

Probing Strain and Defects in Single Crystals with CDI

Advanced Photon Source, Argonne National Lab
Ross Harder

APS Sector 34ID-C

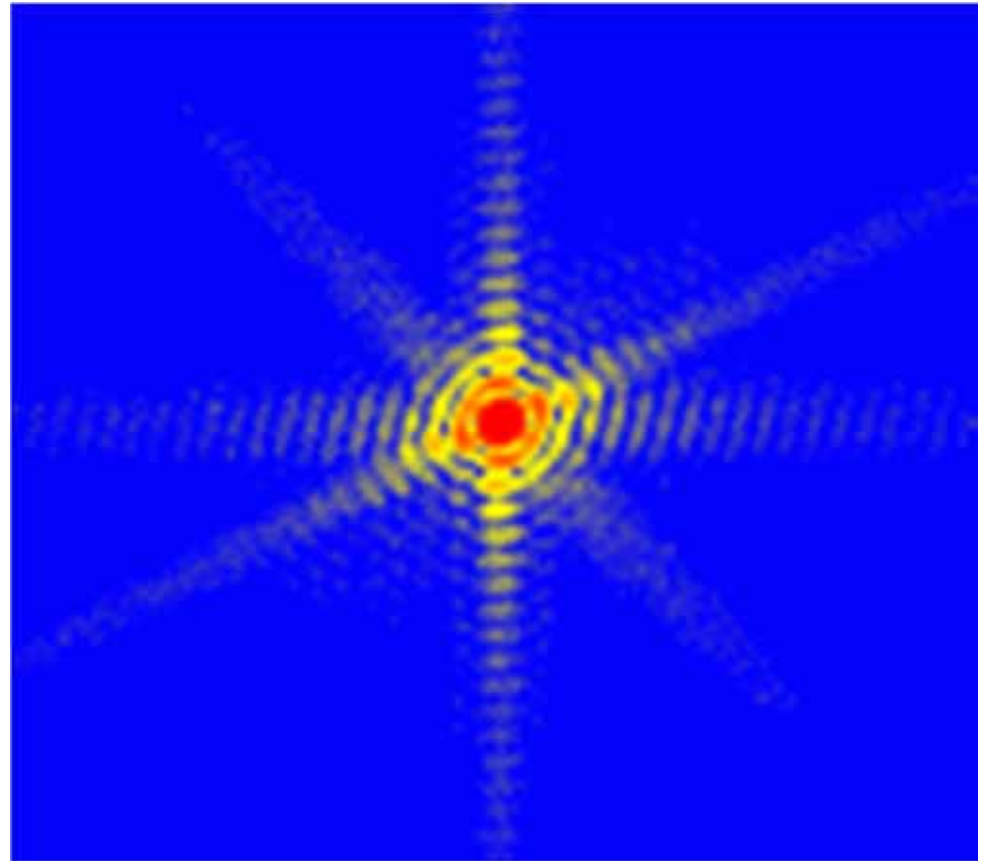
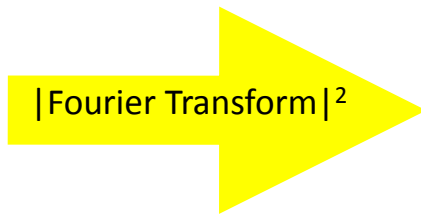
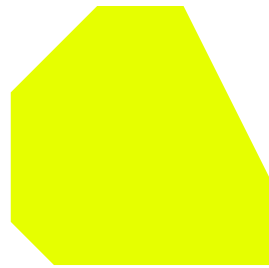
HPSynC, Carnegie Institution of Washington
Wenge Yang
Xiaoqing Huang

Northwestern University, Materials Science
Karen Chen
David Dunand

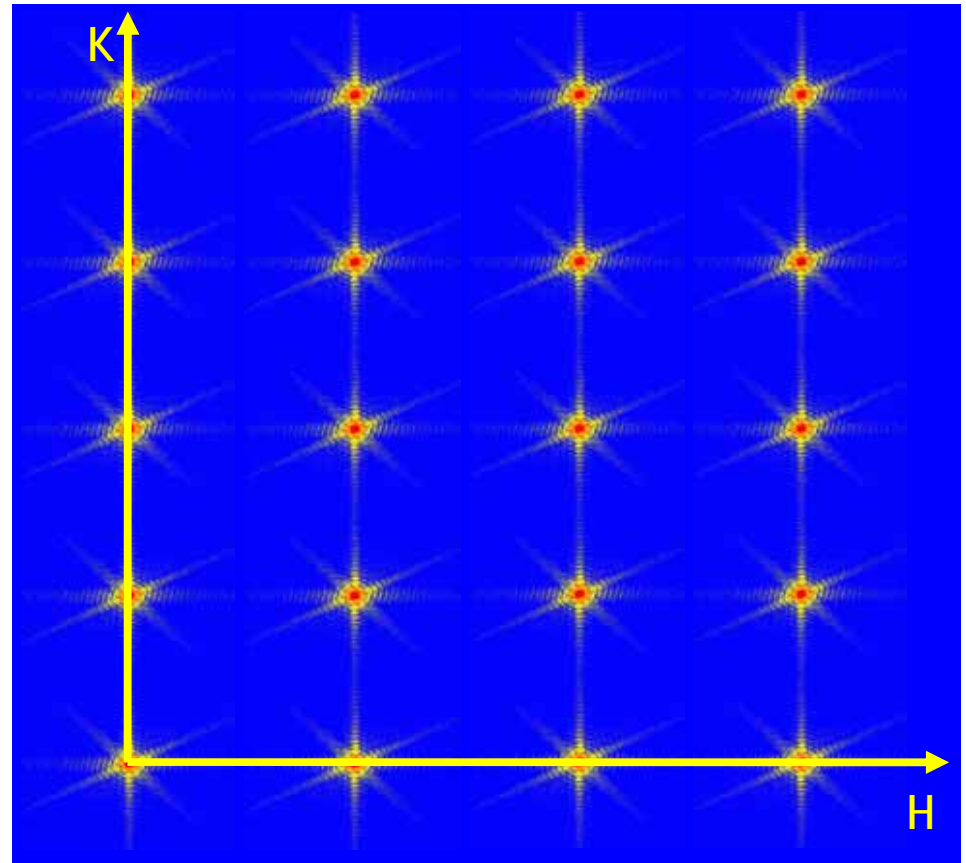
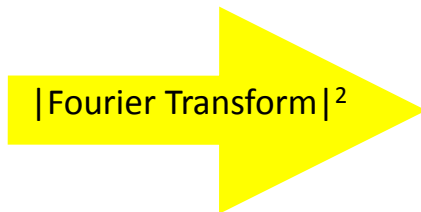
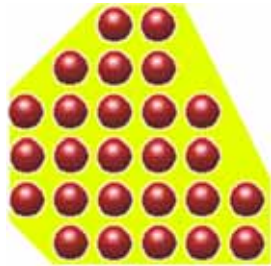
London Centre for Nanotechnology, University College London
Steven Leake
Loren Beitra
Marcus Newton
I.K. Robinson



