Ptychographic imaging of biological tissues

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Taking x-ray phase contrast imaging into mainstream applications

The Royal Society, London

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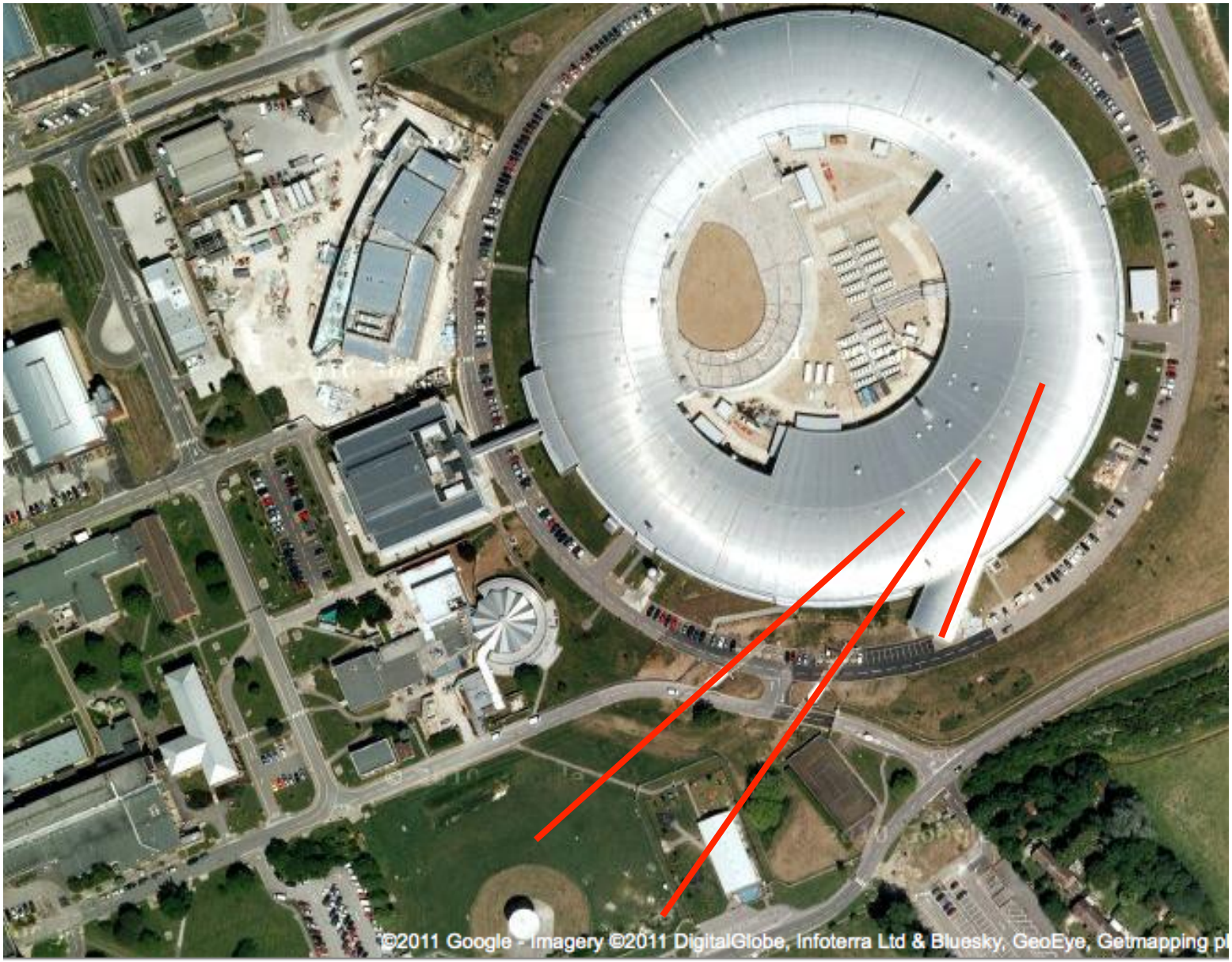
Outline

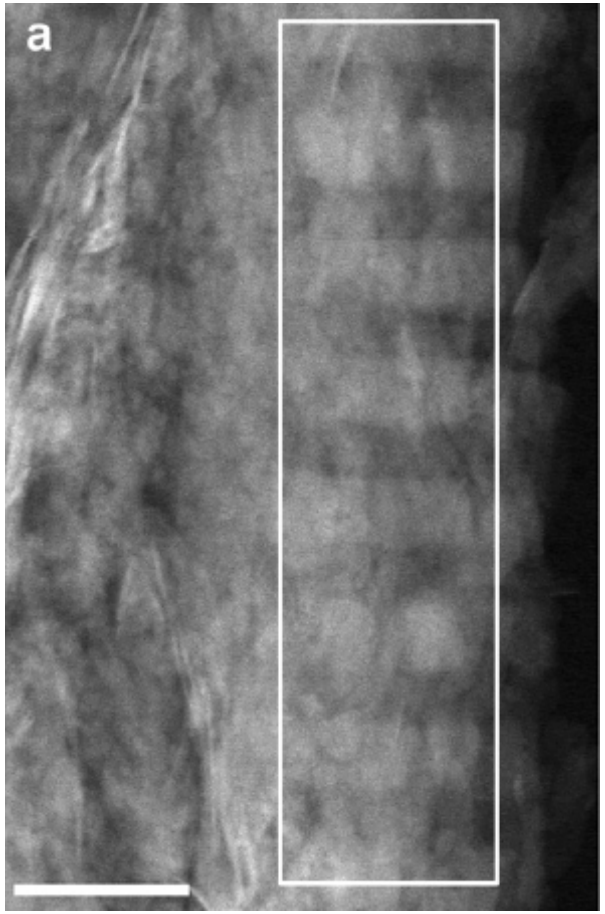
- Phase Contrast Imaging
- Ptychography
- Collagen studies by ptychography
- 3D ptychography
- Complex multicomponent paint

Diamond Light Source, 2009



STEM biomineralisation, AFM

Mike Horton and Laurent Bozec



Collagen Primary Structure

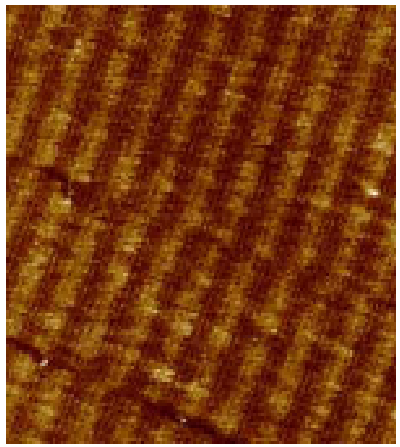
Felisa Berenguer, LCN

- Collagen is the most common protein in animal tissue (bones, teeth, tendon, cartilage, connective tissue)

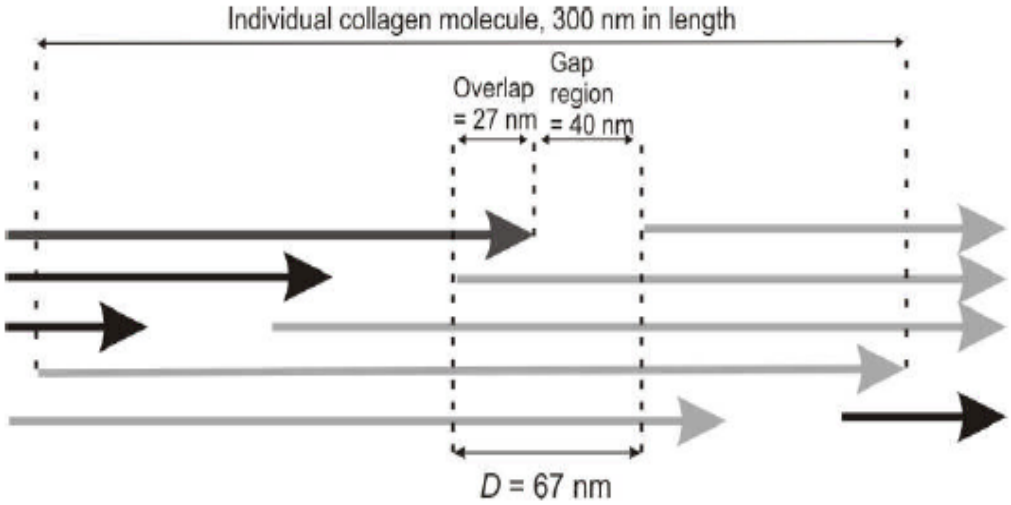
- Potential applications in medicine (artificial bone, skin diseases)

- Collagen packing to built-up fibres is not completely understood

  Different proposed models by Orgel 2007, Wess 2006, Bozec 2007 …



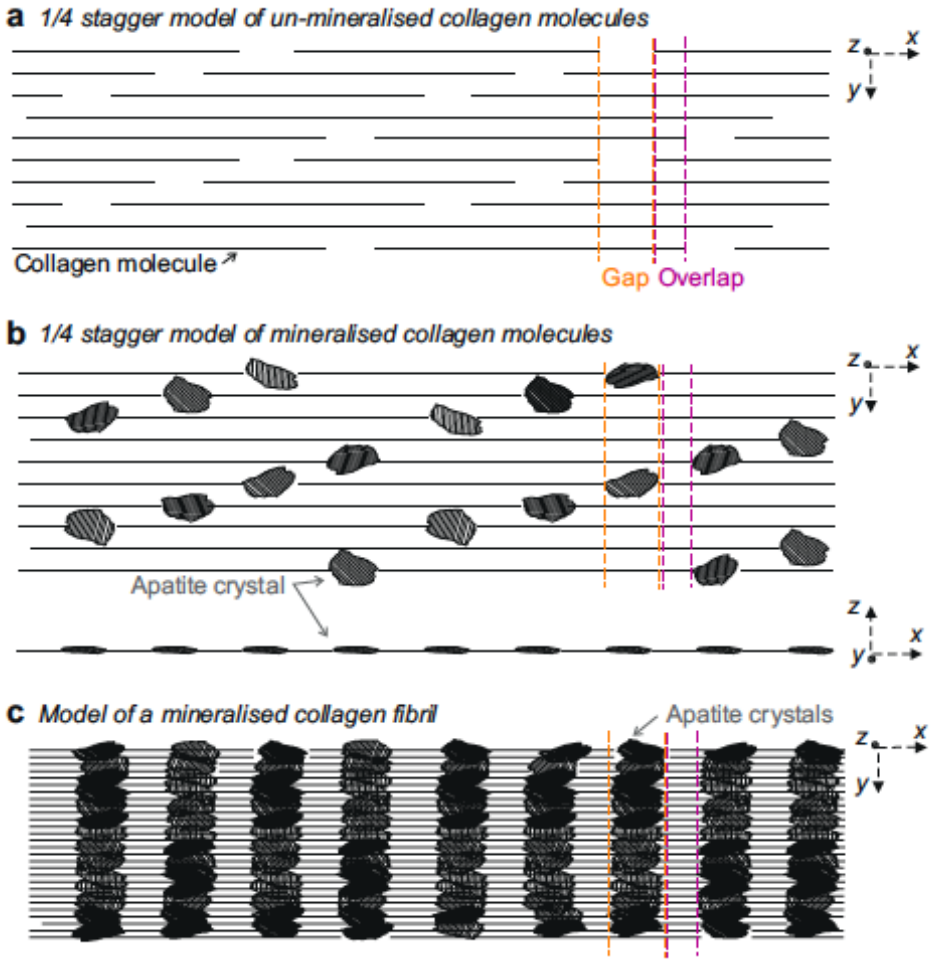
SEM [Cisneros, 2006]



