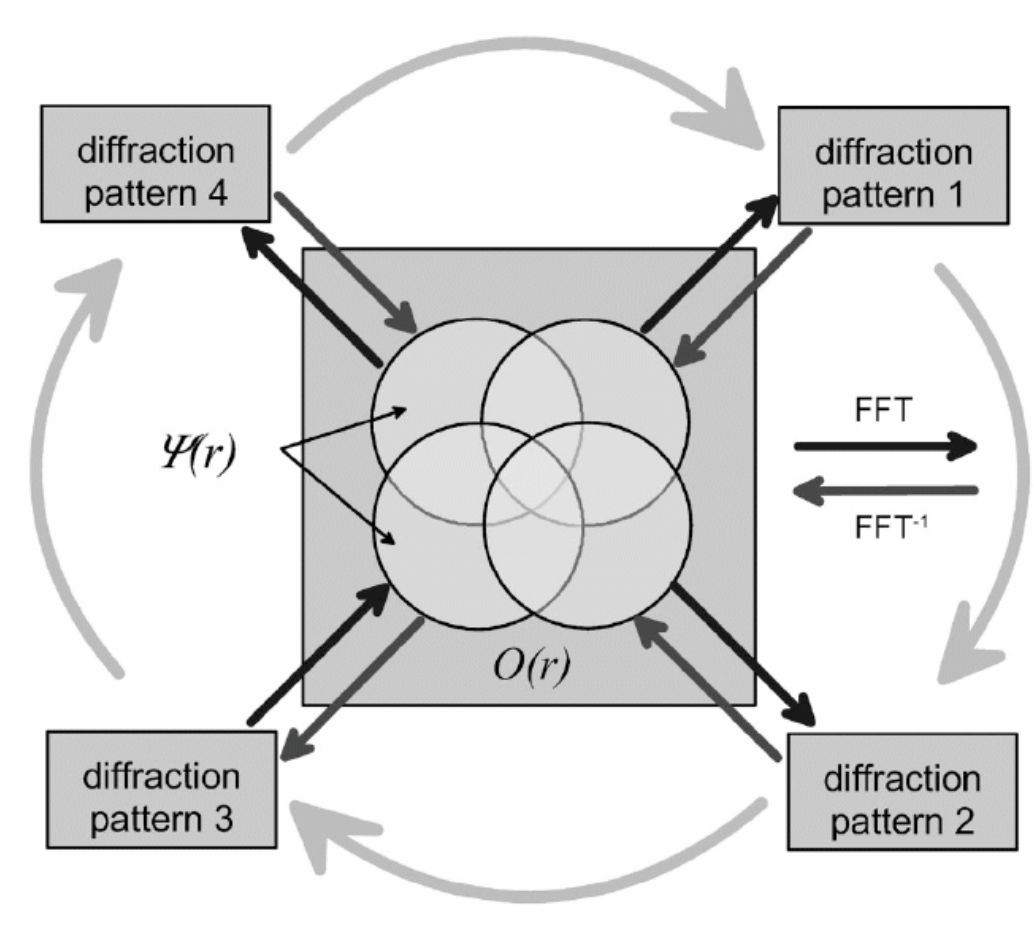
S. Eisebitt et al. Nature 432 885 (2004)



