

Nanometer Scale Imaging Through Coherent X-ray Diffraction

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APS Sector 34ID-C

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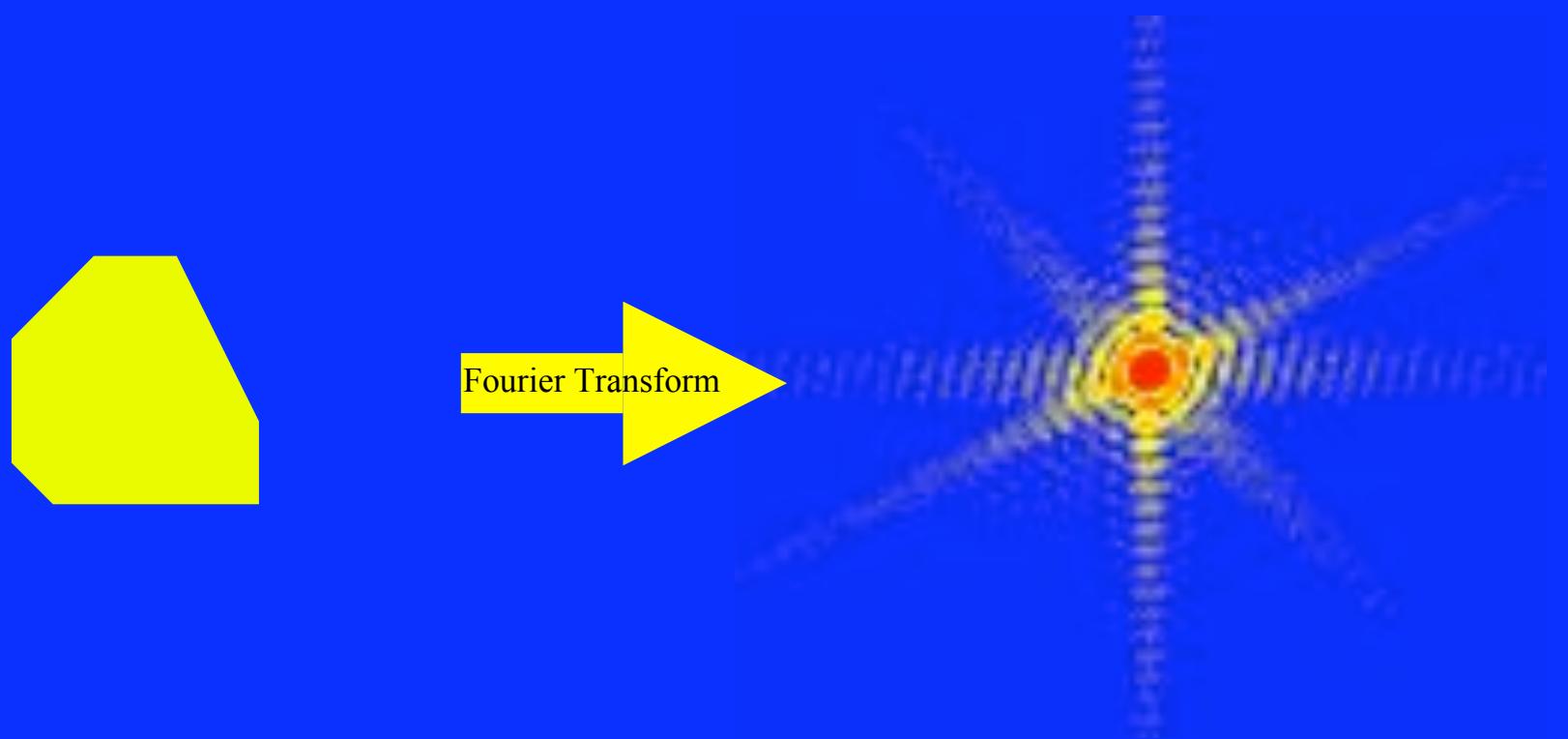
³ Dept. of Physics La Trobe University, Victoria Australia