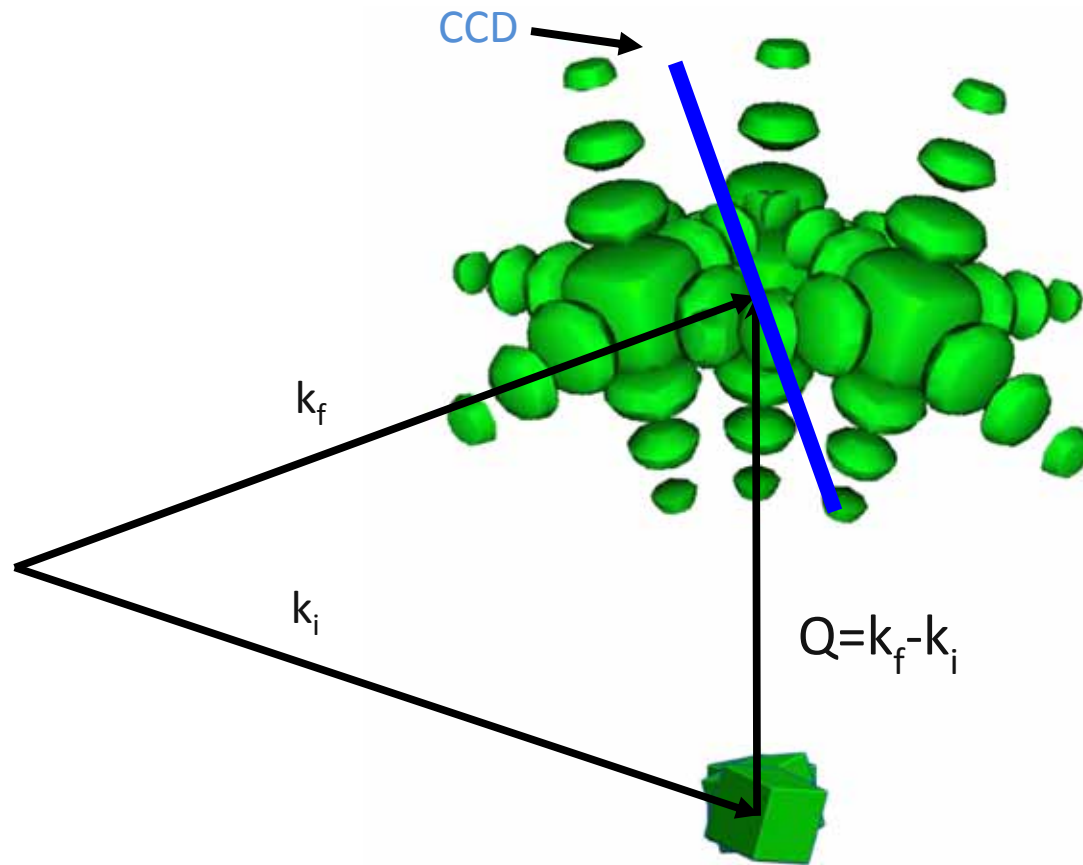
Coherent Diffraction from Crystals



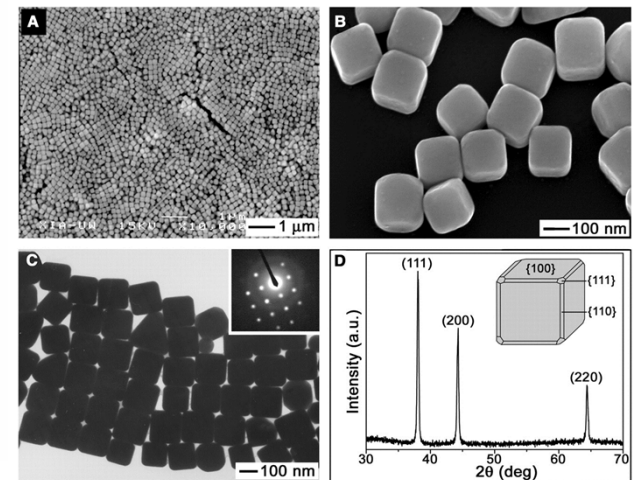
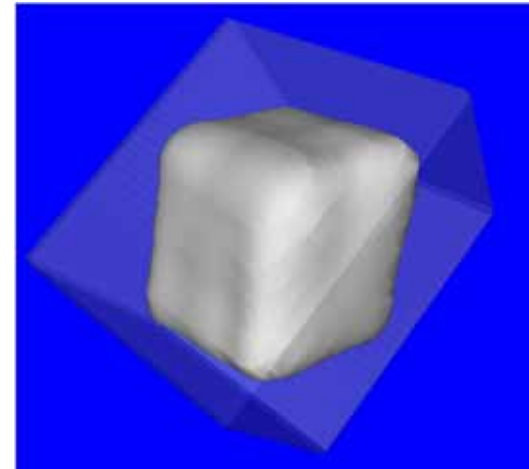
Coherent Diffraction from Crystals



Measuring 3D CXD



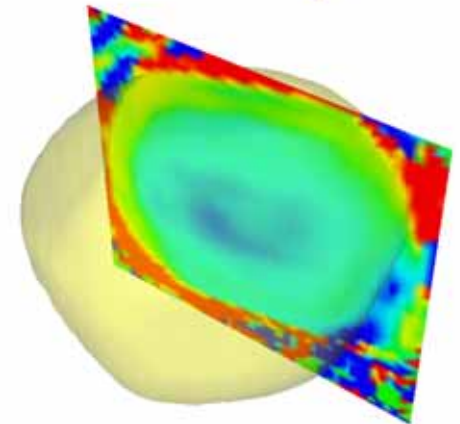
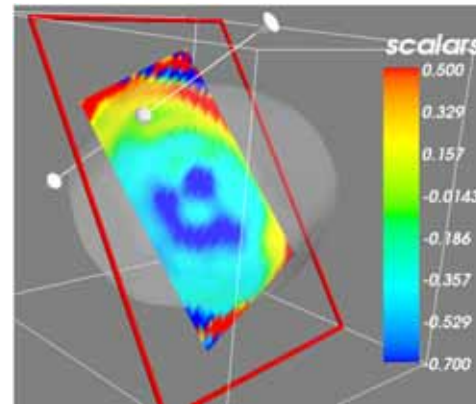
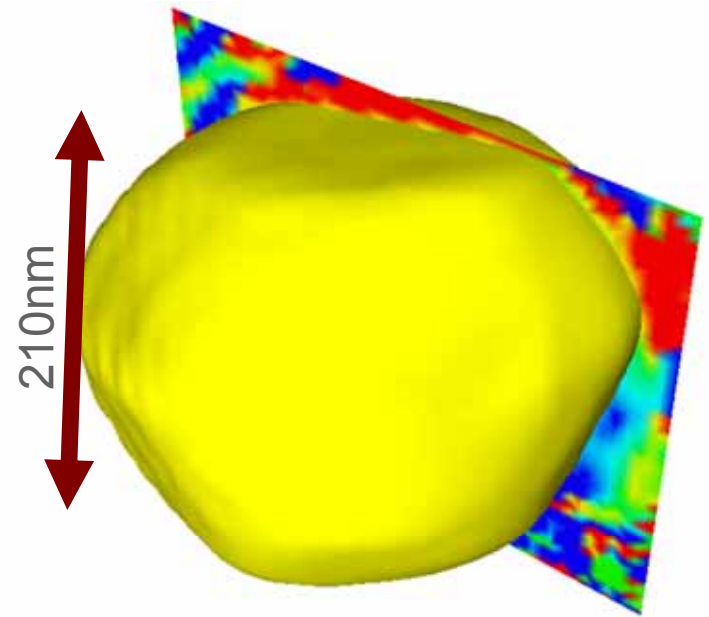
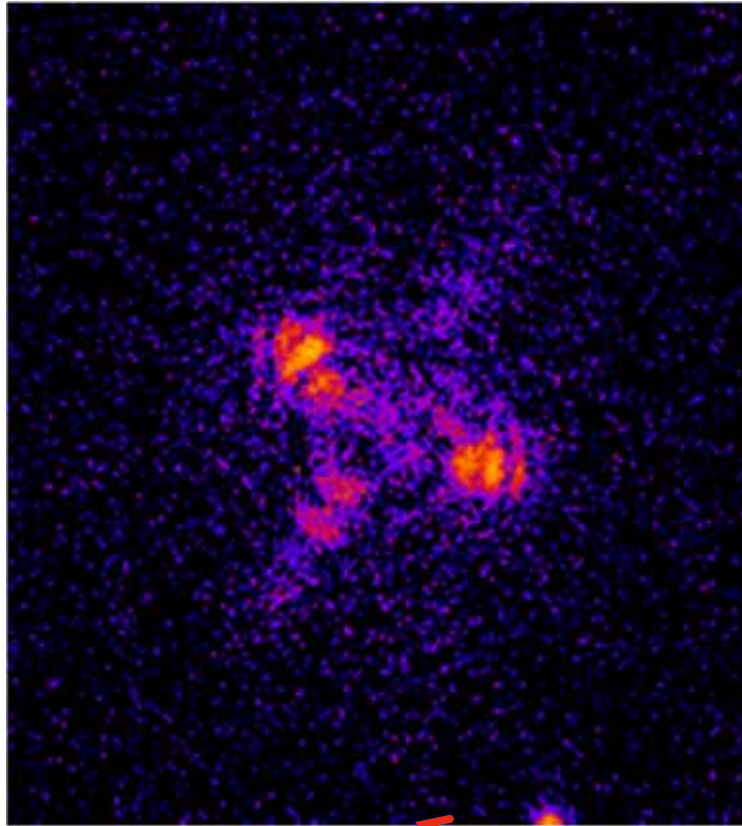
Silver Nano Cube (111)



Yugang Sun and Younan Xia,
Science 298 2177 (2003)



Hi Resolution Imaging?



At APS 34-ID-C:

9.25 hours of scanning

0.64 hours of x-ray exposure

~7nm data

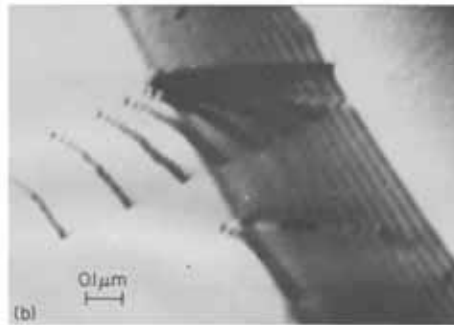
ERL (500x) → 10sec?

http://www.jwave.vt.edu/~rkriz/Projects/create_color_table/color_07.pdf



Slow Dynamics?