Field of view 1.5 µm

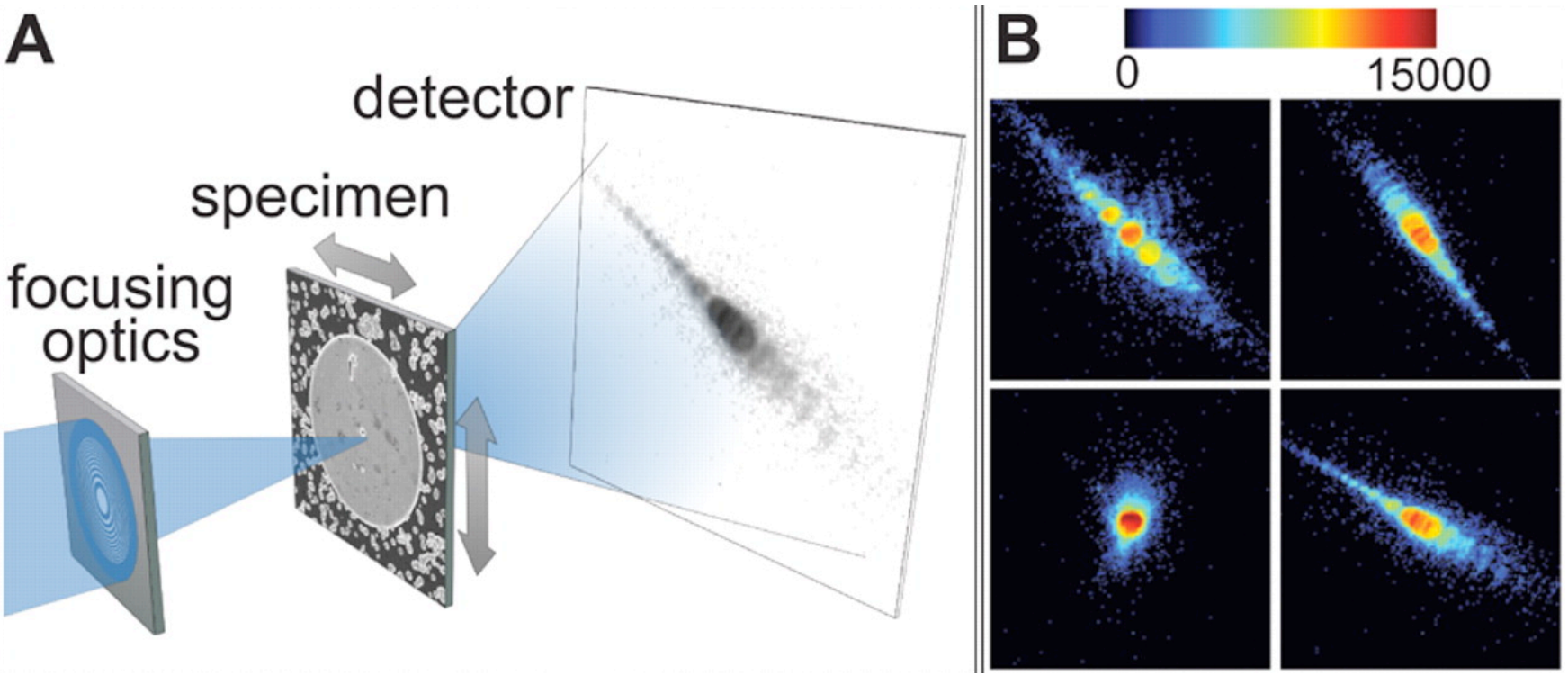
X-ray Ptychography

J. Rodenburg et al, PRL 98, 034801 (2007)



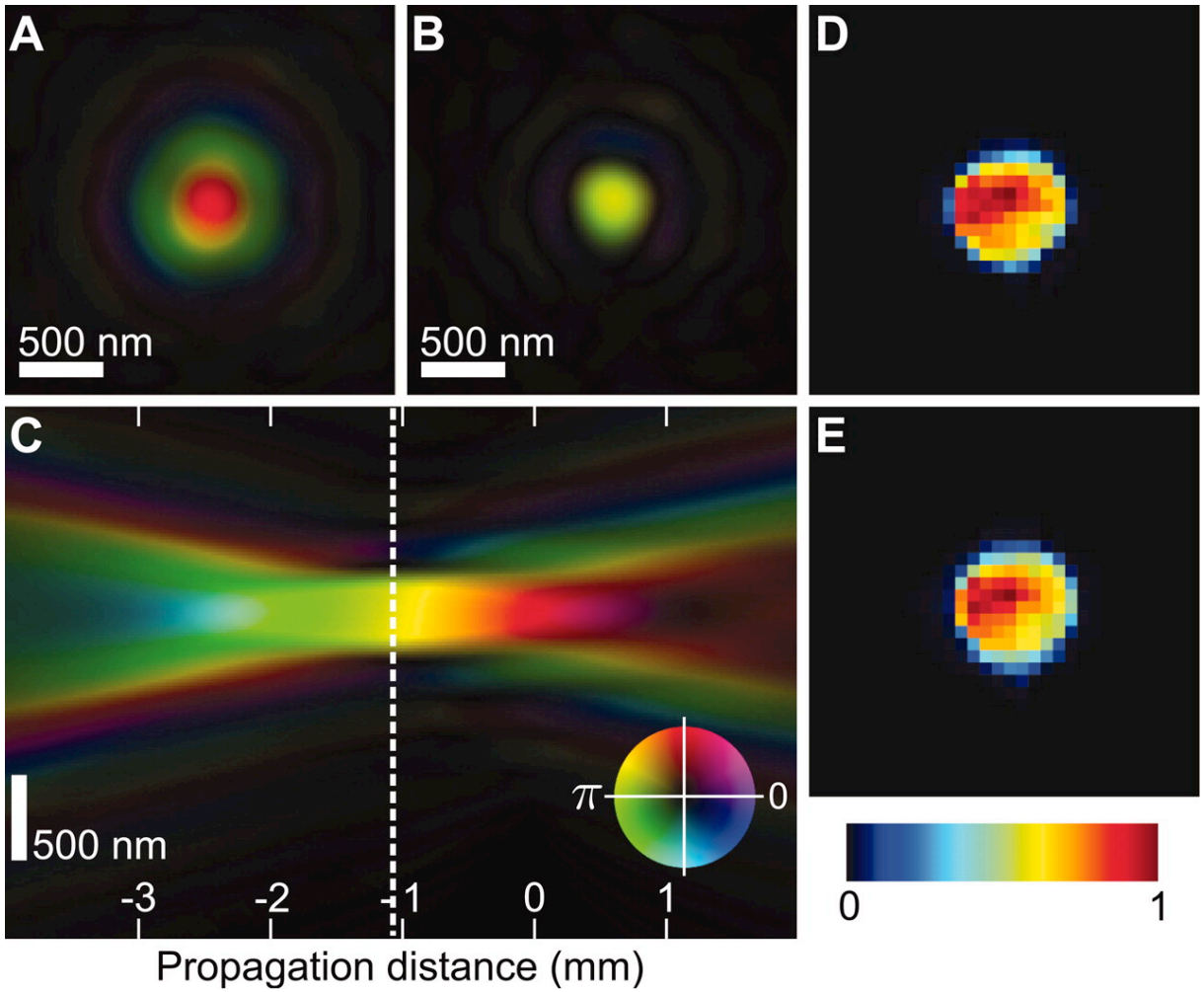
X-ray Ptychography

P. Thibault et al, Science 321 379 (2008)