⁴ School of Physics University of Melbourne Australia

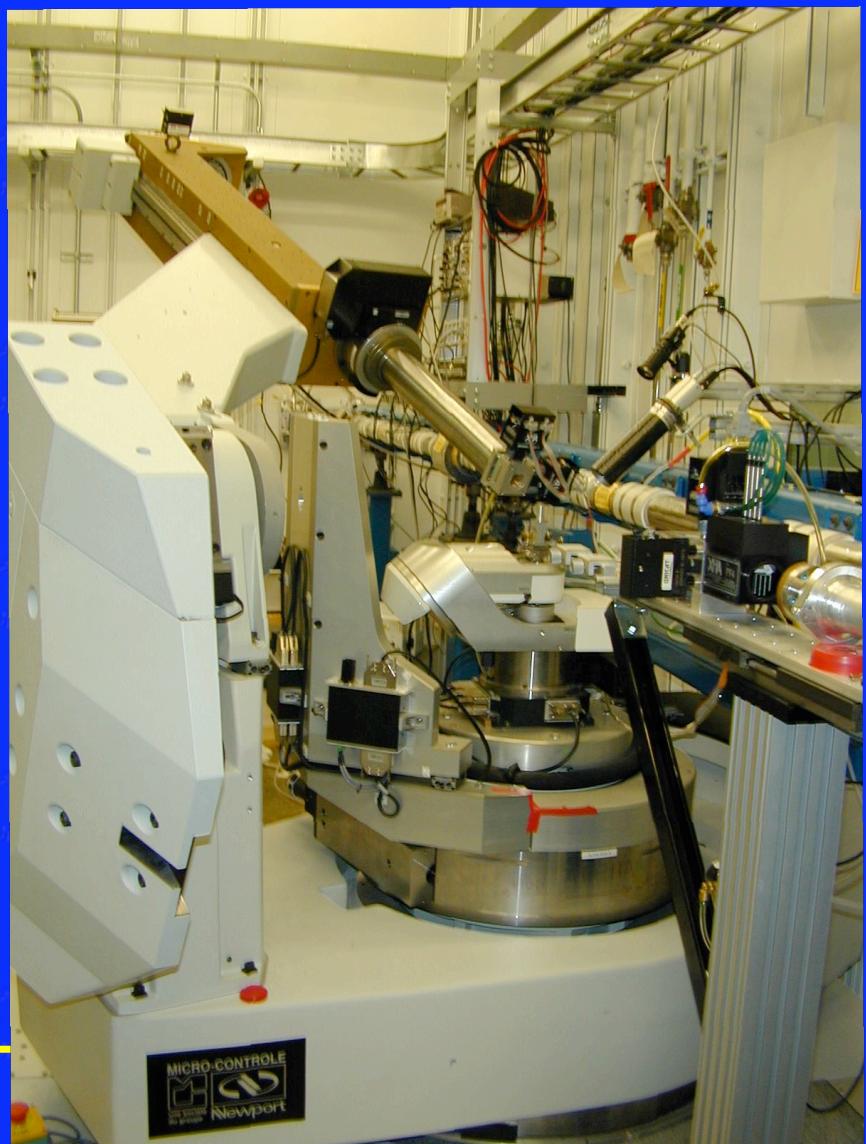
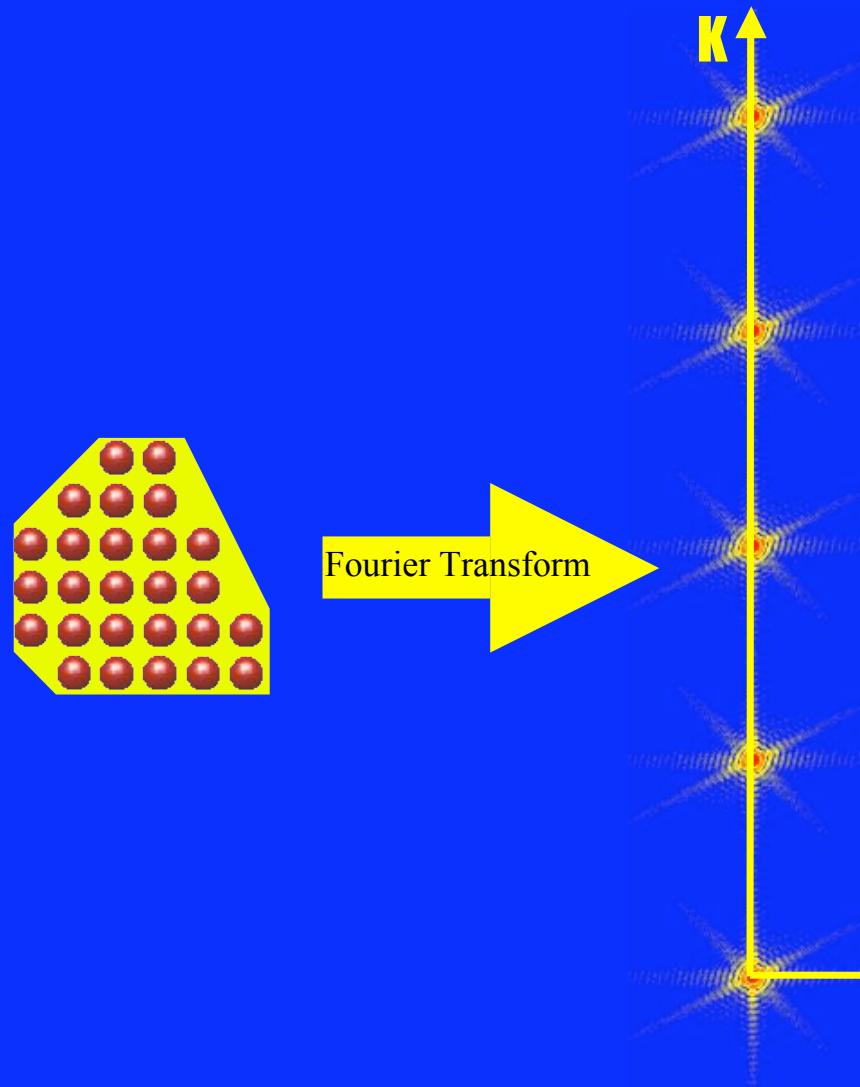
⁵ HASYLAB, DESY Hamburg Germany