- 10 seconds is “almost” static on the scale of hours.
 - Grain Growth (annealing twins in fcc metals)
 - Defect annealing
 - Domain evolution
 - Surface Melting
 - Equilibrium Crystal Shapes

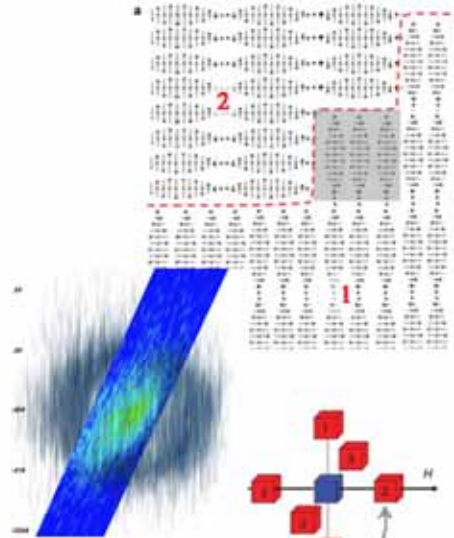
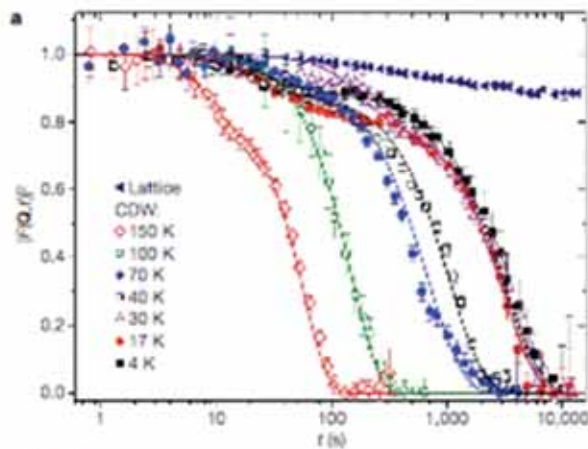


Meyers & Murr,
Acta Metallurgica (1977)

Grain boundary precipitates
in Ni superalloy

Courtesy of Jim Stubbins UIUC

Charge Density wave in Cr



O.G. Shpyrko et al.
Nature Vol. 447 (2007)

J. C. HEYRAUD and J. J. METOIS
Acta Metallurgica (1980)

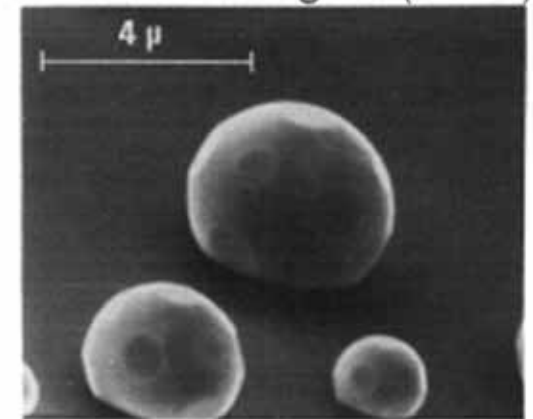
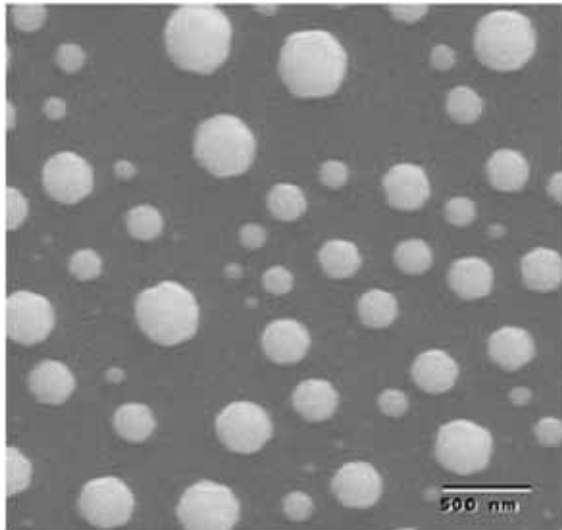


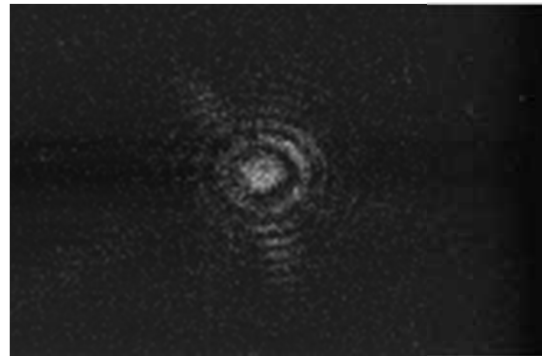
Fig. 2. Equilibrium shape of gold crystallites on graphite obtained after 70 h at 1273 K. Pressure $\sim 10^{-6}$ torr.



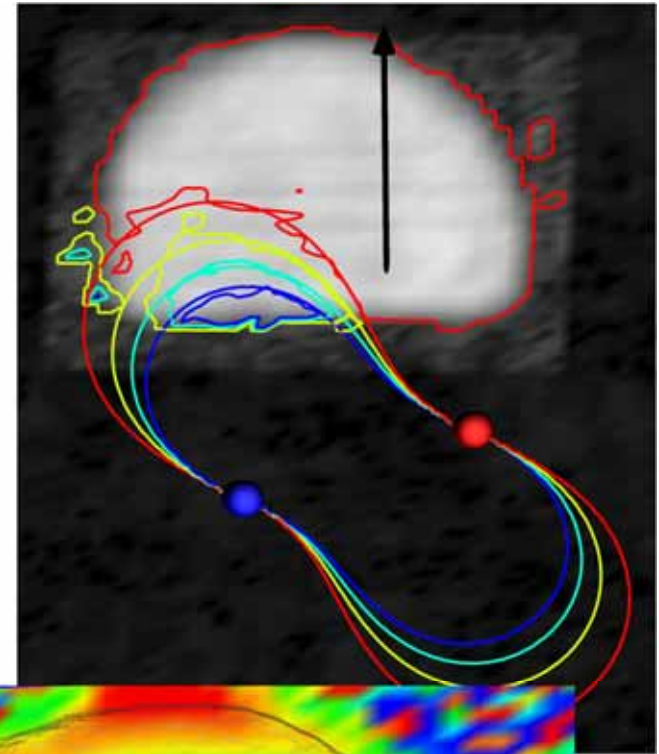
3D Reconstruction of Lead



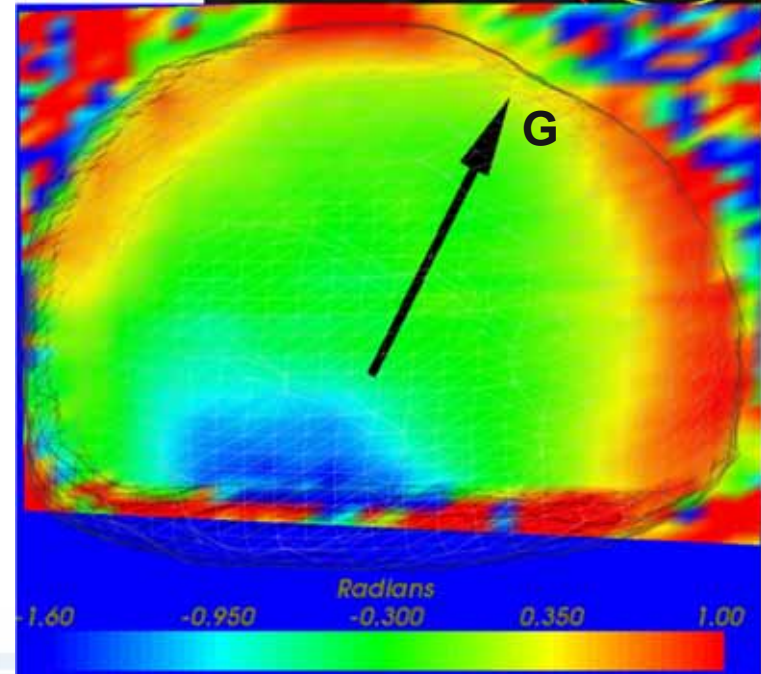
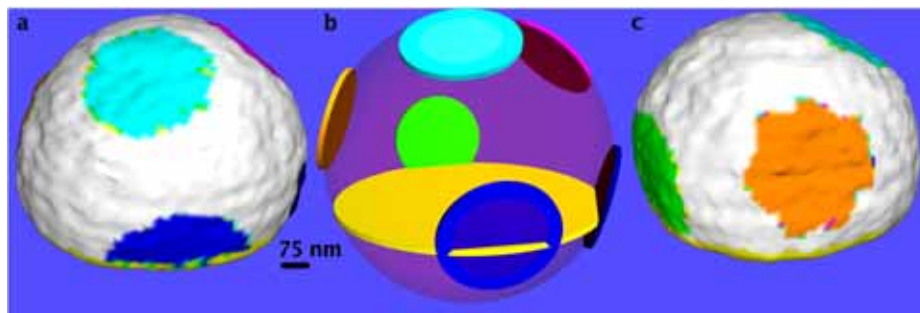
(111) Bragg spot