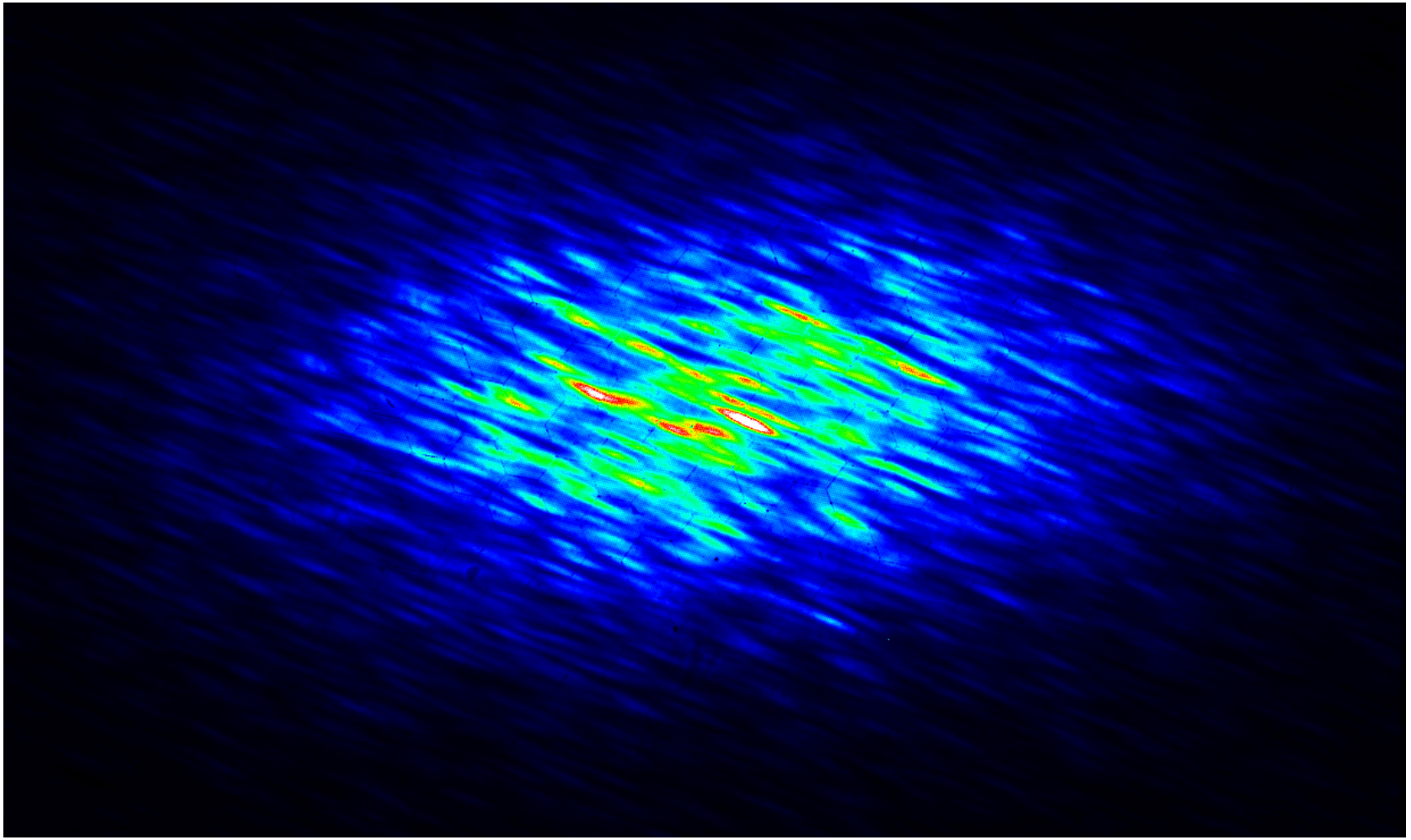
Reconstruction of Probe

P. Thibault et al, Science 321 379 (2008)



Niobium (110) Thin Film Grains

Richard Bean, I-16, Nb110-35 Jan 2009