⁶ Advanced Photon Source, Argonne National Lab

Coherent Diffraction from Crystals

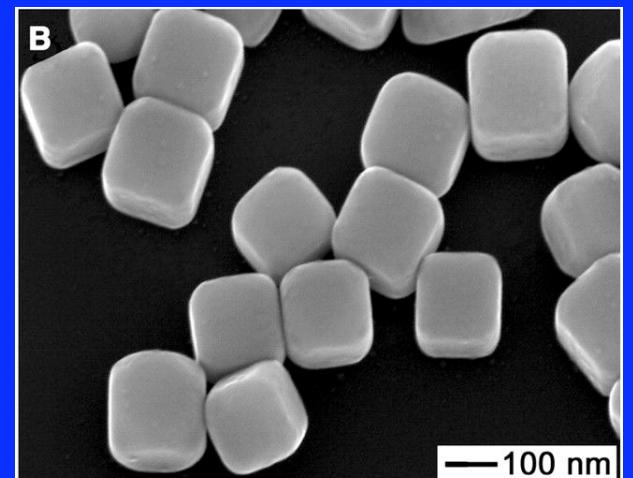
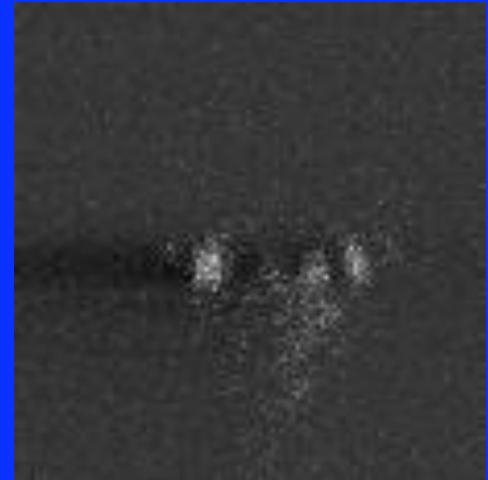
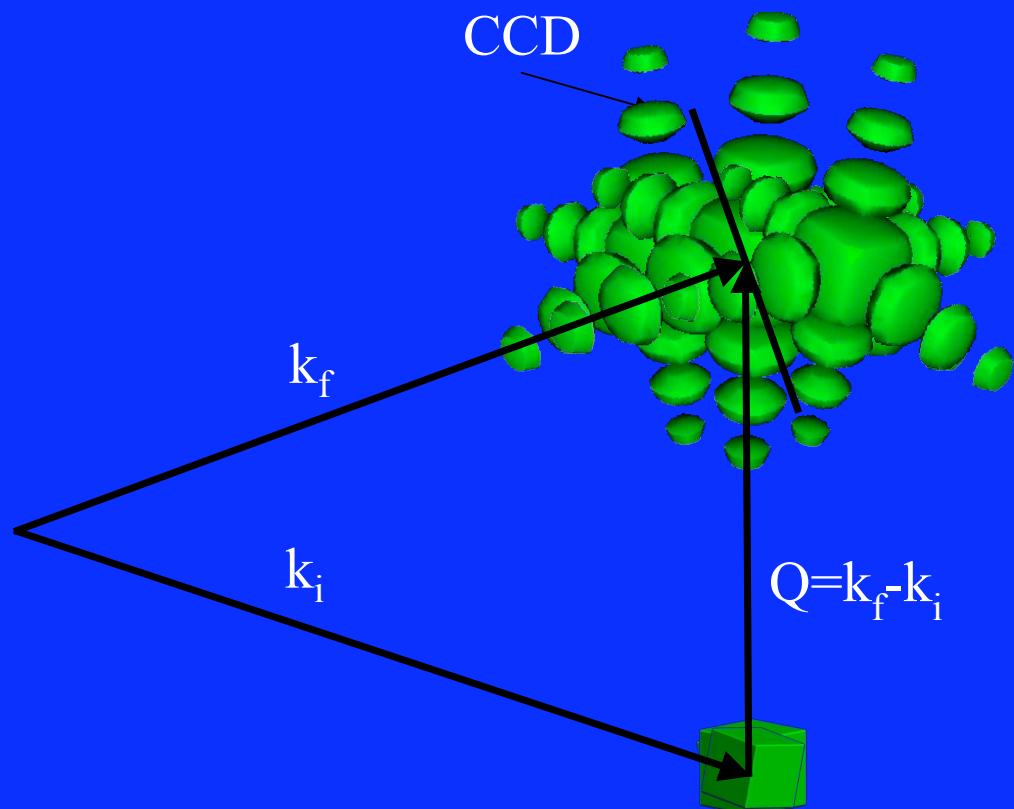