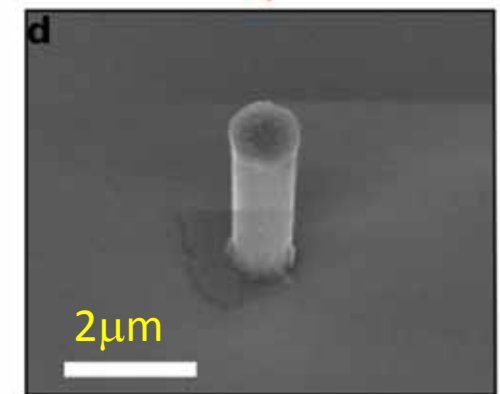
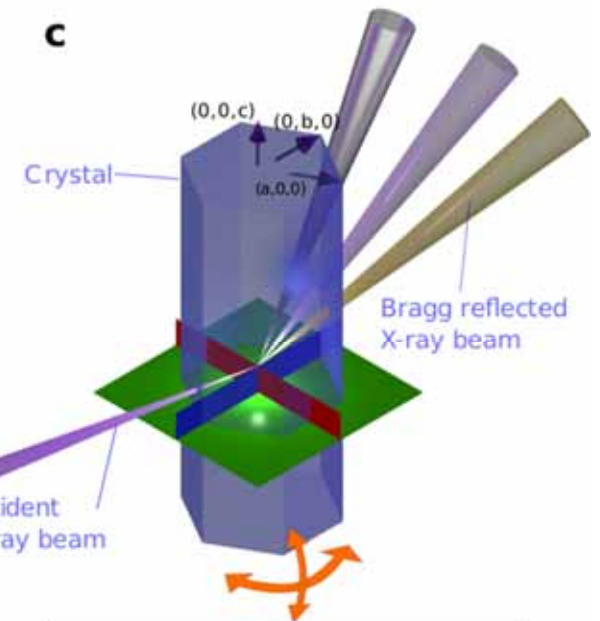
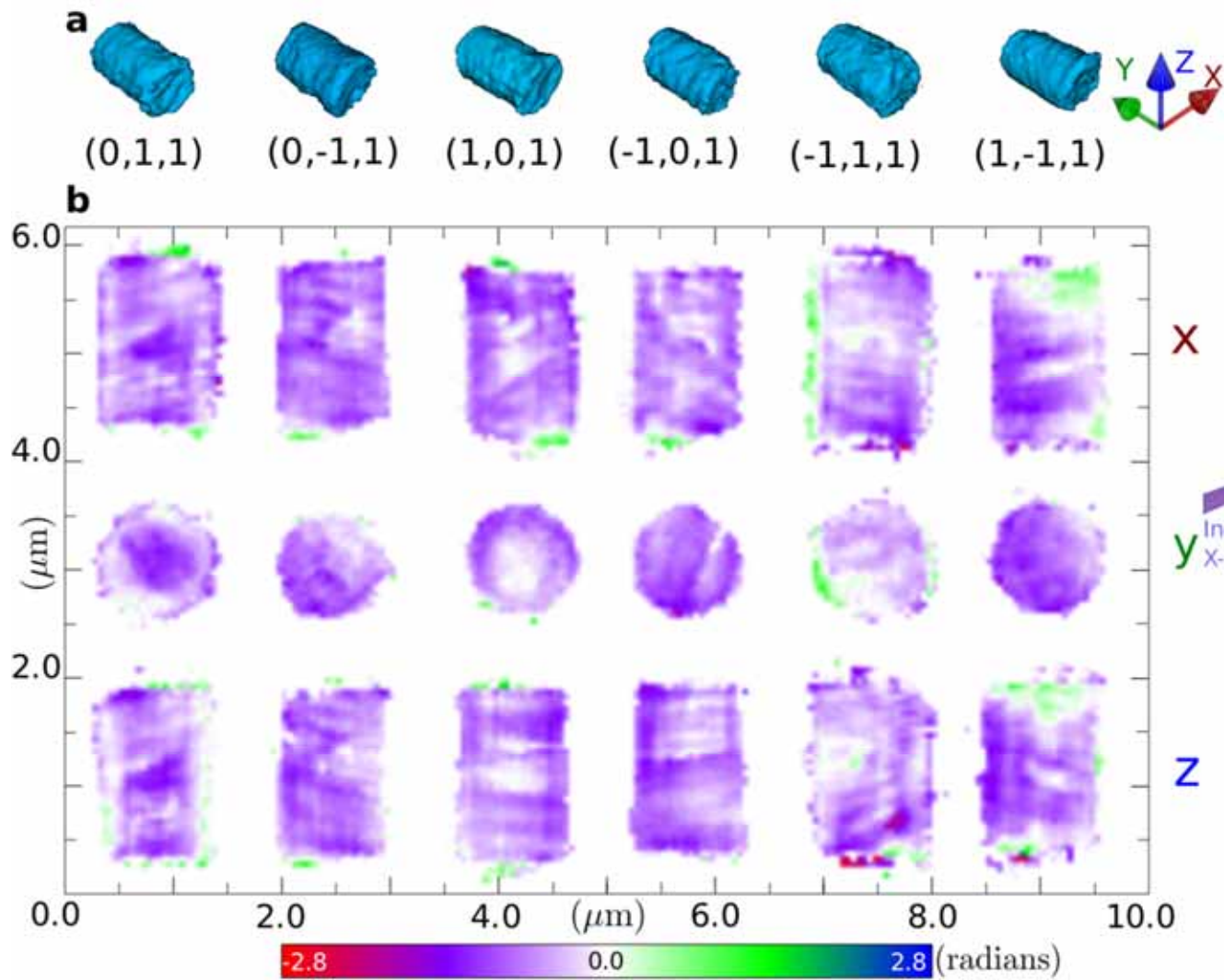
7.9 hour scan
2.1 hour x-ray exposure



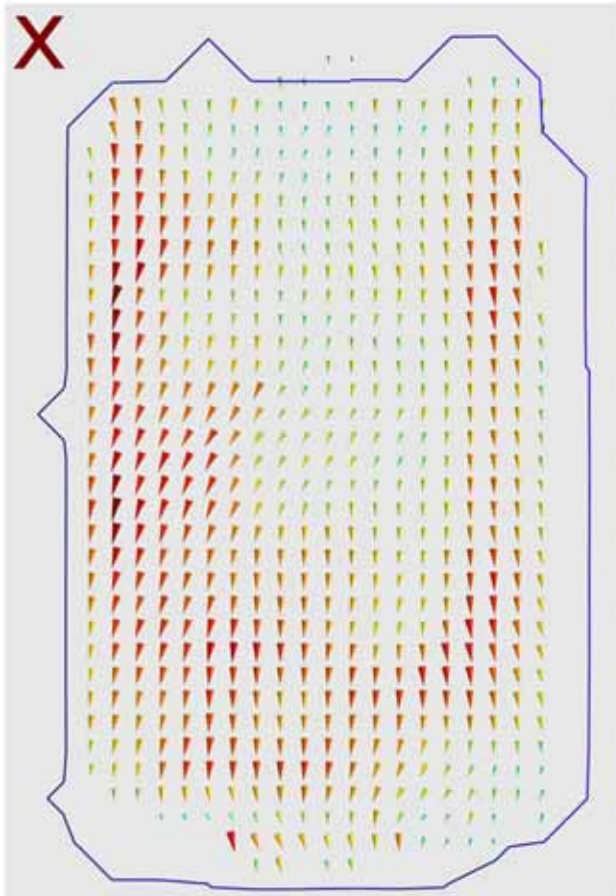
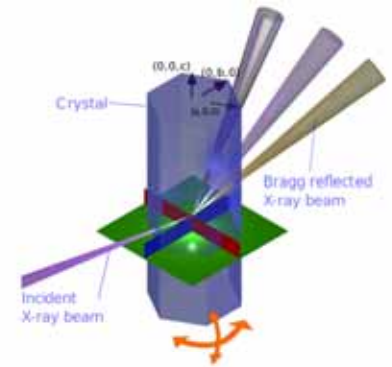
Nature, Vol. 442 p. 63 (July 6 2006)
PhysRevB.76.115425 (2007)