[Hodge and Petruska, 1976]

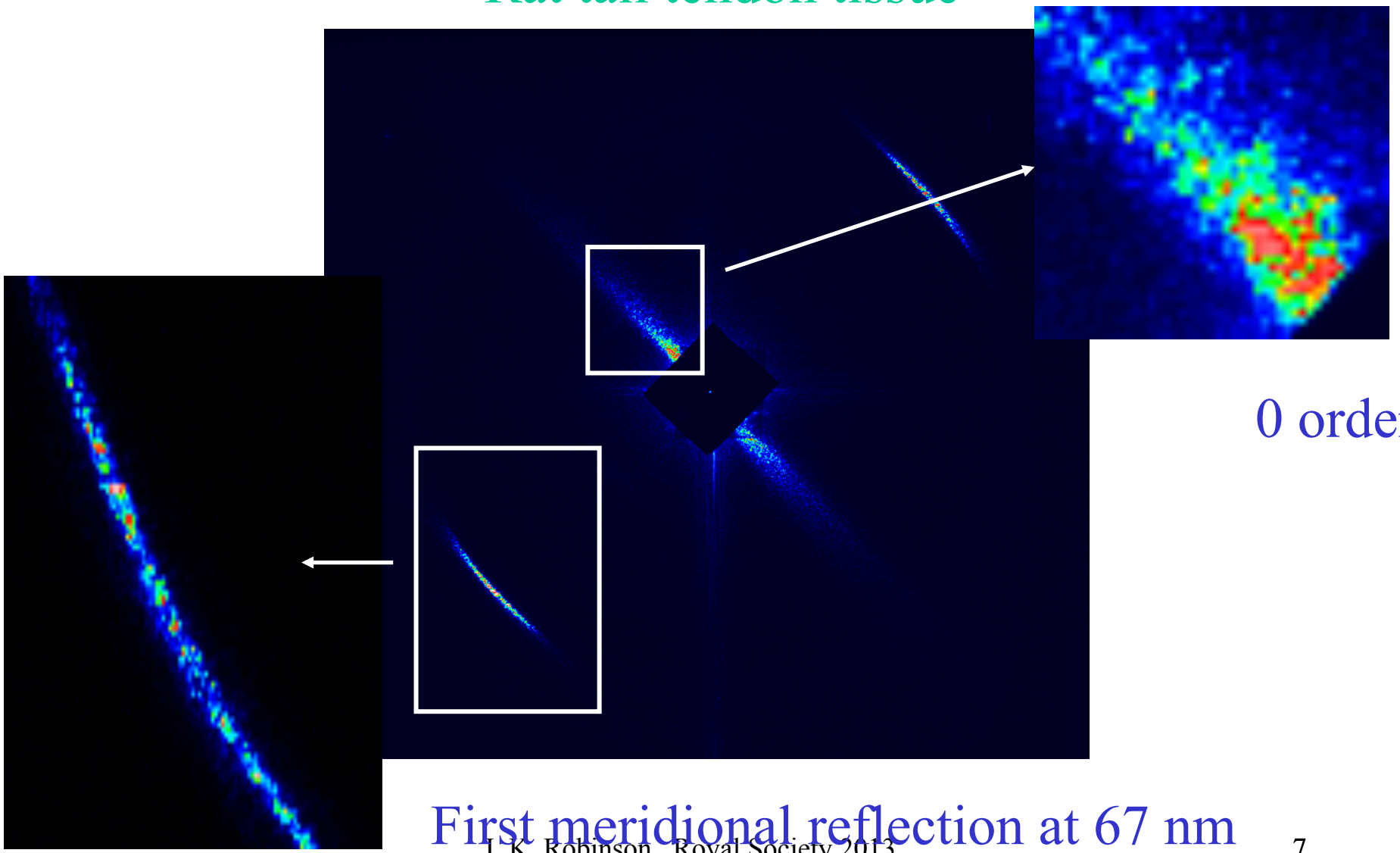
Biomineralisation Model

Jantou-Morris, V, Horton, MA, McComb, DW
Biomaterials 31 5275 (2010)