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FeAl antiphase domains (001)

Lorenz Stadler, PhD dissertation, TU Wien (2005)

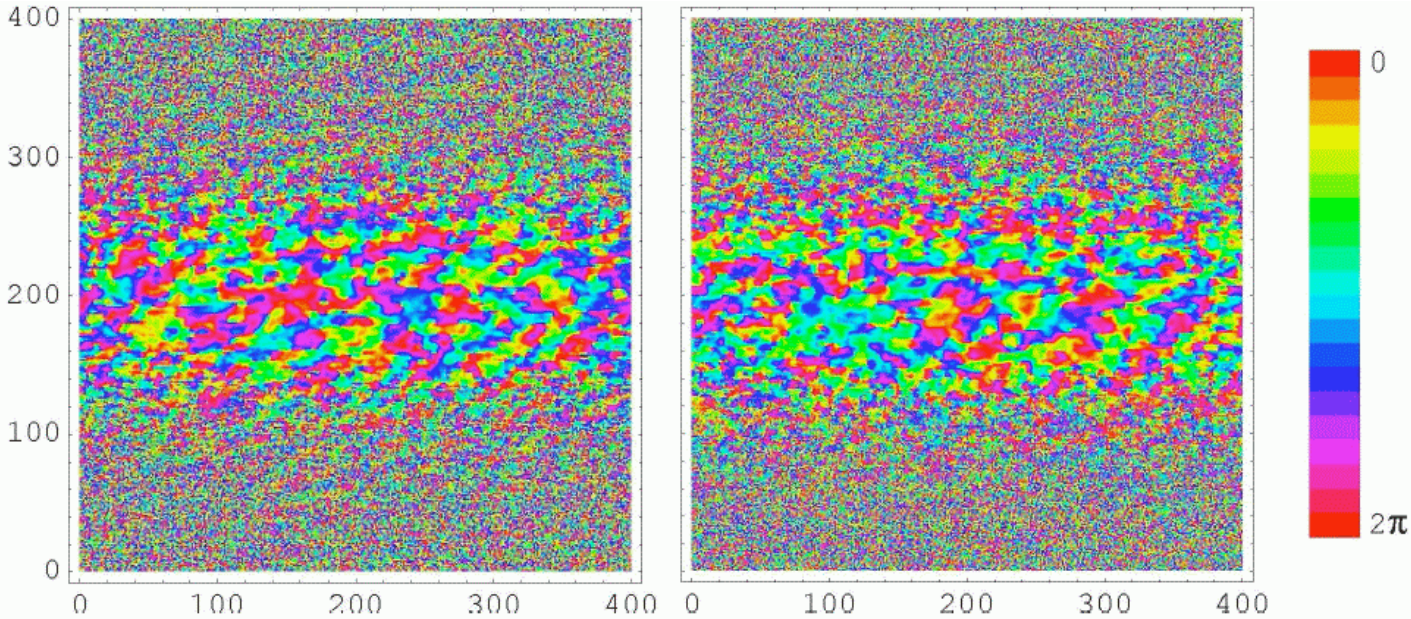
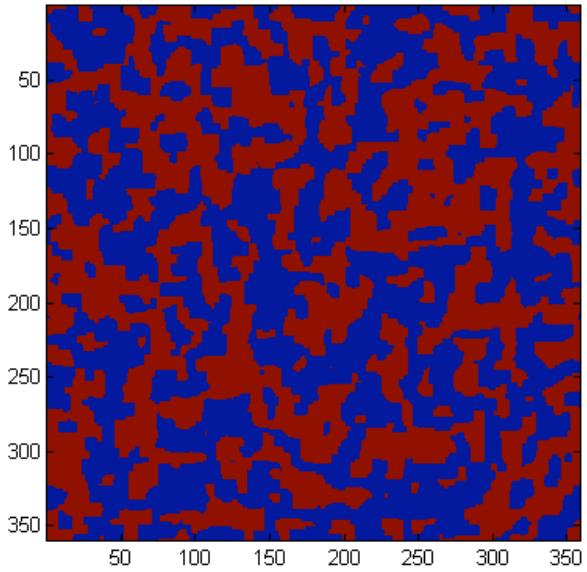