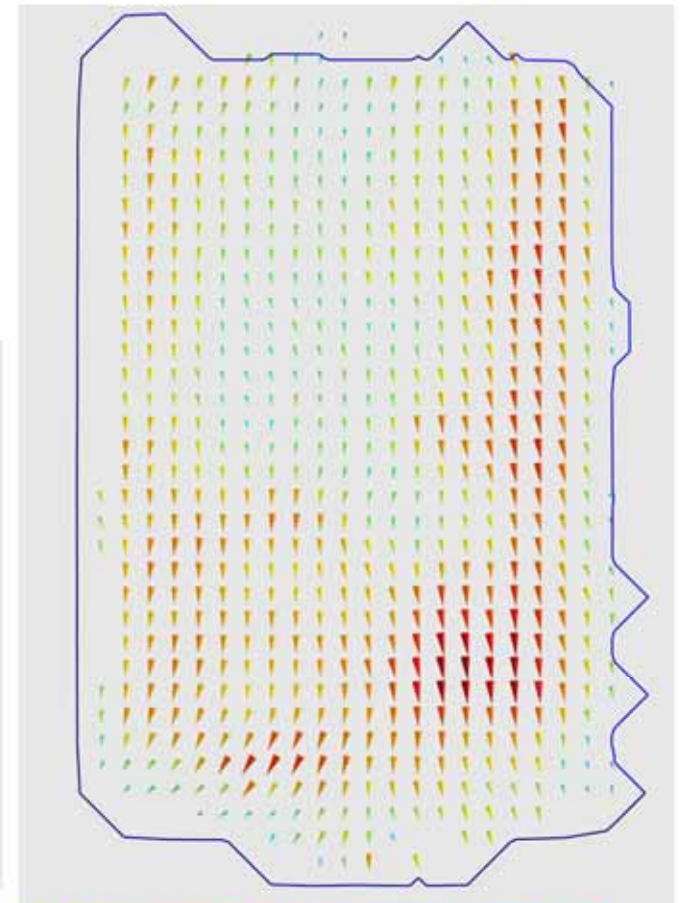
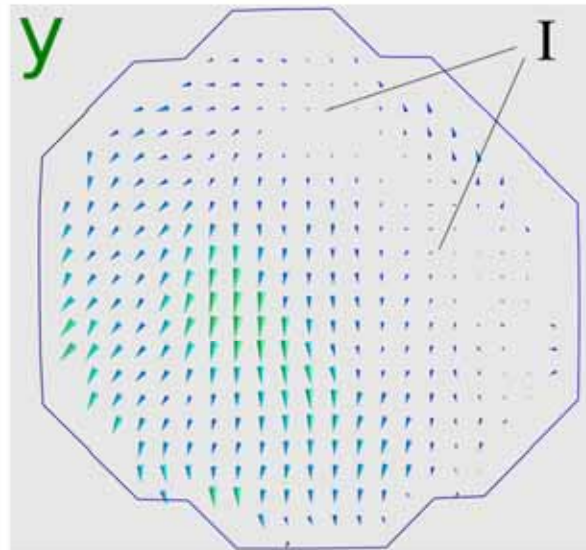
3D Strain Map in ZnO



3D Strain Map in ZnO



$$u_j = \xi_{ji} q_{ki} \phi_k; \quad \xi_{ji} = (q_{kj} q_{ki})^{-1}$$

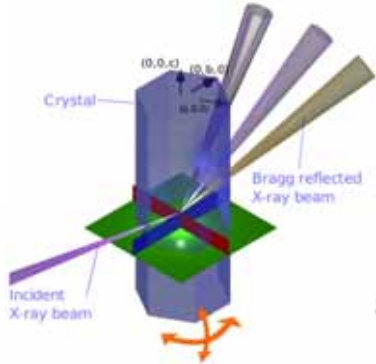


0.0 0.09 nm

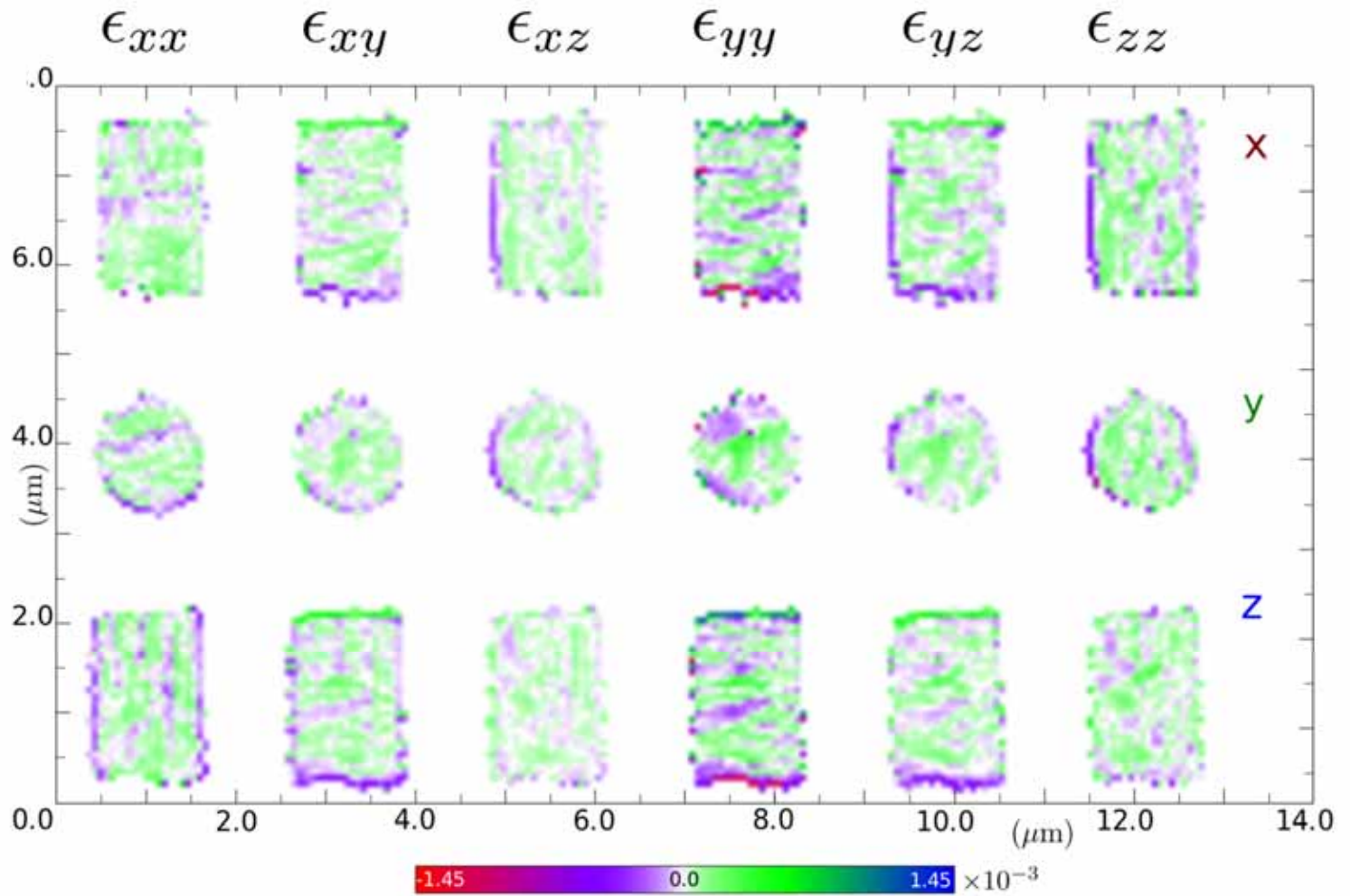
Nature Materials 9, 120 - 124 (2010)