First experimental results on collagen

Rat tail tendon tissue

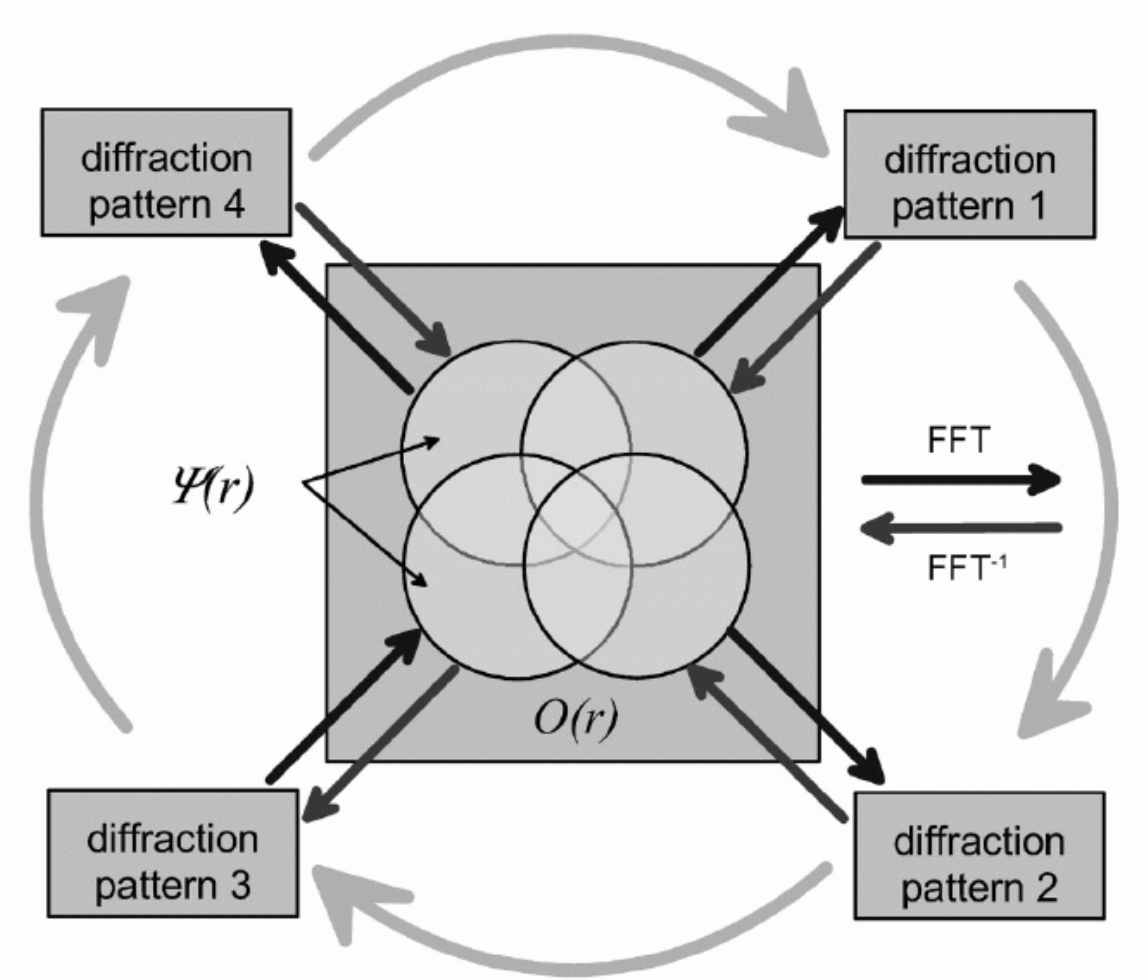


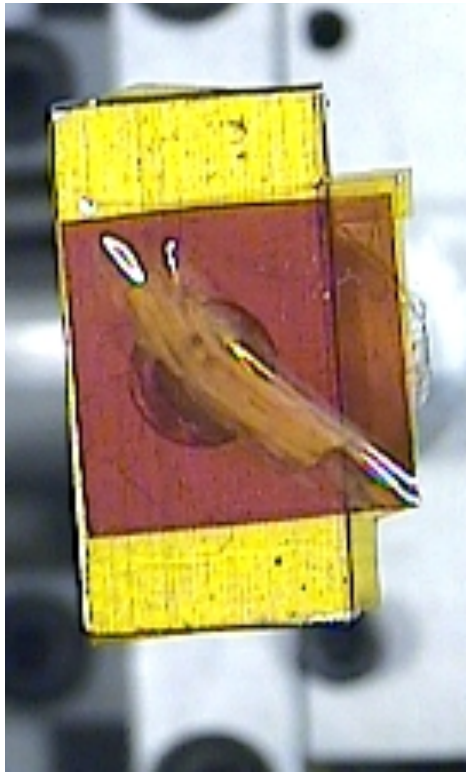
0 order

First meridional reflection at 67 nm

X-ray Ptychography

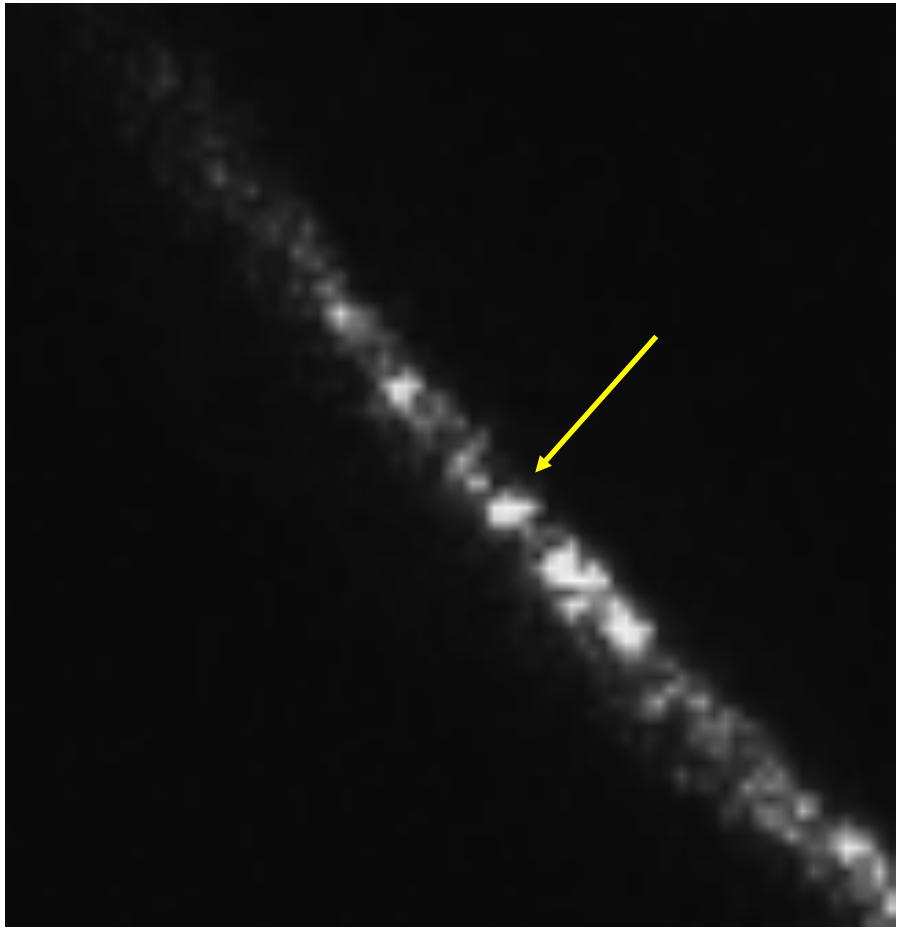
J. M. Rodenburg et al, Phys. Rev. Lett. 98 034801 (2007)