Coherent Diffraction from Crystals



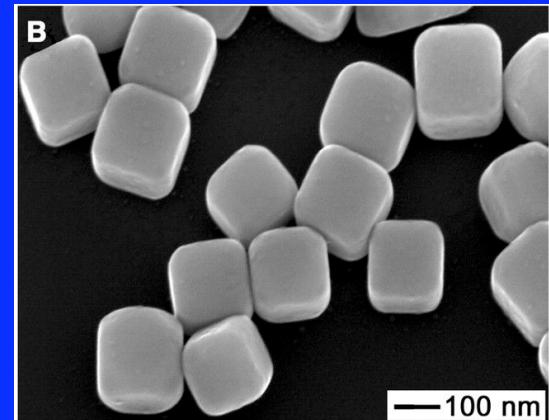
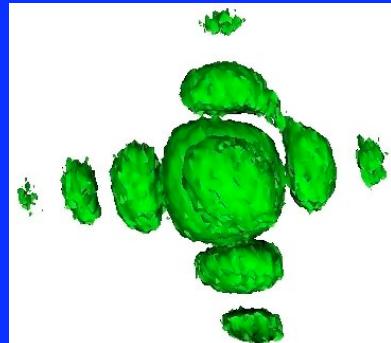
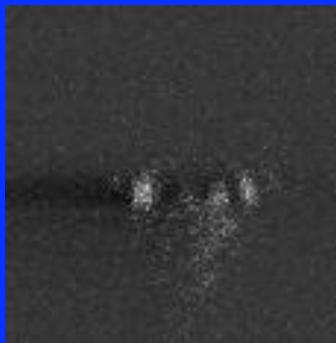
3D Diffraction Method

Silver Nano Cube (111)

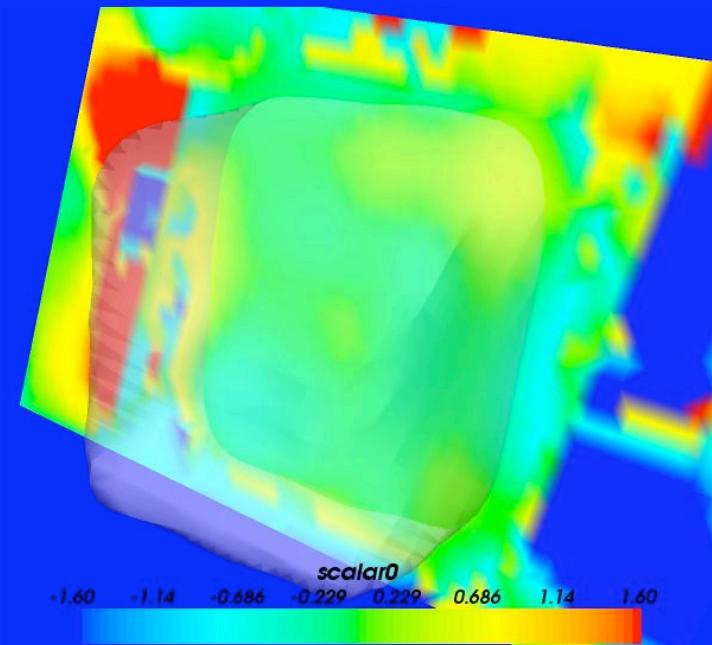
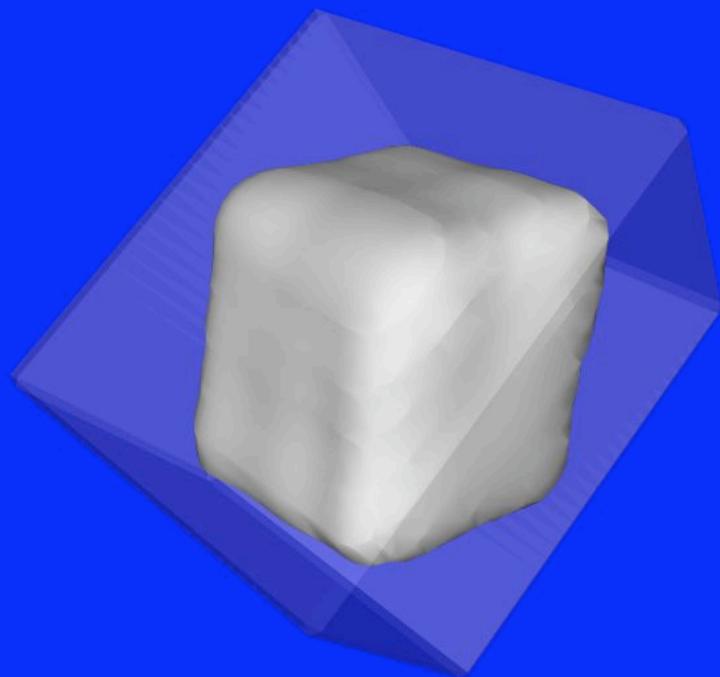