3D Strain Map in ZnO

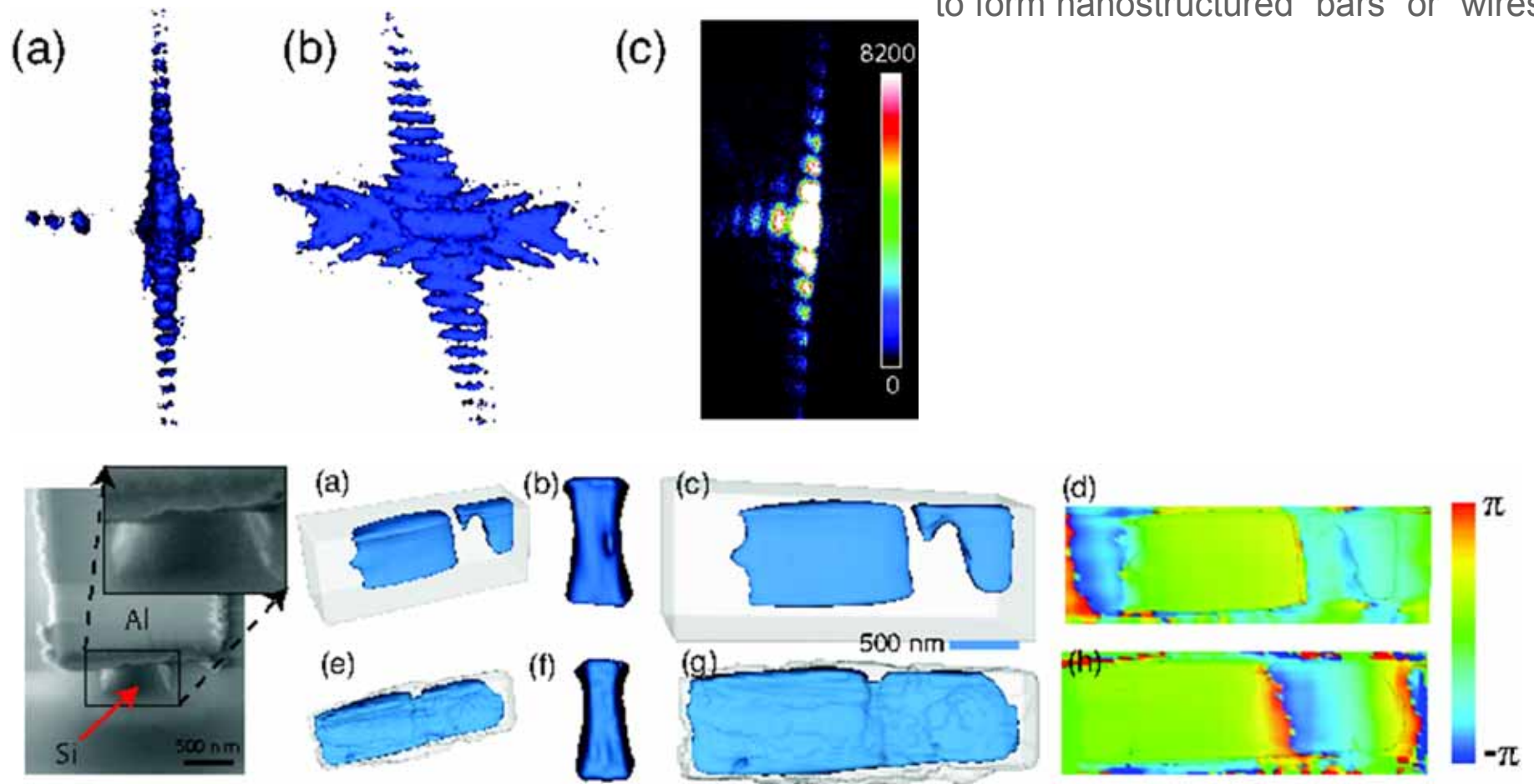


$$\epsilon_{ij} = \frac{1}{2} \left(\frac{\partial u_j}{\partial x_i} + \frac{\partial u_i}{\partial x_j} \right), \quad \tau_{ij} = \left(\frac{\partial u_j}{\partial x_i} - \frac{\partial u_i}{\partial x_j} \right)$$



Highly Strained crystals?

Silicon on Insulator (SOI)
Reactive Ion Etched from a thin film
to form nanostructured “bars” or “wires”



Huang et al. (submitted PRB)



Codes?

<http://code.google.com/p/pythonphasing/>



The screenshot shows the Google Code project page for 'pythonphasing'. The browser address bar displays 'code.google.com/p/pythonphasing/'. The page header includes the project name 'pythonphasing' and the description 'Phasing library for Coherent X-ray Diffraction'. A search bar is present with the text 'Search projects'. Below the header, there are navigation links: 'Project Home', 'Downloads', 'Wiki', 'Issues', 'Source', and 'Administer'. A 'Summary' section is visible, containing a tip: 'Tip: Project owners, see our [Getting Started](#) guide for steps to configure your project.' The 'Project Information' section includes a star icon for 'Star project', 'Activity' with a green bar and 'Medium' label, and 'Project feeds'. The main content area describes the library: 'A library of phasing codes, and other supporting codes, for inverting CXD to images. These are particularly developed for phasing CXD measured in the vicinity of Bragg spots at APS 34id-c. The majority of the library is written in C and run from python scripts. The C code is wrapped with swig. Documentation is basically API docs. The phasing scripts have slightly better docs.'

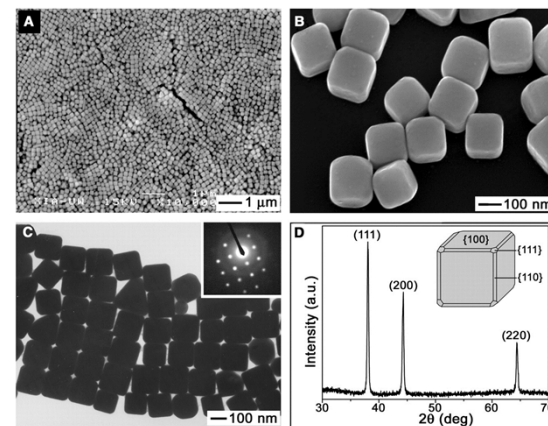
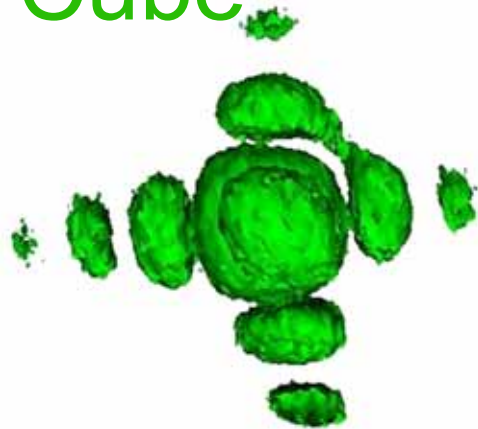
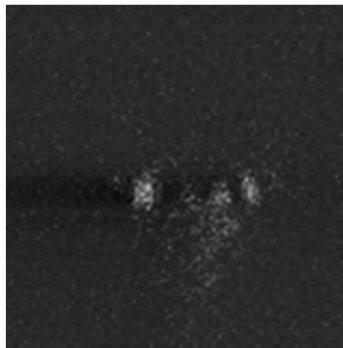
<http://code.google.com/p/mypythonphasing/>

<http://code.google.com/p/pythonphasing-scripts/>

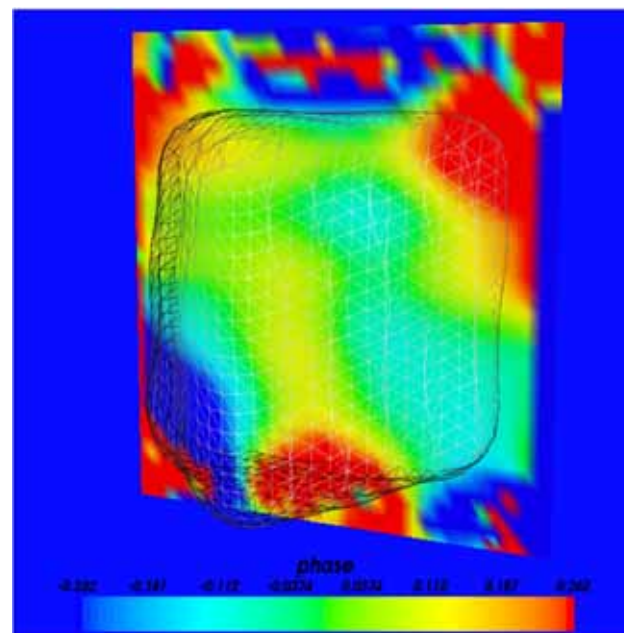
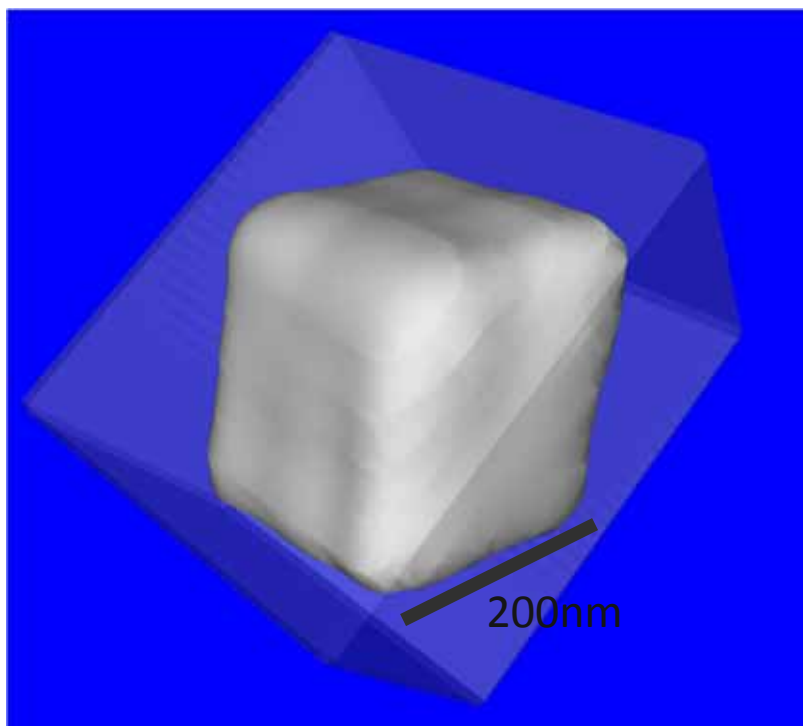
<http://groups.google.com/group/pythonphasing>