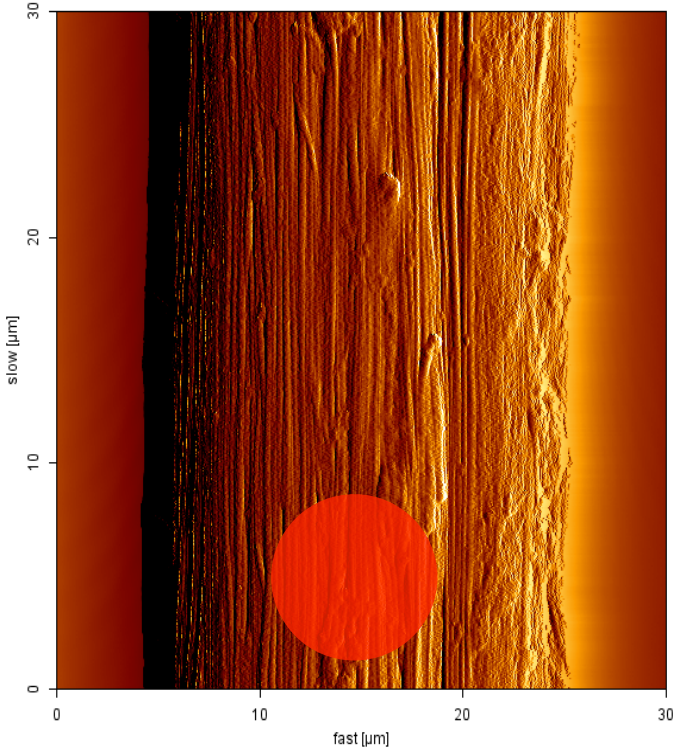


X-ray Ptychography

First meridional reflection



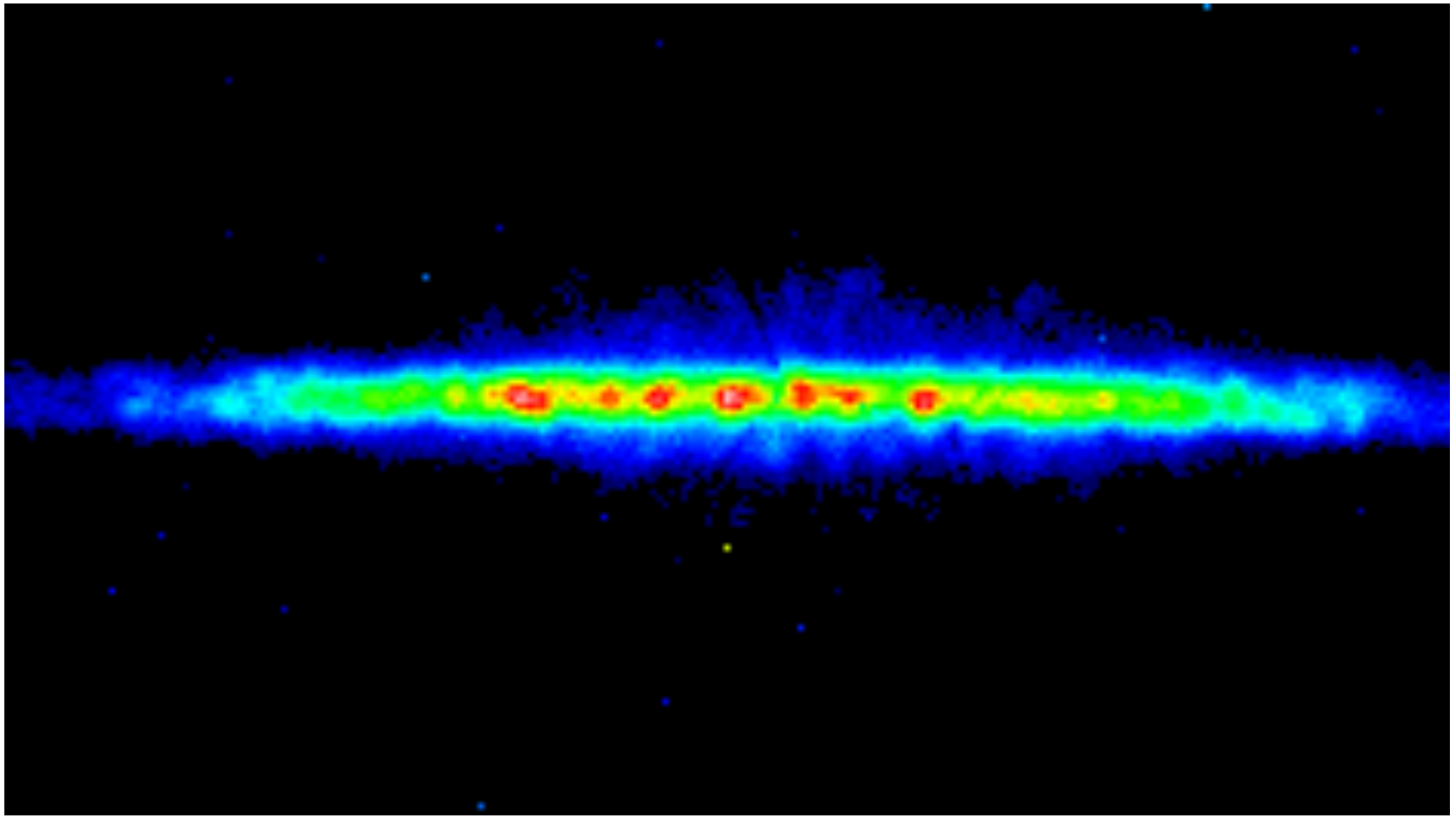
10 μm beam



Dark field imaging:
collagen distribution in different tissues

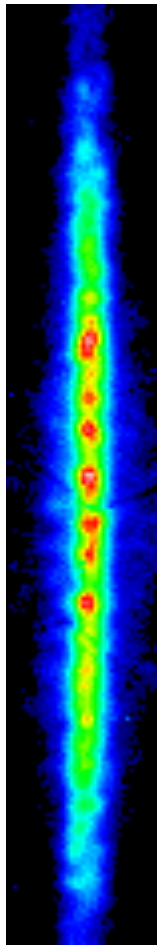
Improved collagen sample prep

Diamond I-22, Nov 2008



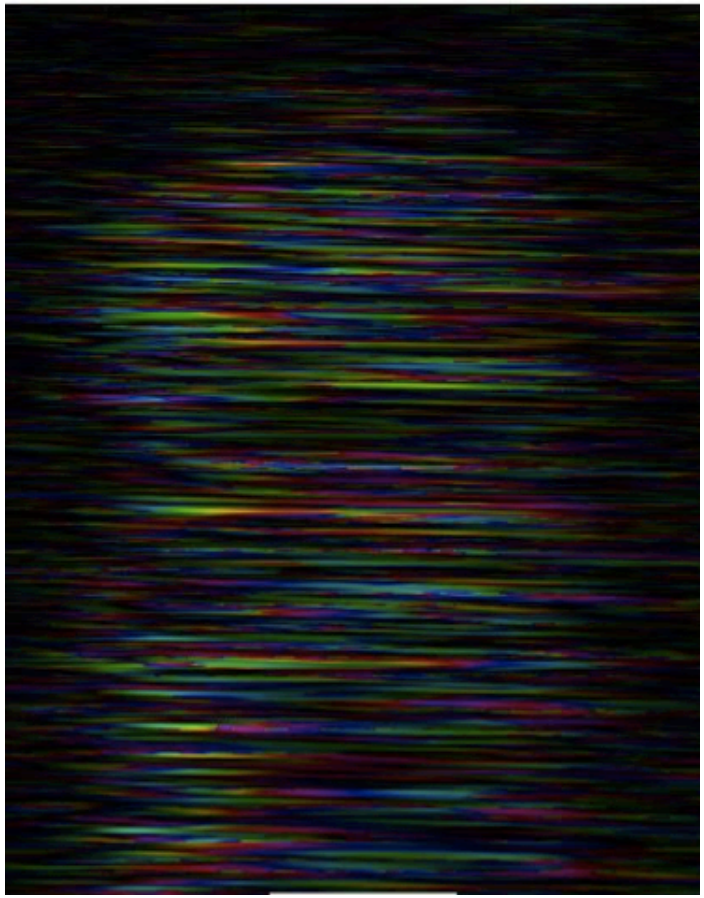
Collagen imaged with Bragg peak

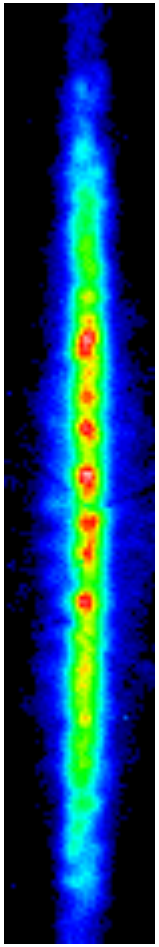
1μm fibrils cut by 20μm beam



Collagen imaged with Bragg peak

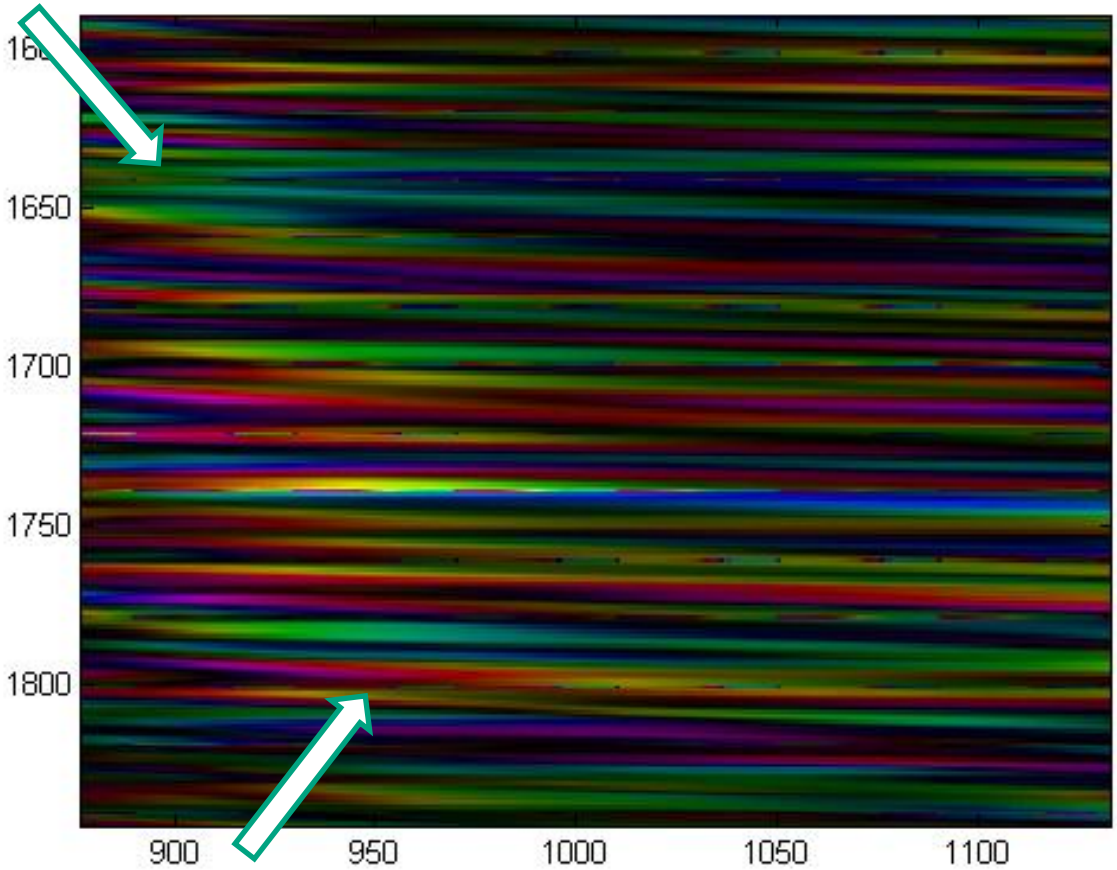
Felisa Berenguer, X-ray ptychography

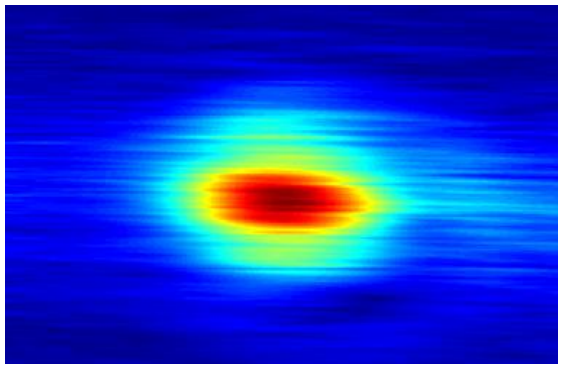




Collagen fibre “fusions”

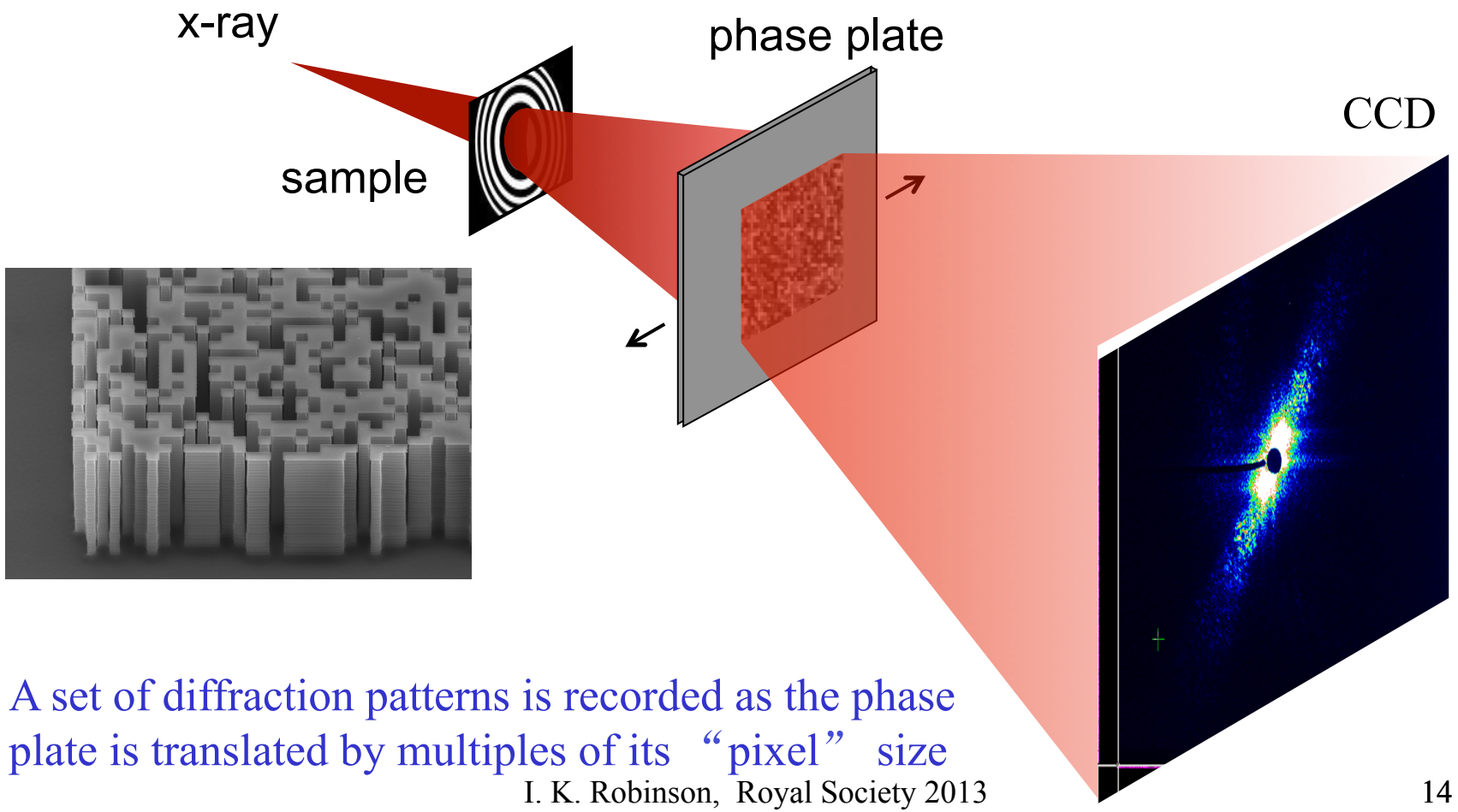
Felisa Berenguer, Laurent Bozec, in preparation