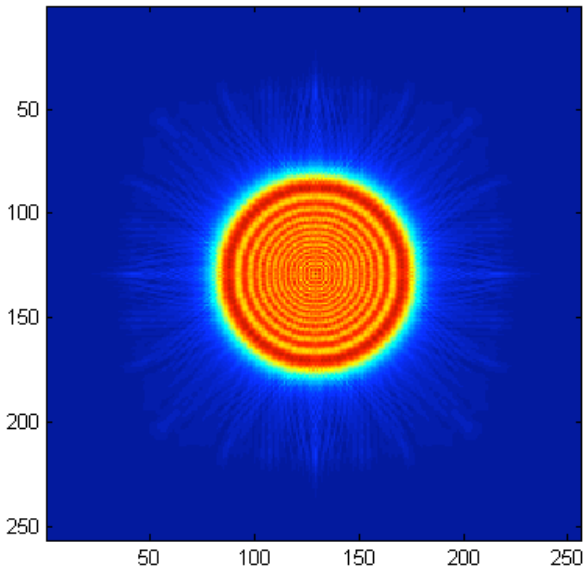
Figure 7.11: Typical reconstructed phases from runs with different combinations of algorithms and supports derived from the 2D Gaussian fit of the illumination function. Numbers in brackets denote how many iterations of the particular algorithm were done each cycle. Graphs on the left are from reconstruc-

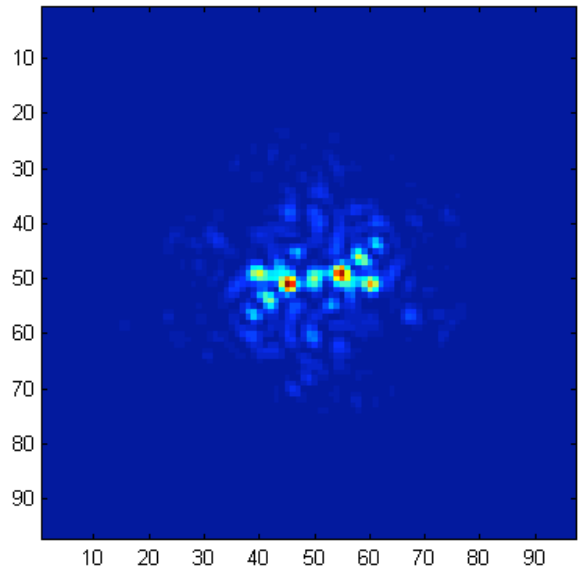
Ptychography phasing tests

Diffraction patterns computed from i) simulated domain array ii) propagated pinhole function with an overlap of ~80% between adjacent positions.