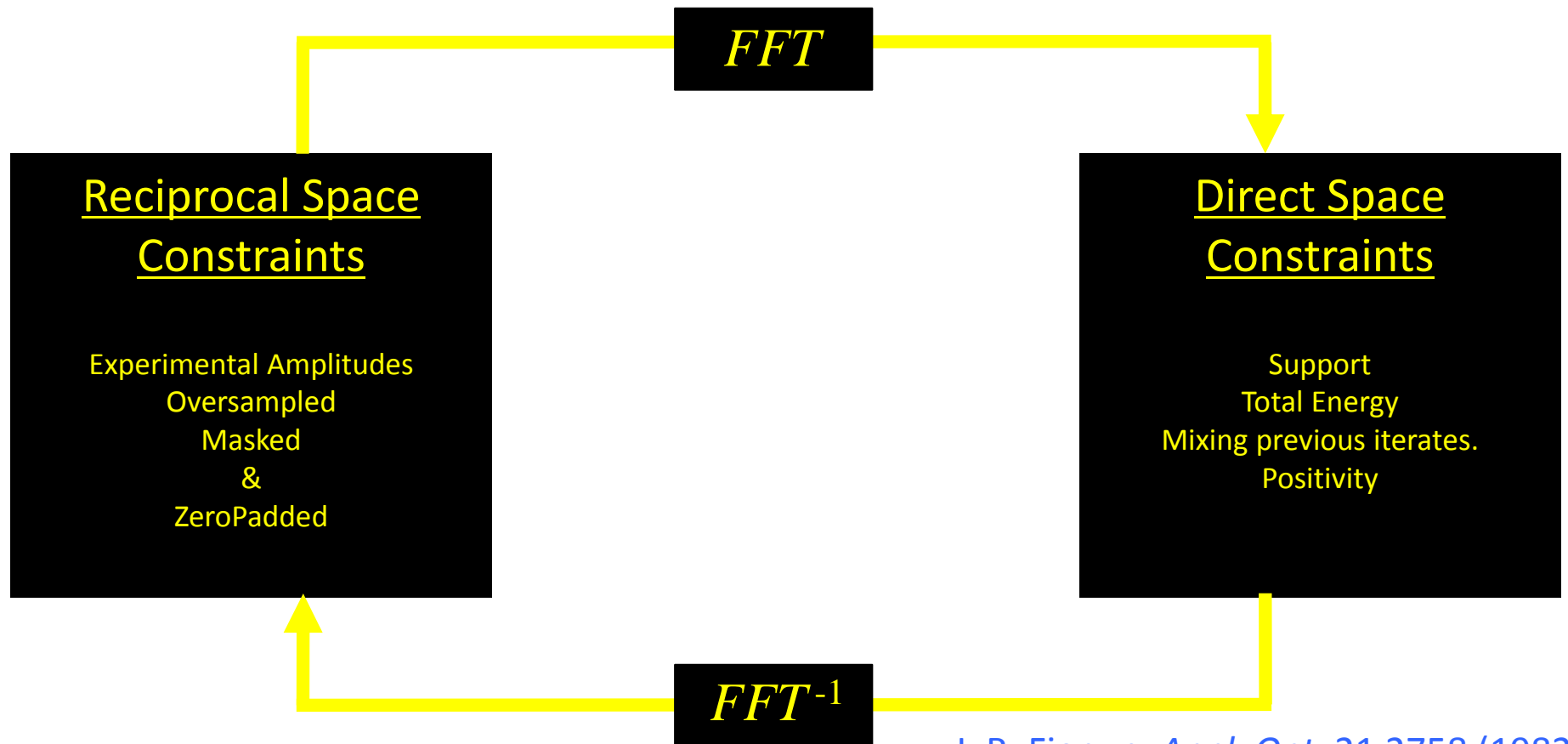
3D Ag Nano Cube



Yugang Sun and Younan Xia,
Science 298 2177 (2003)