Imaging by wavefront modification

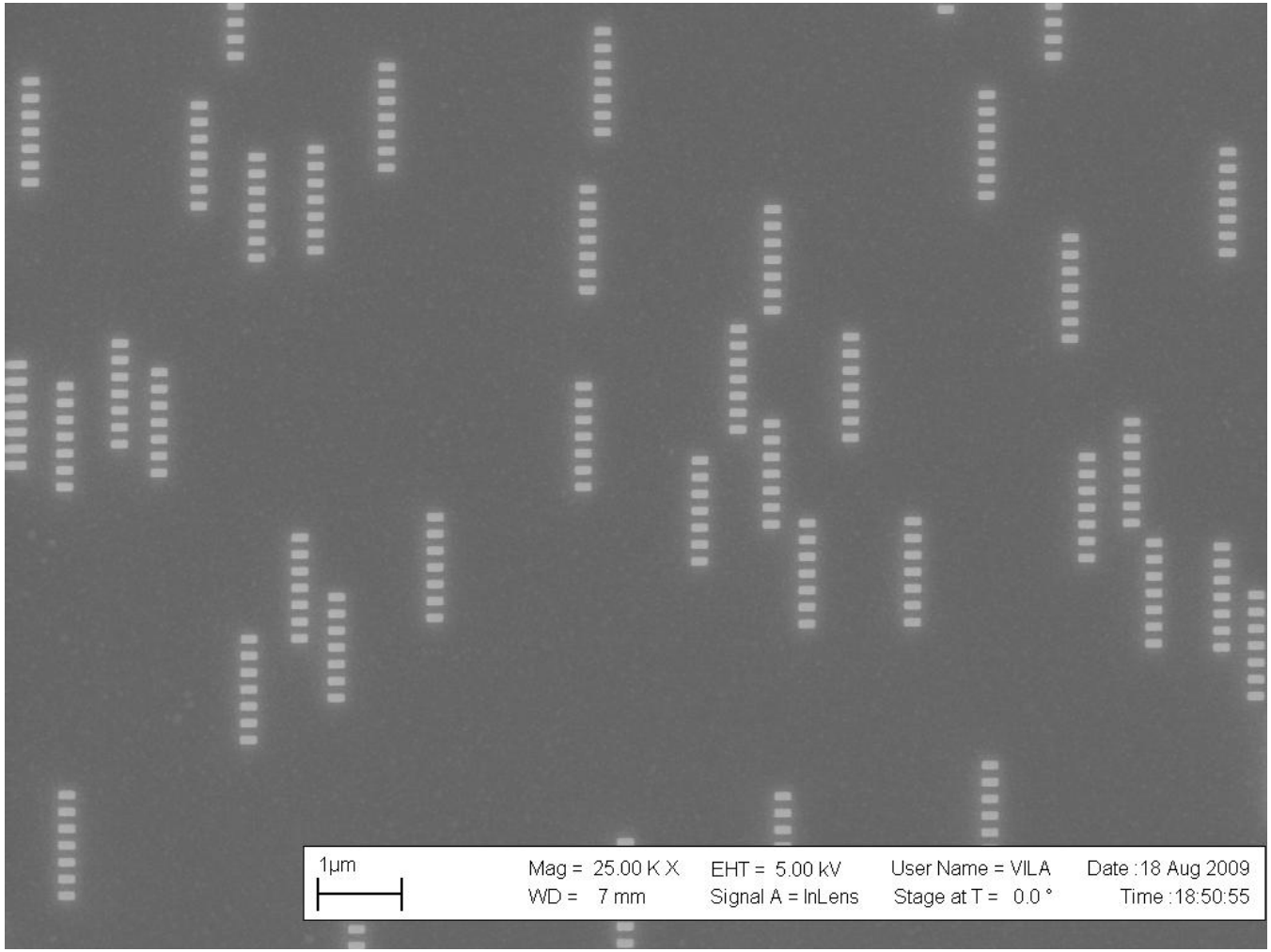
F. Zhang *et al.*, Phys Rev A 75 (2007)
I. Johnson *et al.*, Phys Rev Lett 100 (2008)



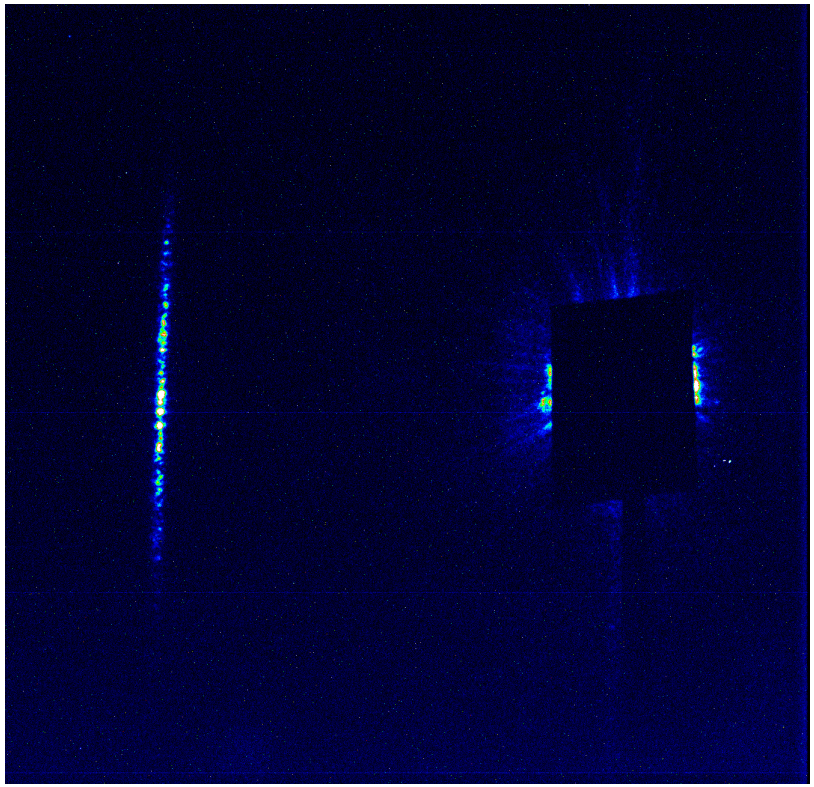
A set of diffraction patterns is recorded as the phase plate is translated by multiples of its "pixel" size