Richard Bean, UCL, Jan 2009

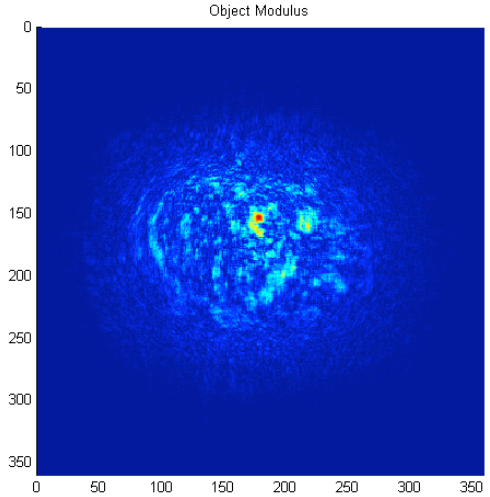


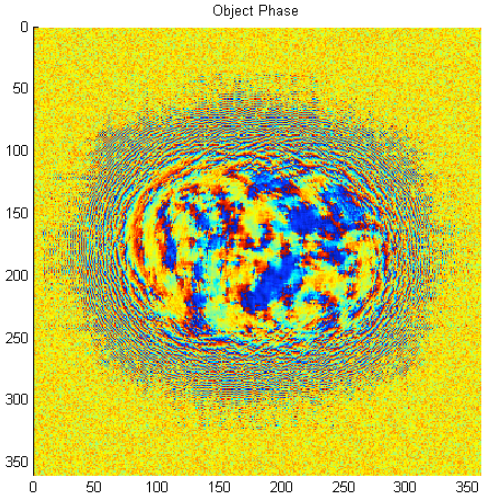




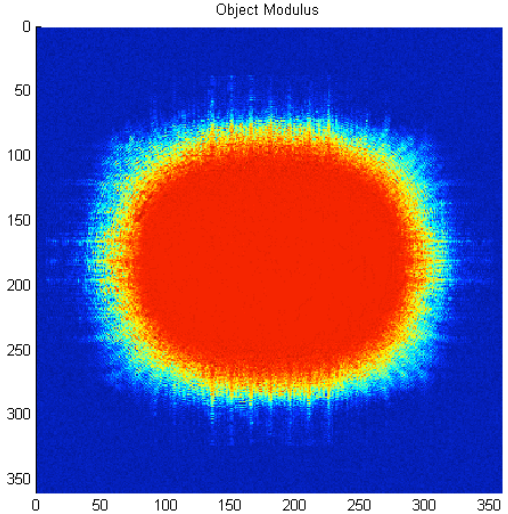
Ptychography phasing tests

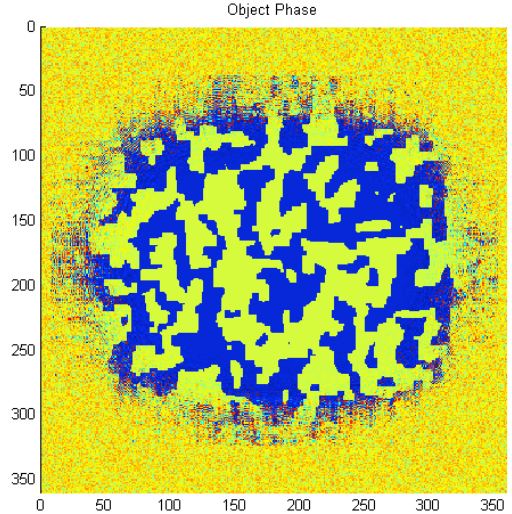
Sheffield Ptychography algorithm starting with an array of random numbers in both amplitude and phase. 7x3 array. Richard Bean, Jan 2009





Amplitude and phase after 1 iteration.