Yugang Sun and Younan
Xia, Science 298 2177 (2003)

3D Ag Nano Cube

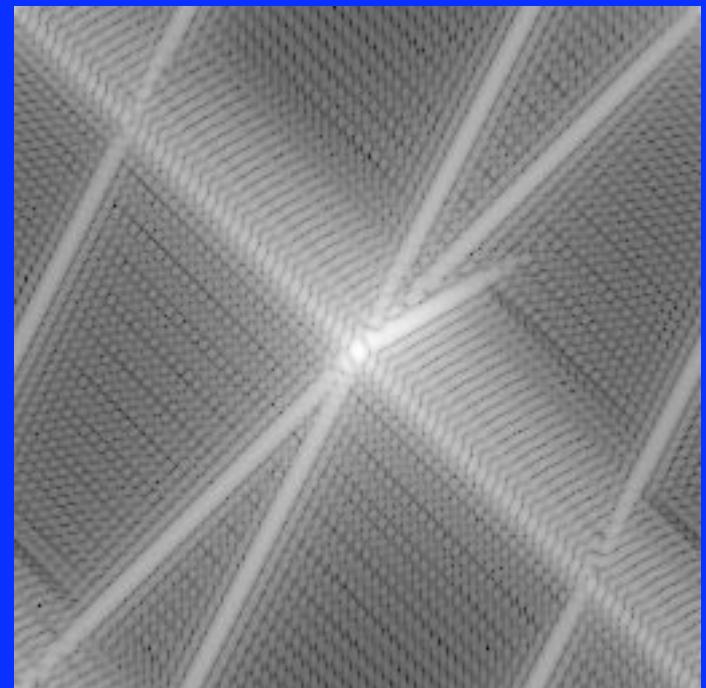
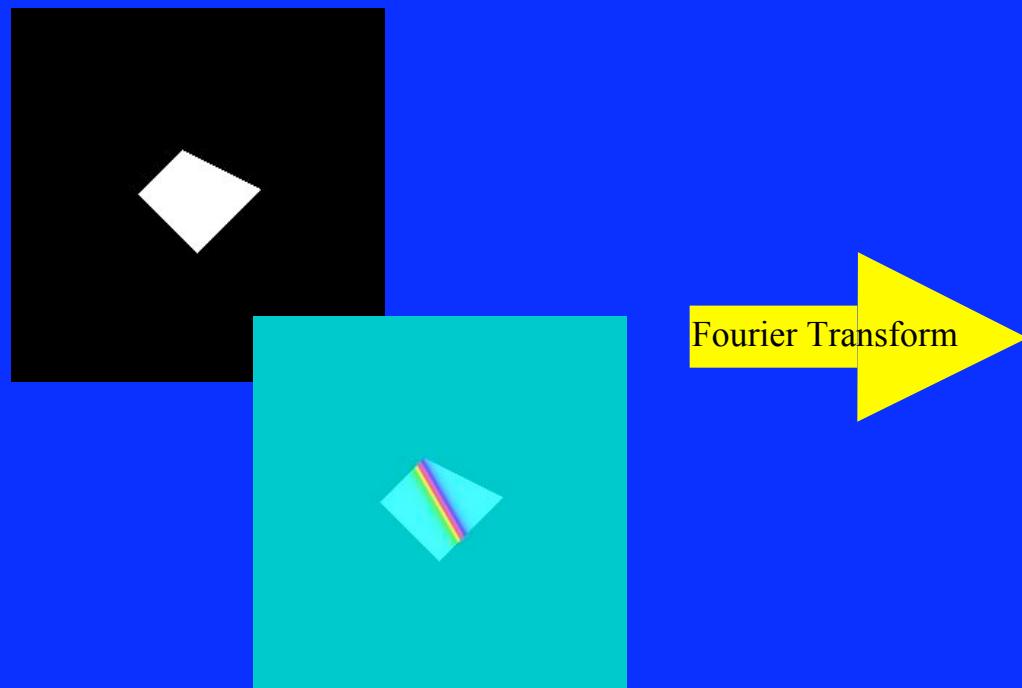
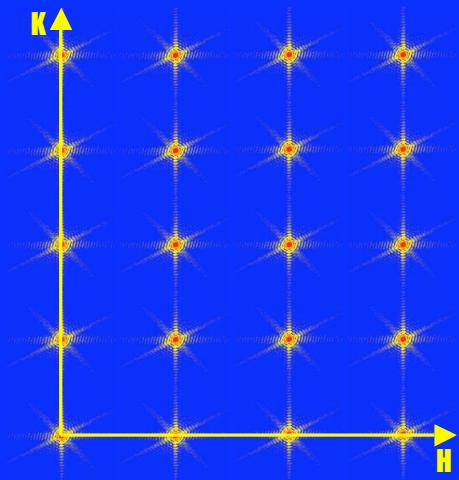