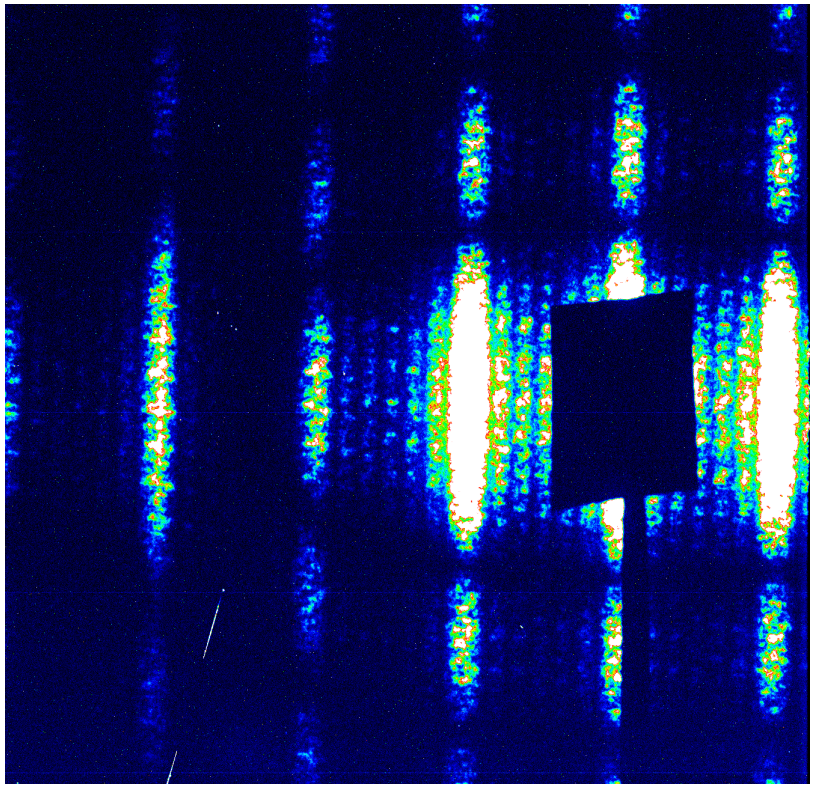
New phase plate design

R. Bean and J. Vila-Comamala, PSI

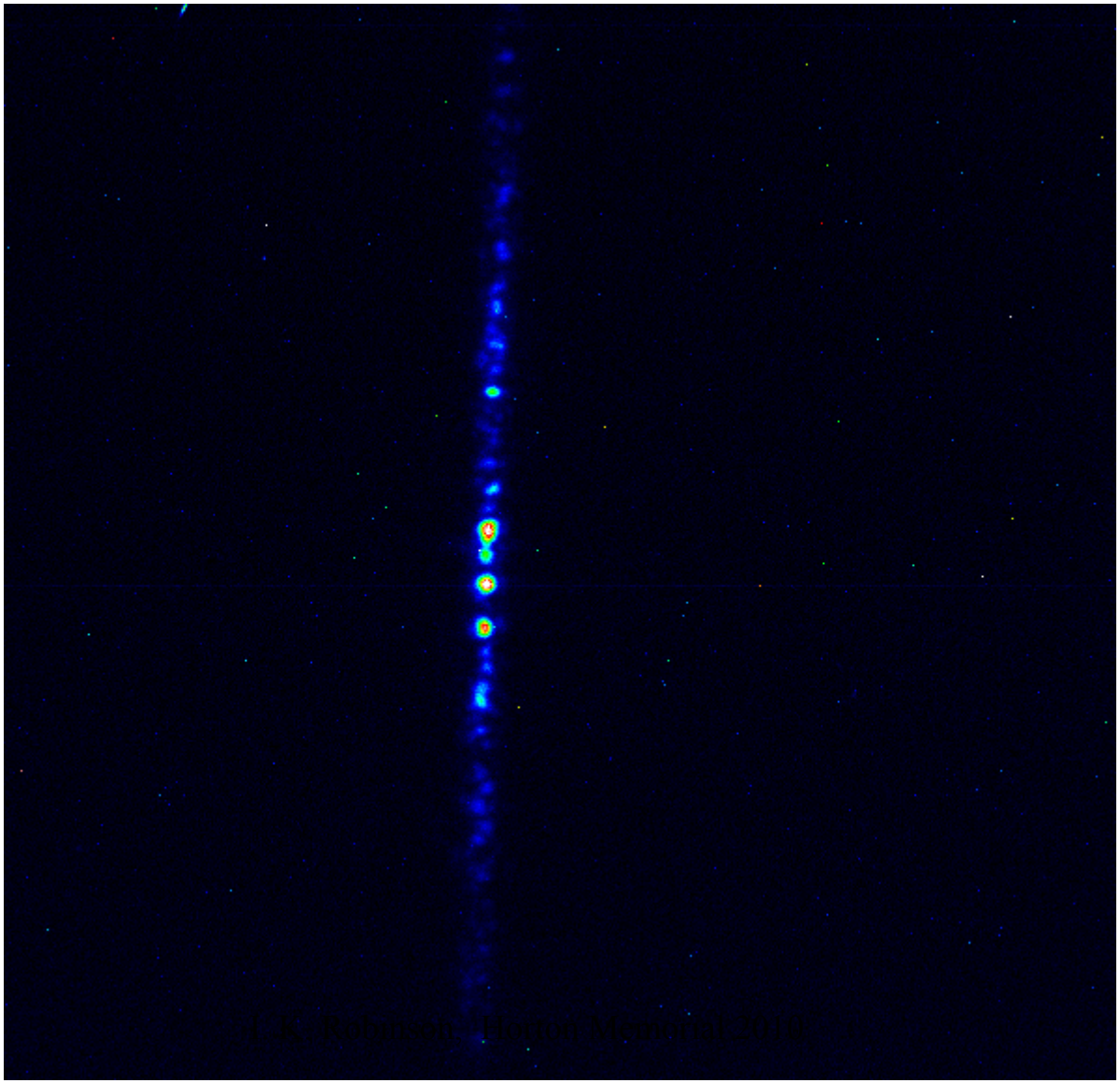


Collagen in liquid cell +/- phase plate





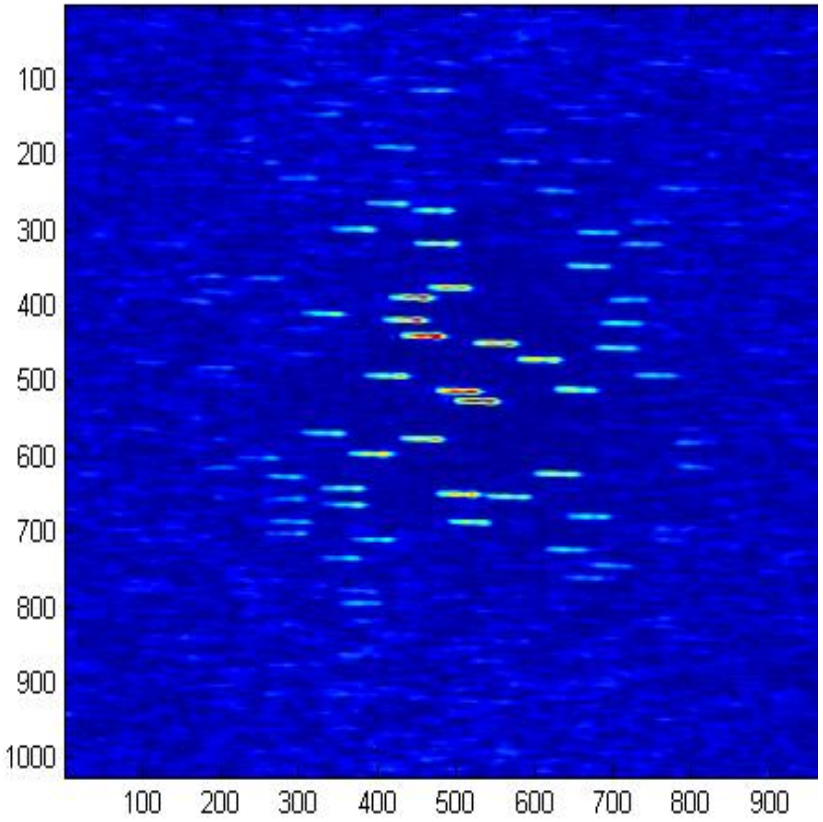
Sample+phase plate interference



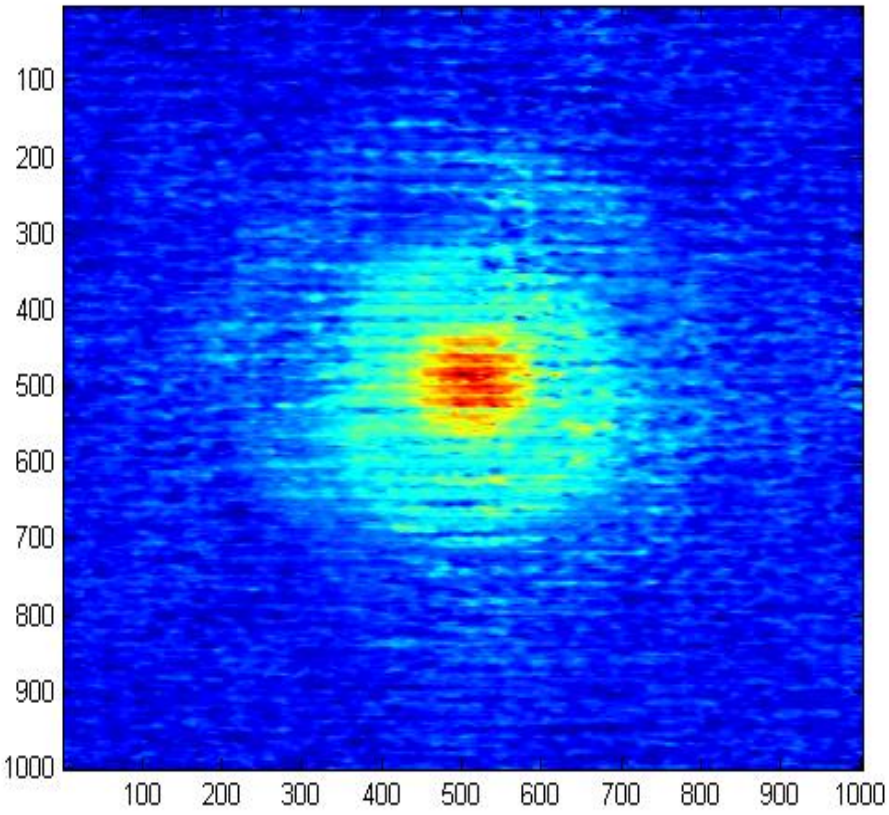
Reconstruction of the First Order Peak

Richard Bean 2011

Phase plate

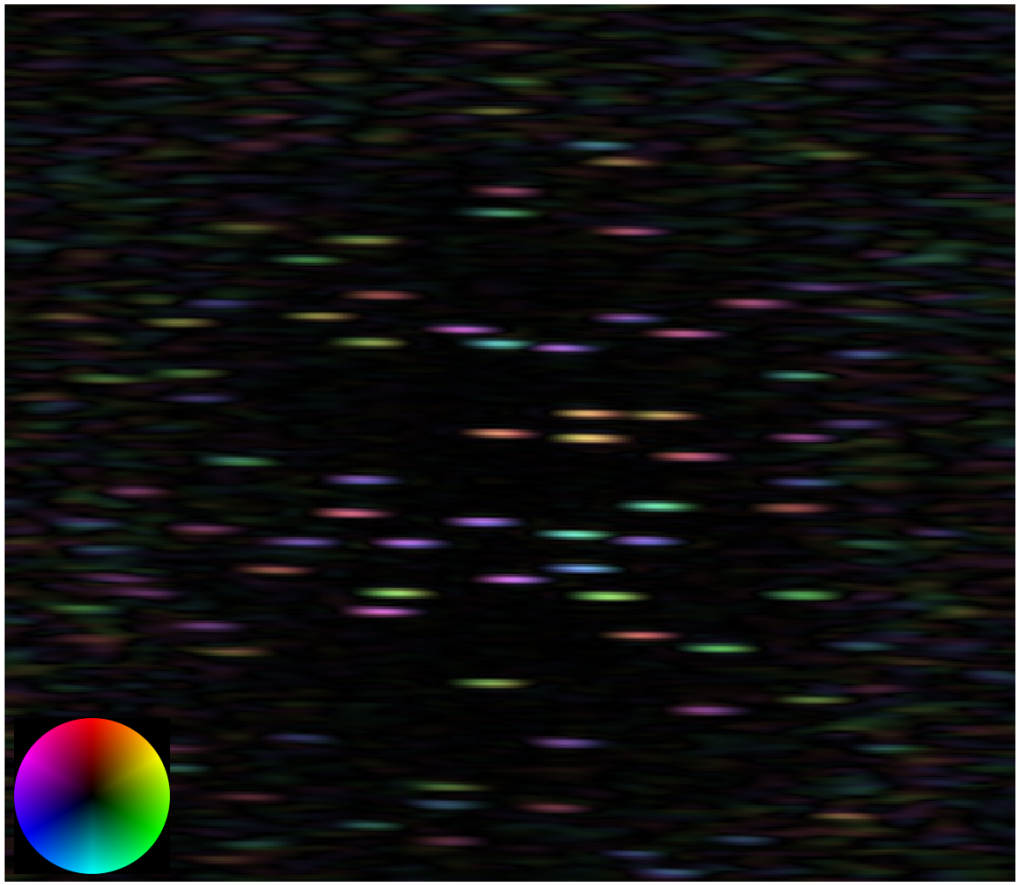


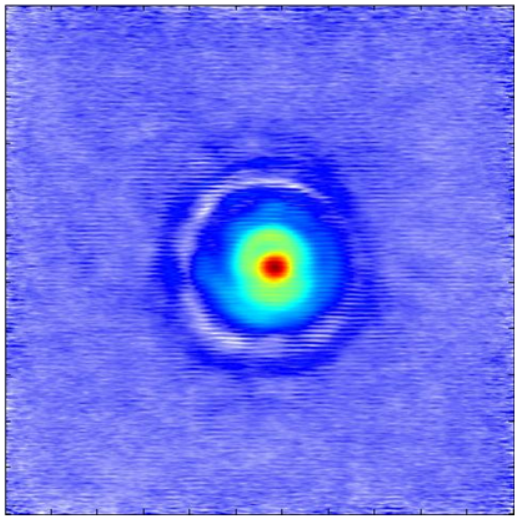
"Probe" (inc. wave)