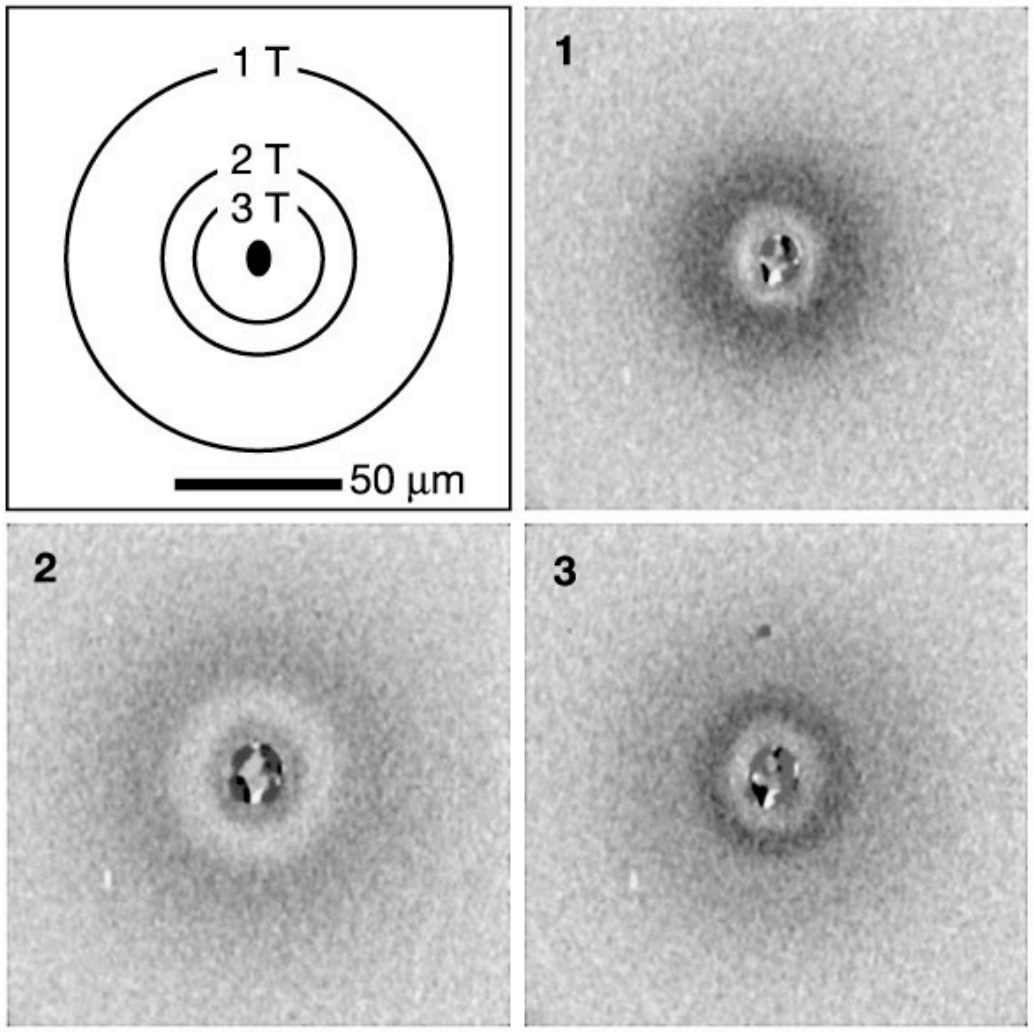


Amplitude and phase after 20 iterations.

Kerr microscopy after 28GeV SLAC pulses

14-nm perpendicular granular magnetic recording media (CoCrPt)

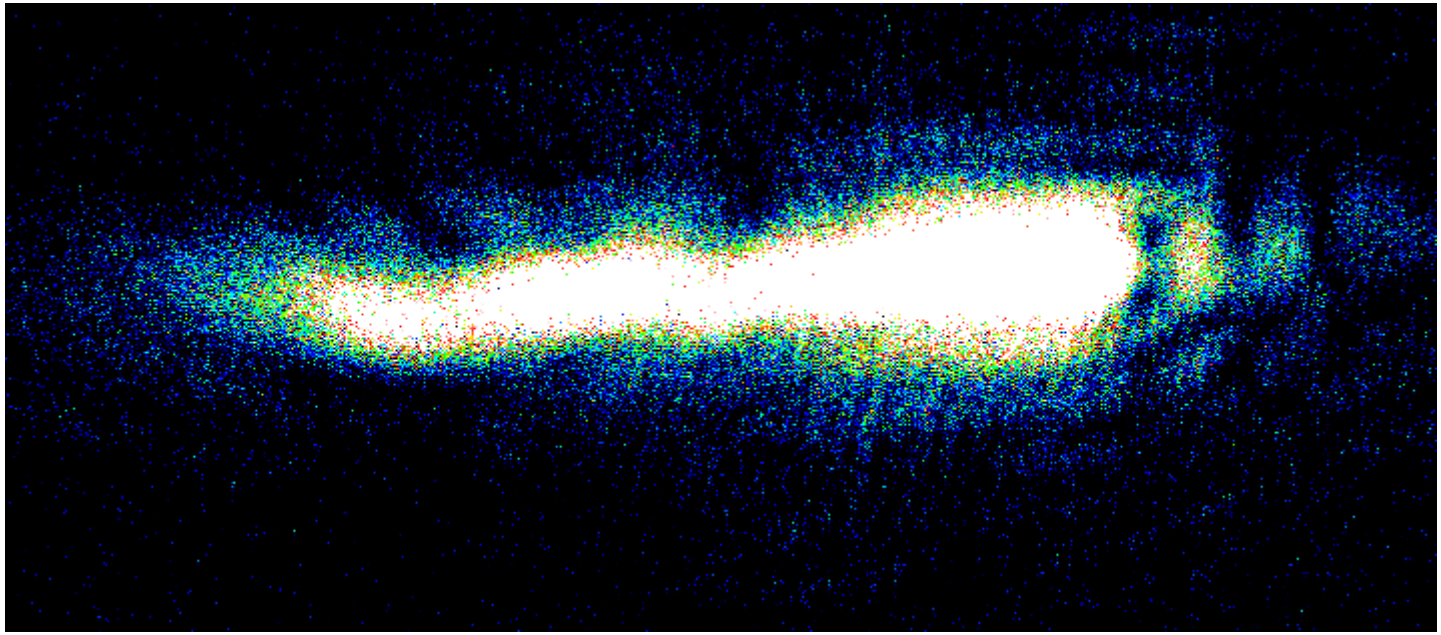
I. Tudosa et al, Nature 428 831 (2004)