Yugang Sun and Younan
Xia, Science **298** 2177 (2003)

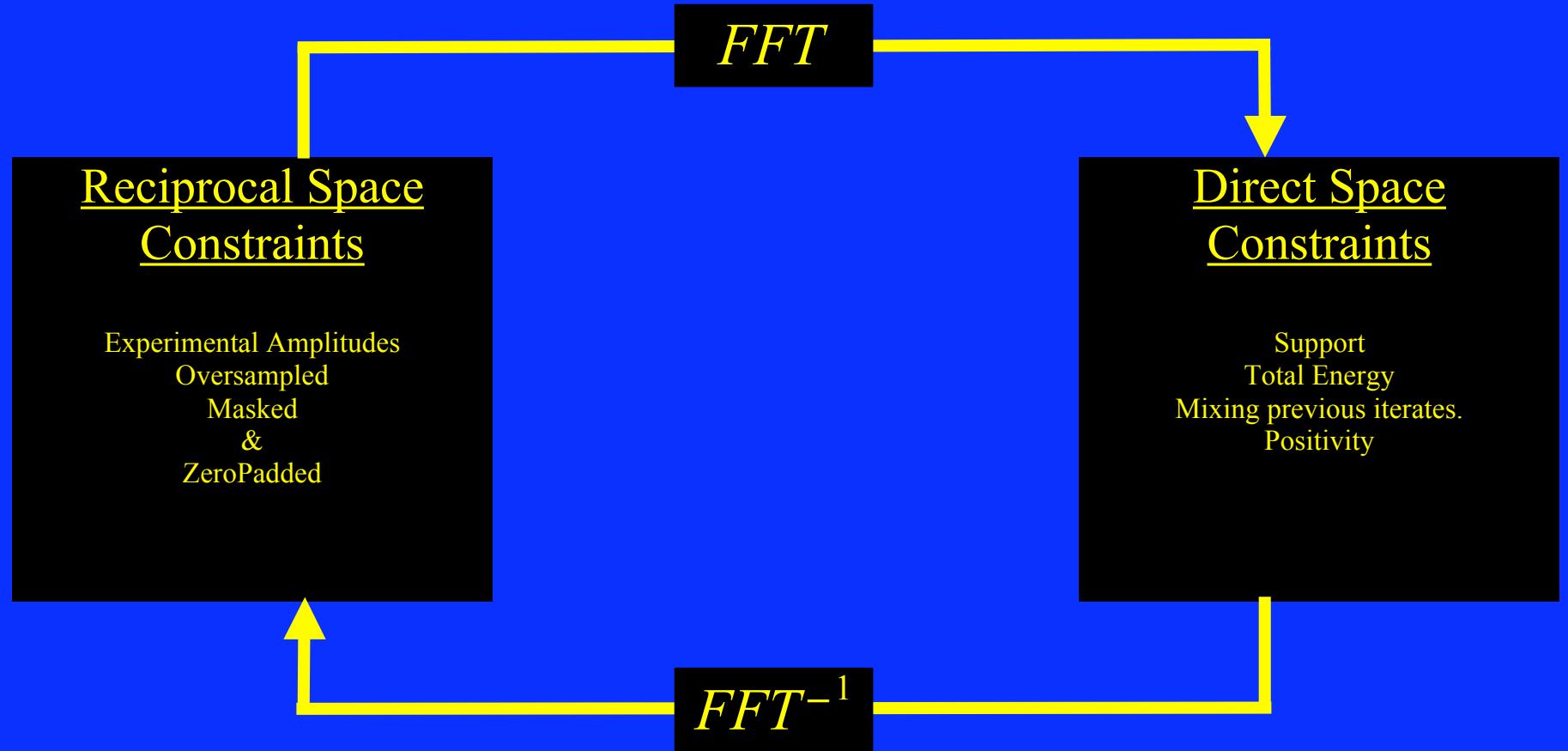


Coherent Diffraction from Crystals

$$E(Q) = C \int \sum_n^{\text{unitcell}} \rho(\mathbf{r} - \mathbf{r}_n) * s(\mathbf{r}) \sum_{m=-\infty}^{\infty} \delta(\mathbf{r} - \mathbf{r}_m - \mathbf{u}(\mathbf{r}_m)) e^{i Q \cdot \mathbf{r}} d\mathbf{r}$$
$$E(Q) \simeq F(Q) \sum_{m=-\infty}^{\infty} s(\mathbf{r} + \mathbf{u}(\mathbf{r}_m)) e^{i Q \cdot (\mathbf{r} + \mathbf{u}(\mathbf{r}_m))}$$
$$E(Q) \simeq F(Q) \sum_{m=-\infty}^{\infty} s(\mathbf{r}) e^{i Q \cdot \mathbf{u}(\mathbf{r}_m)} e^{i Q \cdot \mathbf{r}_m}$$