Plot of reconstruction

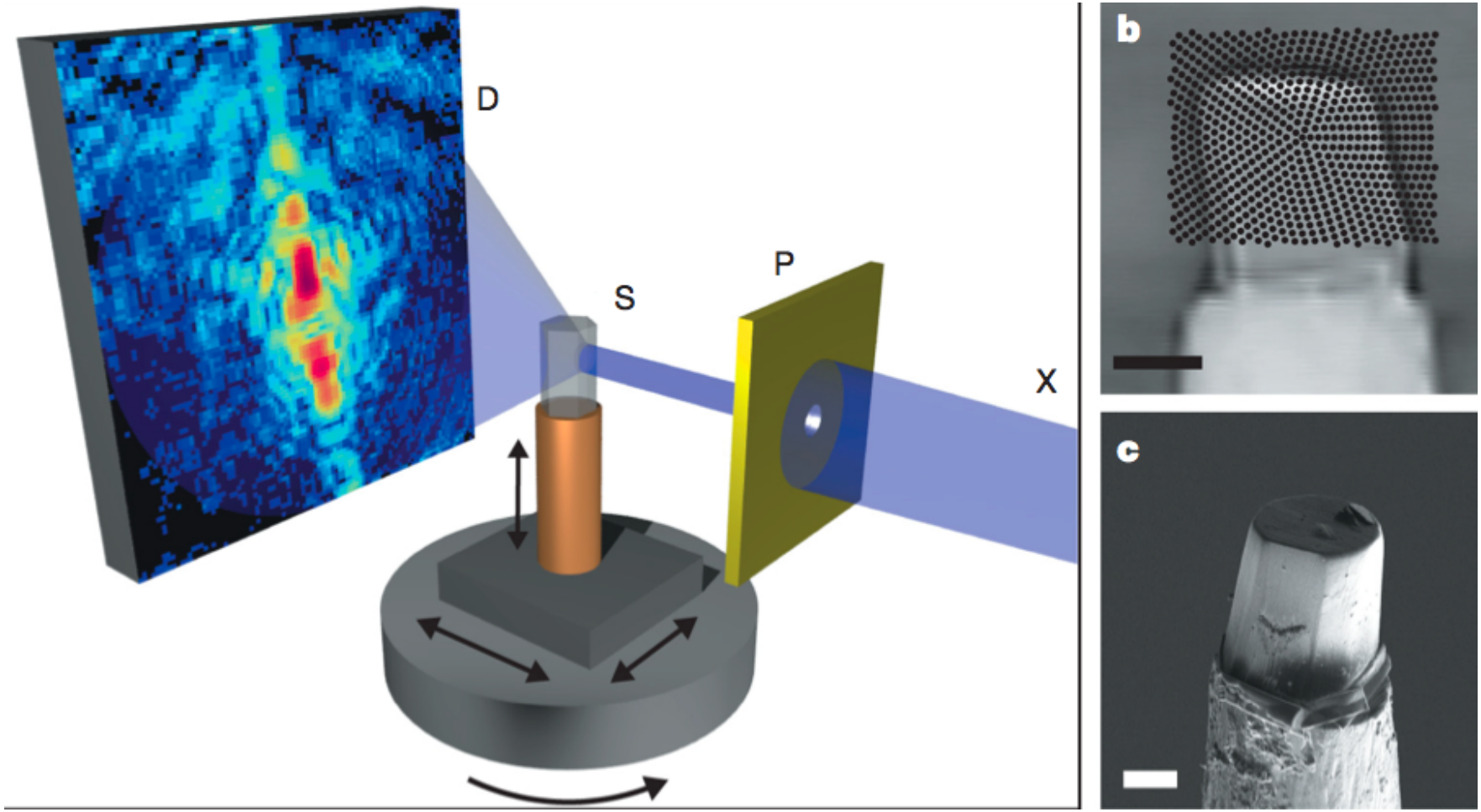
Amplitude (brightness)/ phase (colour)





Probe function

"Ptychographic X-ray computed tomography at the nanoscale" M. Dierolf, A. Menzel, P. Thibault, P. Schneider, C. Kewish, R. Wepf, O. Bunk & F. Pfeiffer, Nature 467 436 (2010)



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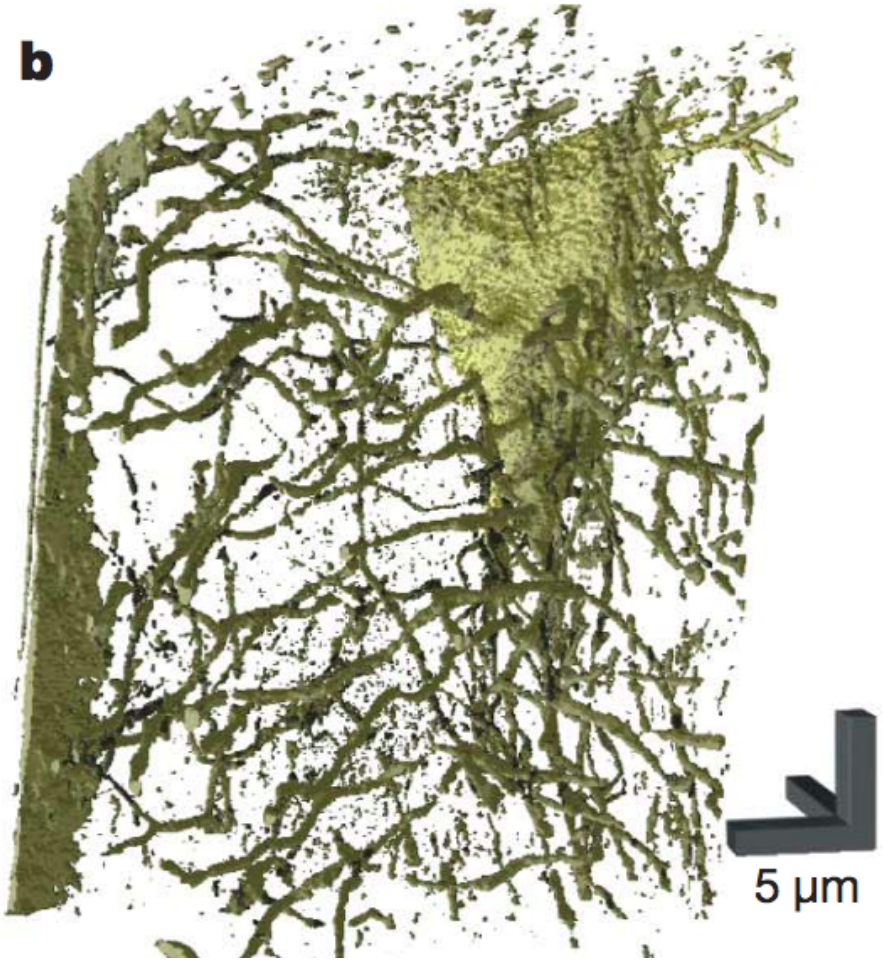
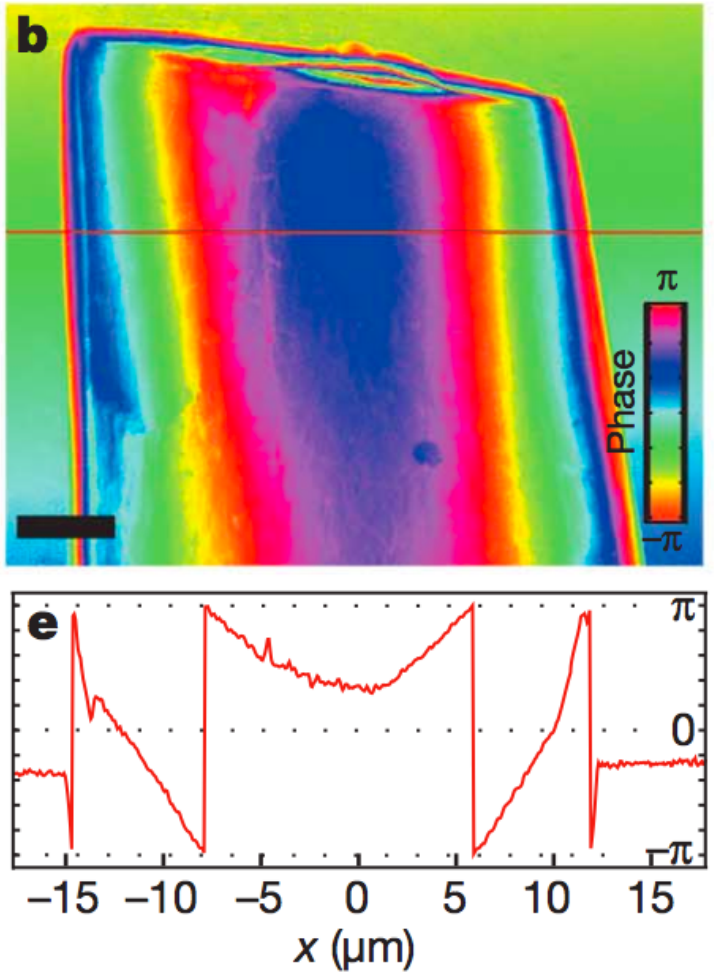
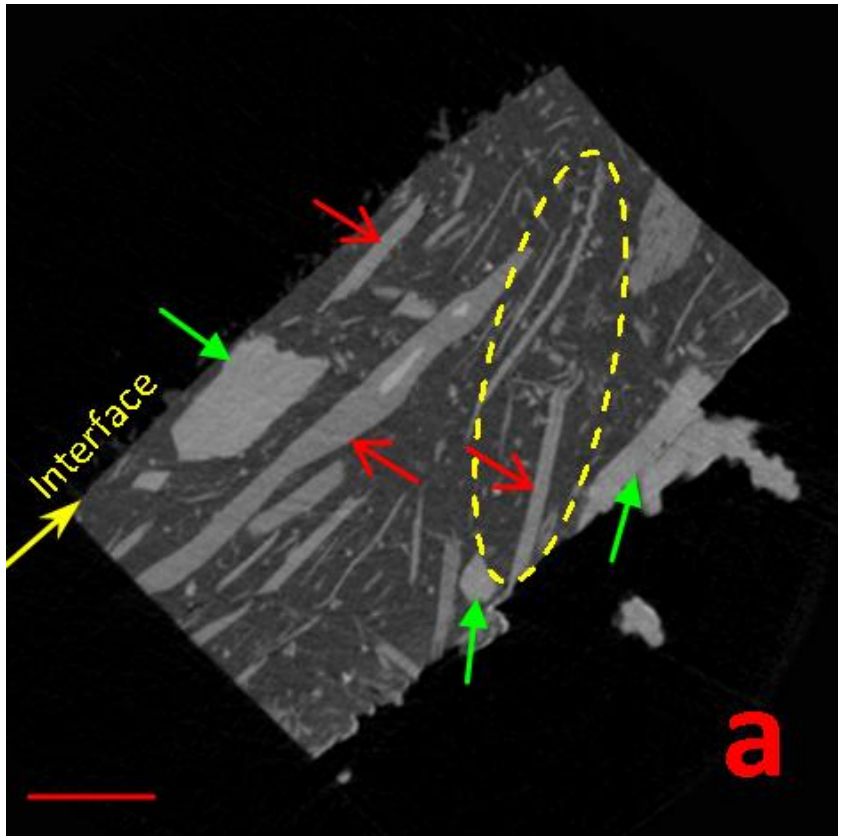
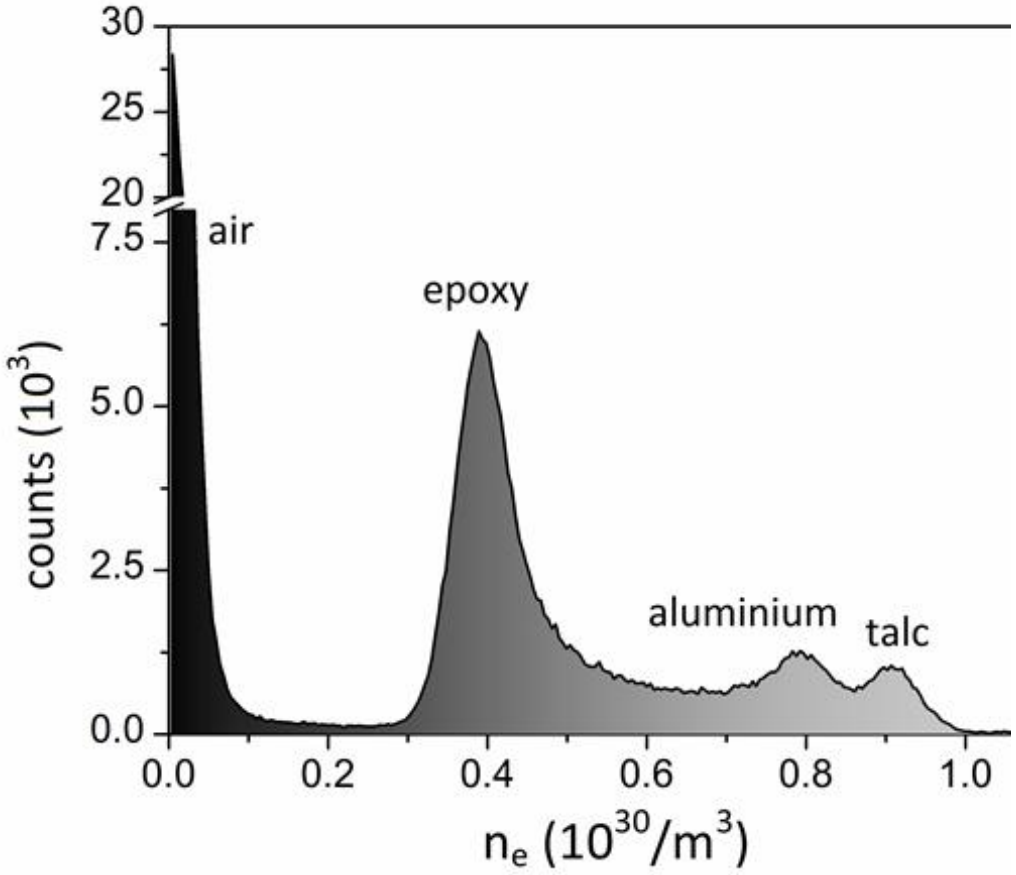