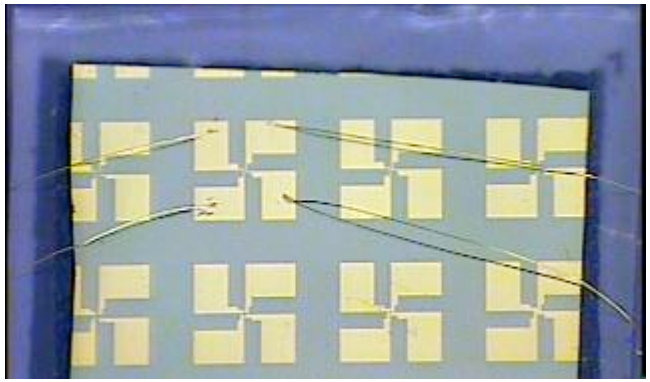


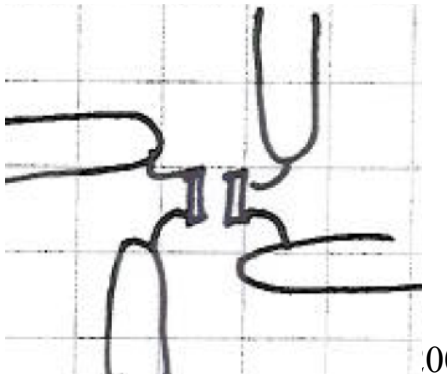
number of 2.3ps pulses

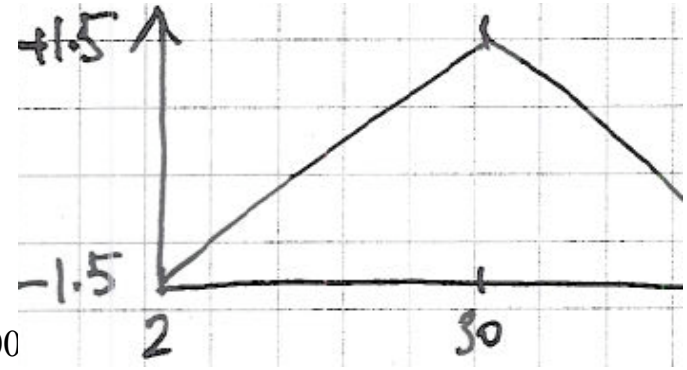
Apply Electric Field along ZnO NC

Marcus Newton. 34-ID-C zno808-18 Aug 2008









Special thanks to:

- Ross Harder 34-ID-C beamline
- Ivan Vartaniants, Garth Williams, Mark Pfeifer
- Marcus Newton, Steven Leake ZnO
- Moyu Watari, Loren Beitra Au
- Richard Bean, Felisa Berenguer Nb

- ERC-FP7, EPSRC, Royal Society, DOE

Conclusions and Outlook

- Small crystal imaging
- Strains visible as real-space phase
- Domain imaging should work soon
- Magnetic domains should be visible as strain
- Ptychography reveals probe structure also
- Pulsed field dynamics in future