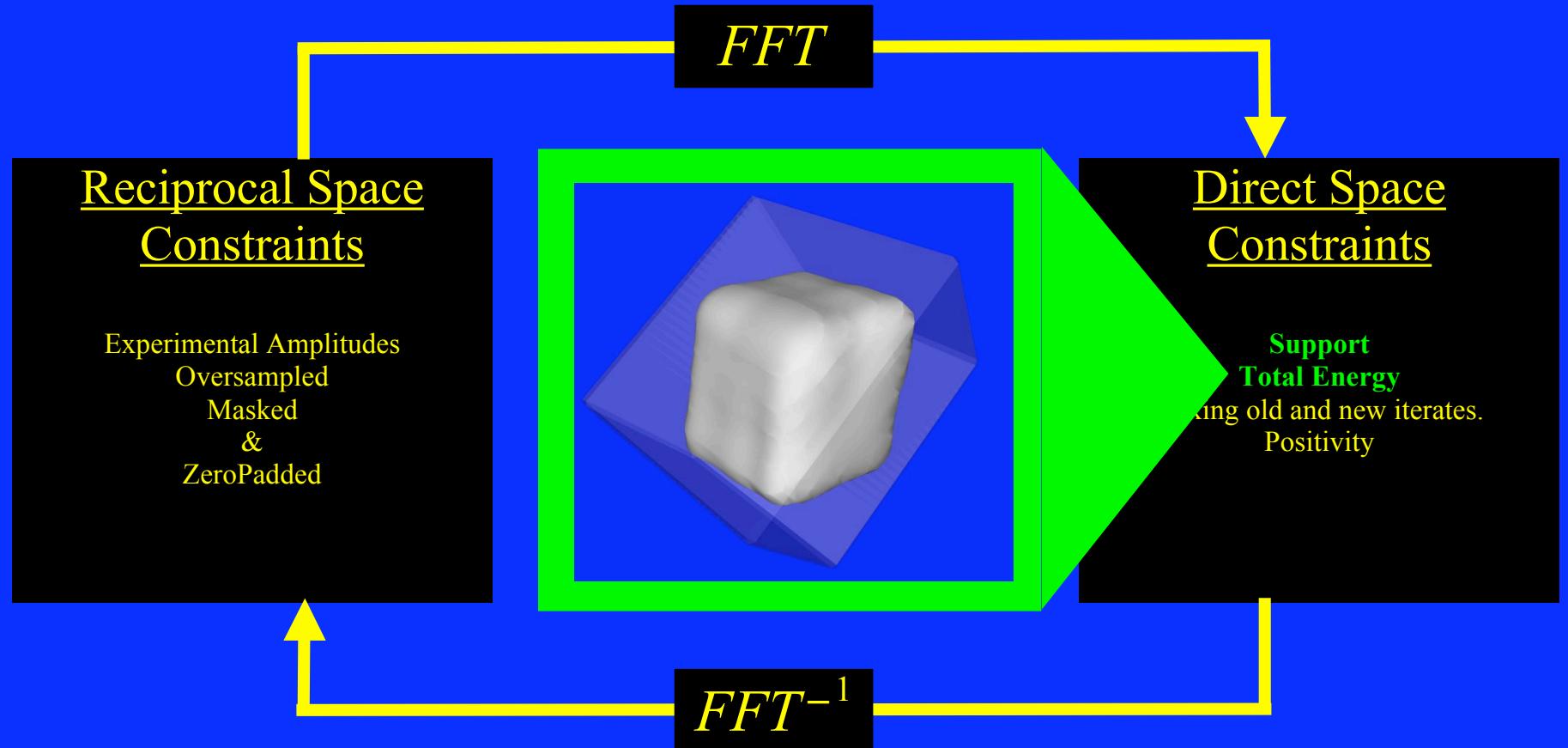
Input Output Algorithms



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 