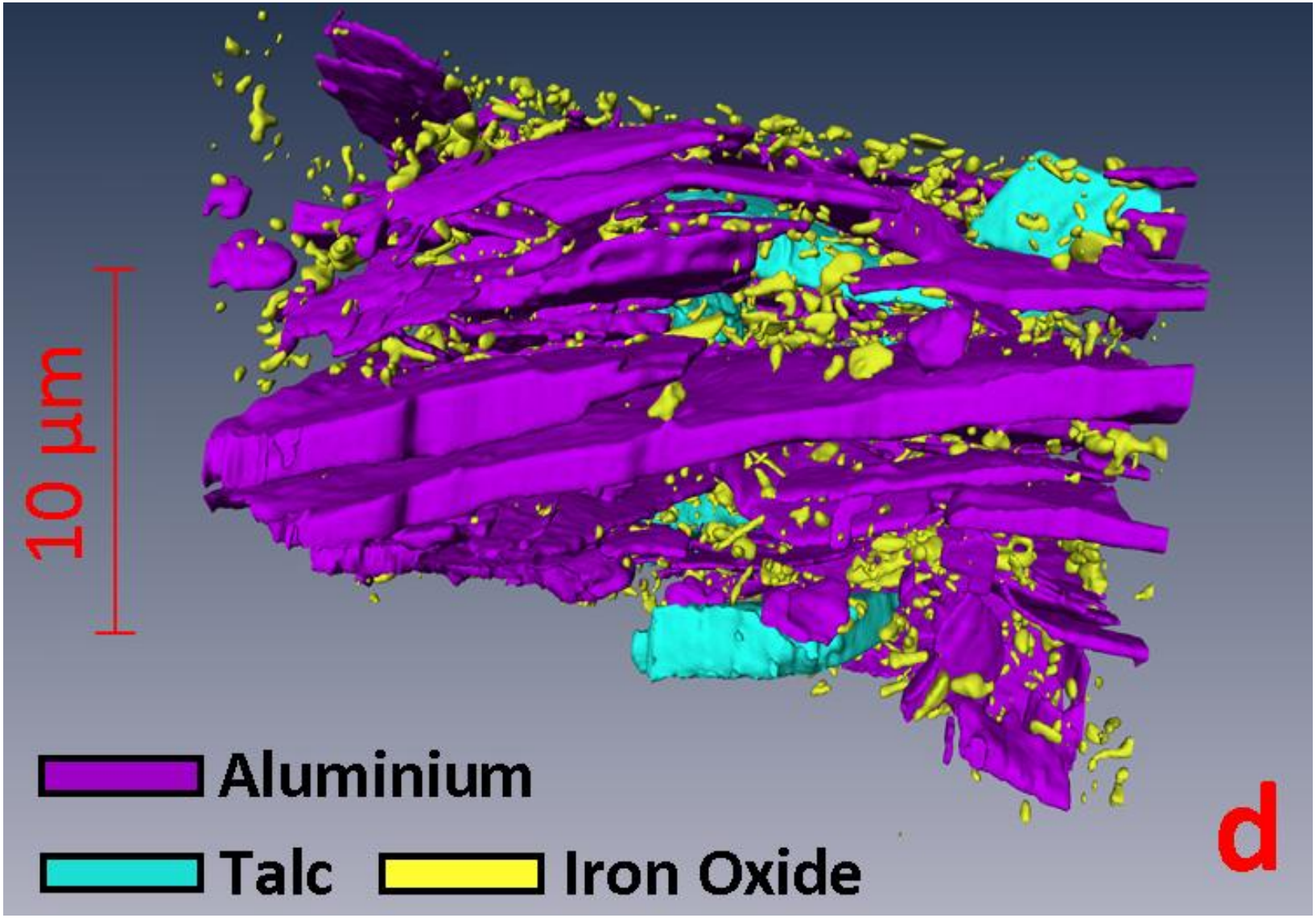


"Three-Dimensional Structure Analysis and Percolation Properties of a Barrier Marine Coating", Bo Chen, M. Guizar-Sicairos, G. Xiong, L. Shemilt, A. Diaz, J. Nutter, N. Burdet, S. Huo, J. Mancuso, A. Monteith, F. Vergeer, A. Burgess & I. Robinson, Nature Scientific Reports 3 1177 (2013)

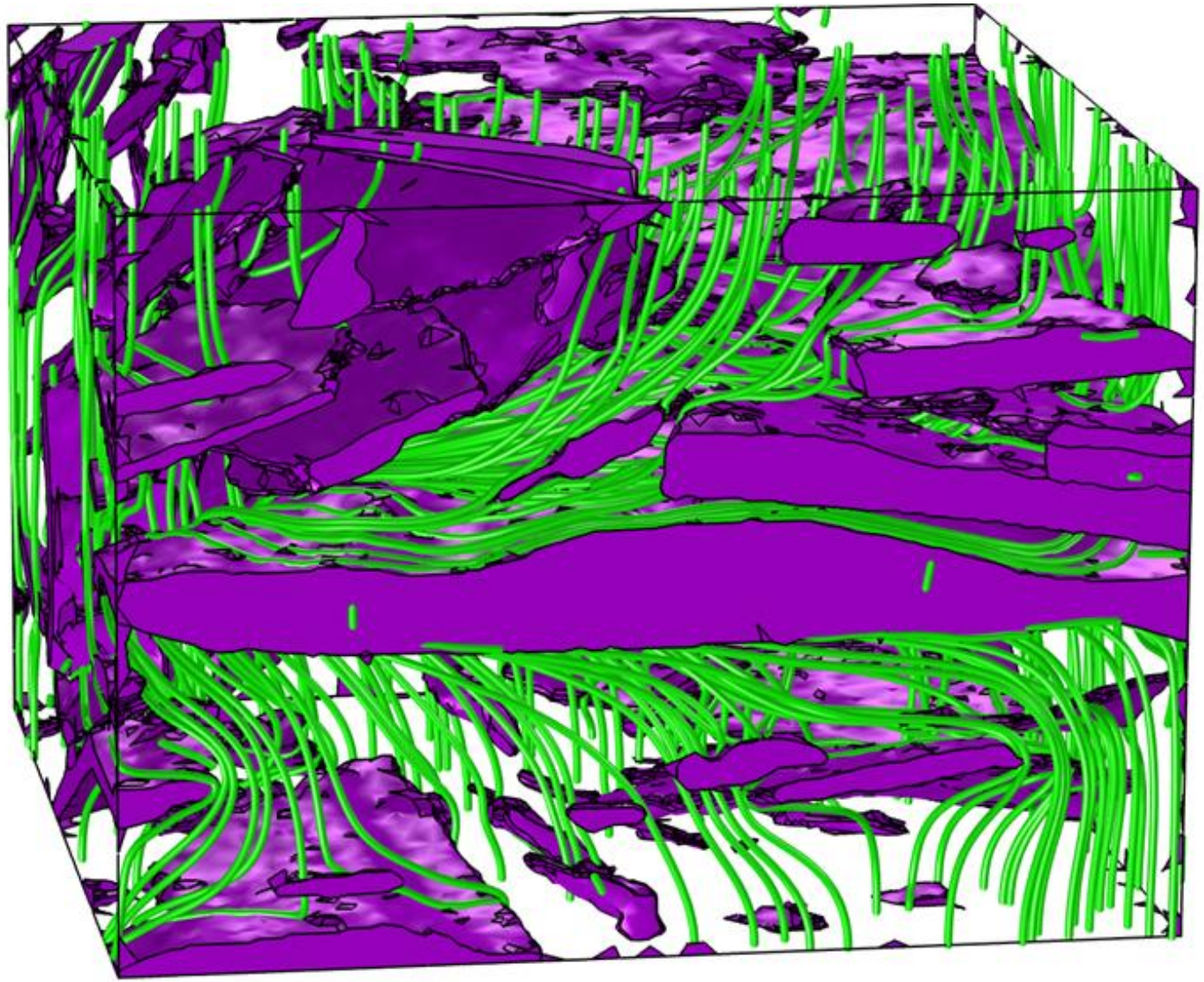




"Three-Dimensional Structure Analysis and Percolation Properties of a Barrier Marine Coating", Bo Chen et al (2013)



“Three-Dimensional Structure Analysis and Percolation Properties of a Barrier Marine Coating”, Bo Chen, et al (2013)



Conclusions

- Ptychography has ‘ultimate’ phase contrast
- Collagen Fibrils within intact tendon
- 3D imaging needed in materials & biology
- Ptycho-tomography demonstrations