Input Output Algorithms

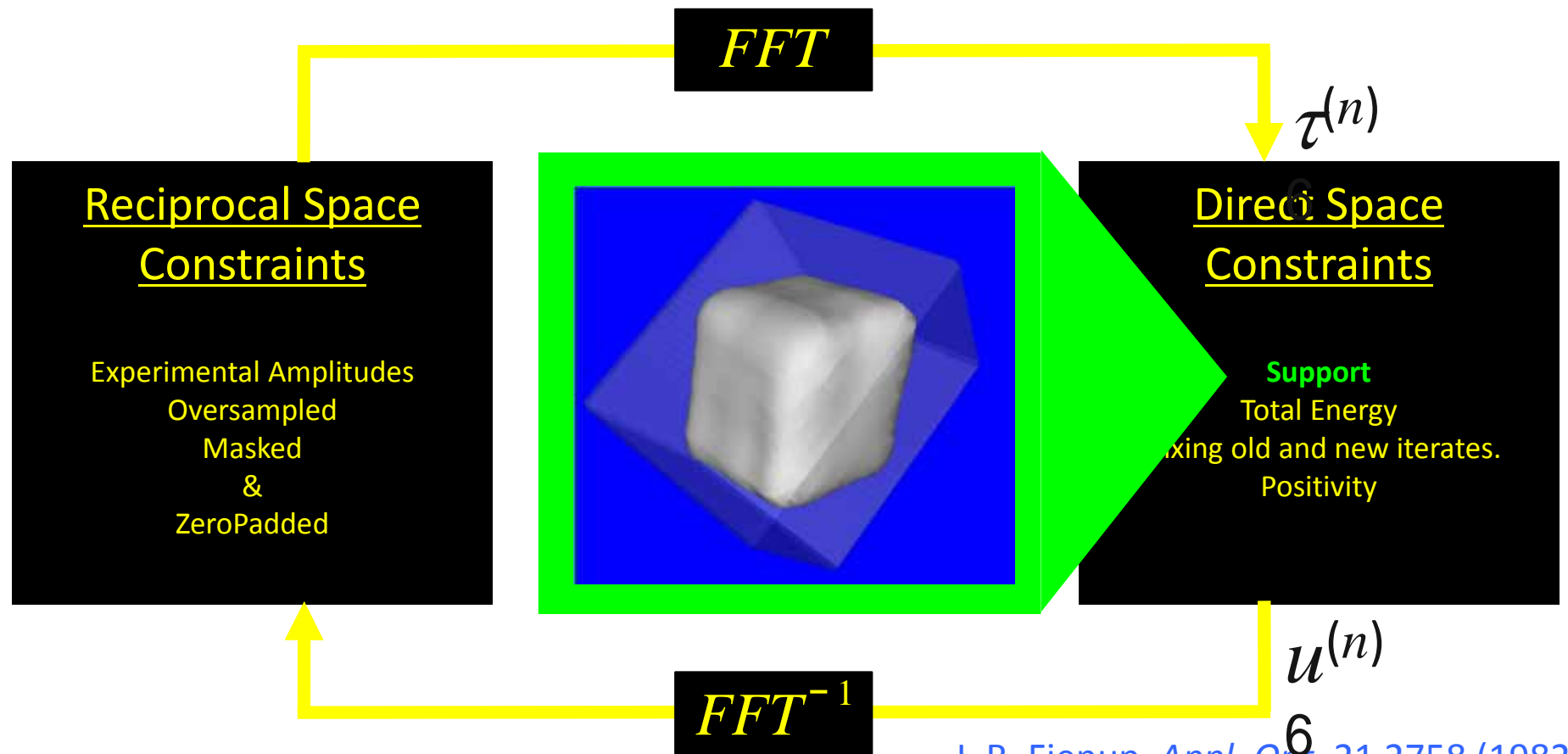


J. R. Fienup *Appl. Opt.* 21 2758 (1982)
Collins *Nature* 298, 49 (1982)

R. W. Gerchberg and W. O. Saxton *Optik* 35 237 (1972)



Input Output Algorithms

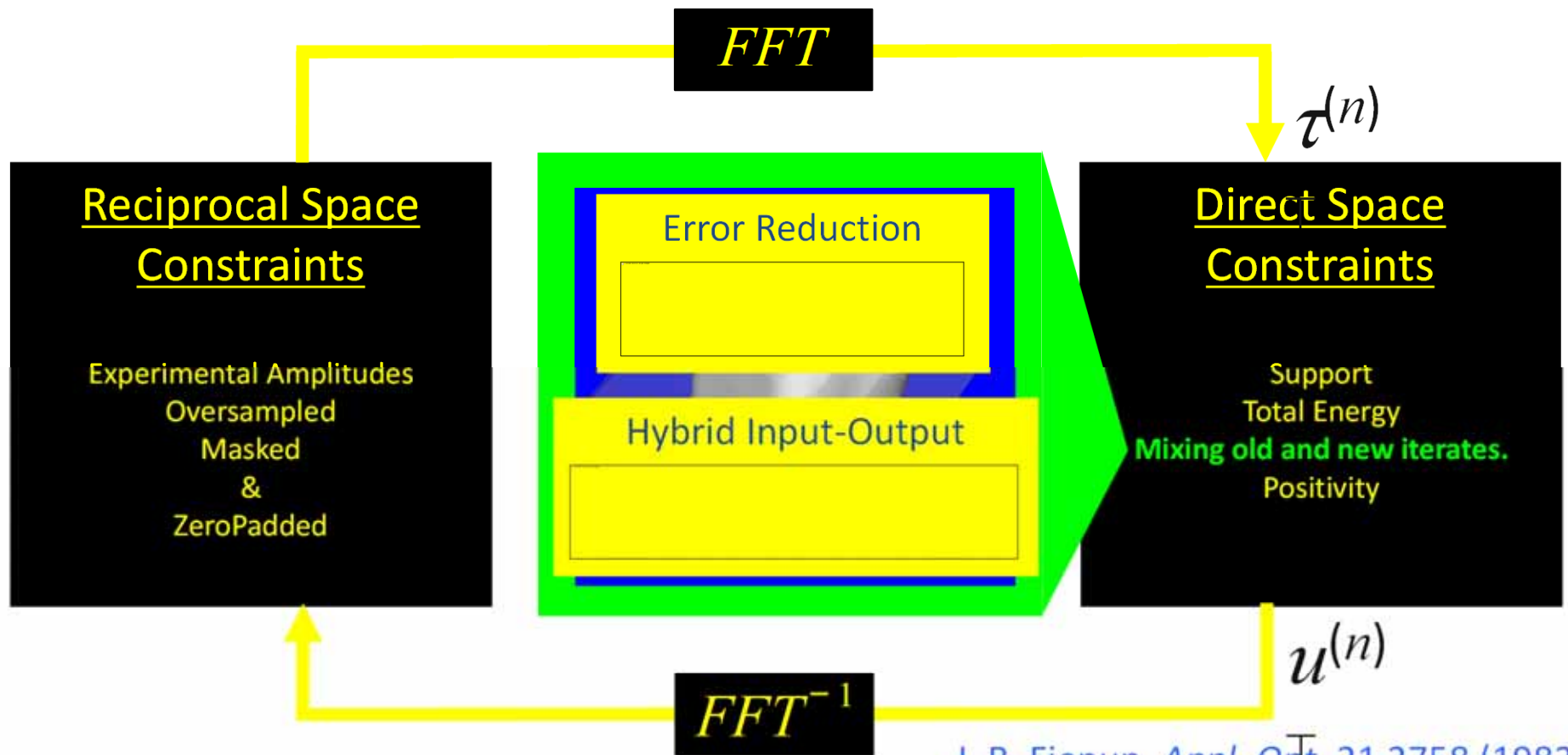


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Input Output Algorithms

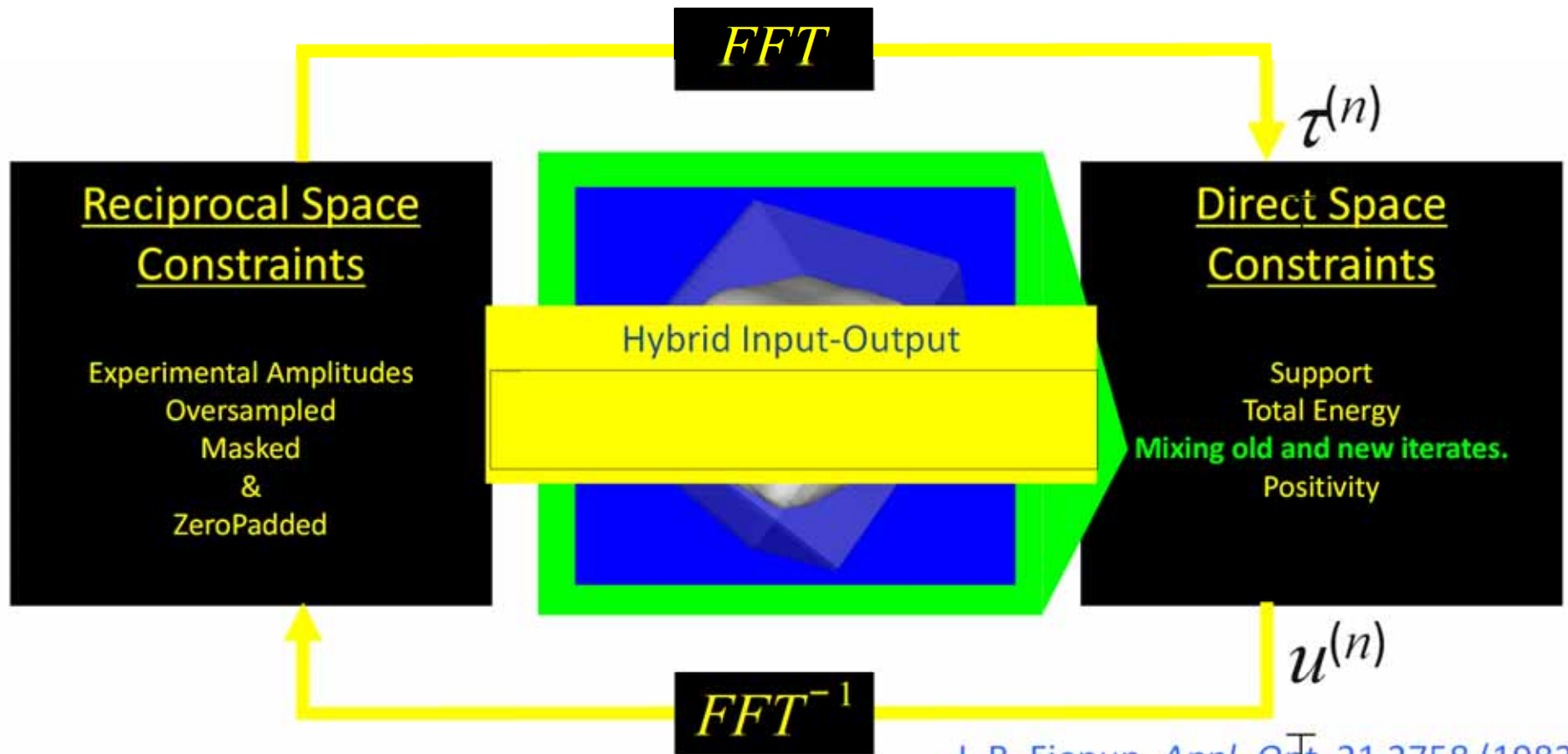


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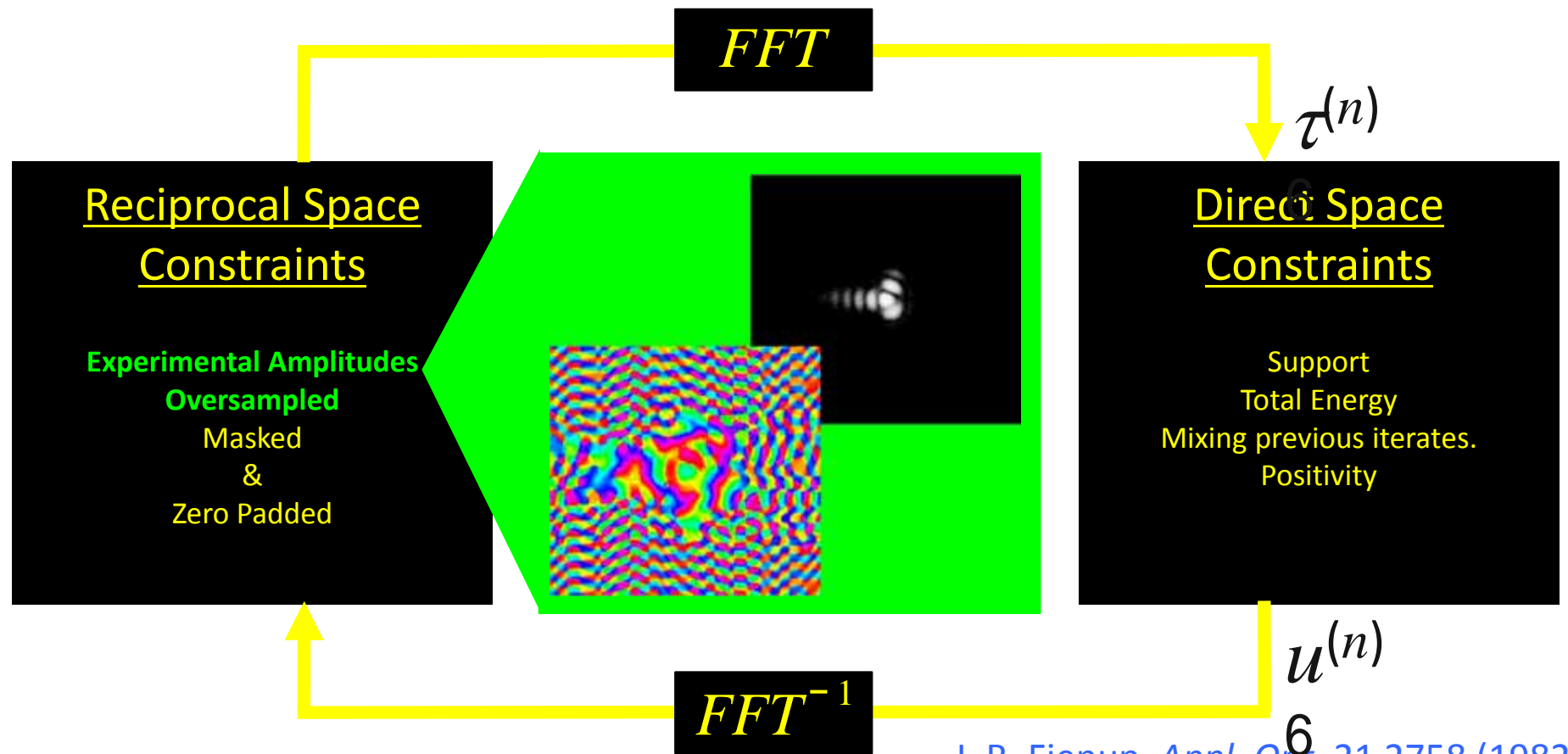


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