Algorithm's

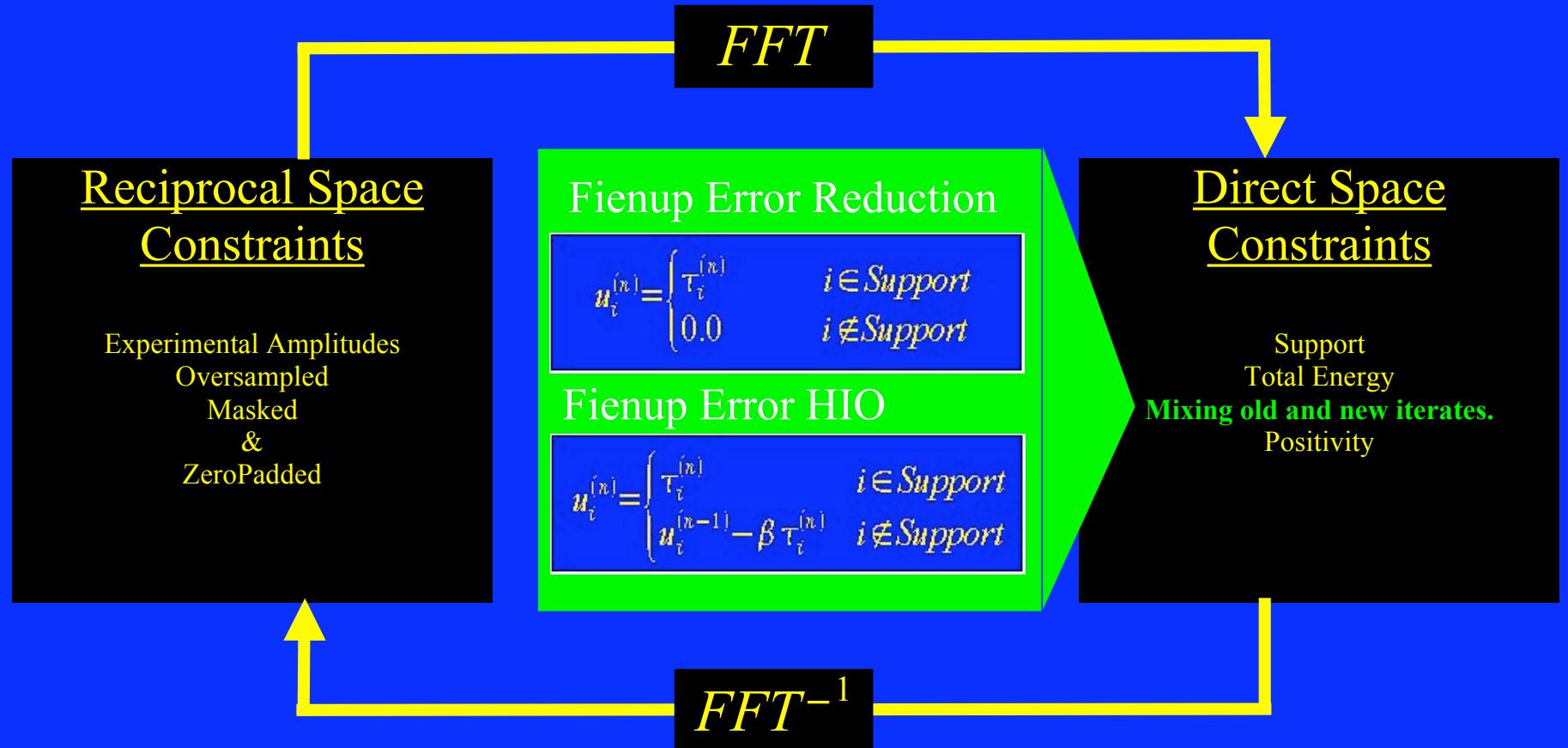


J. R. Fienup *Appl. Opt.* 21 2758 (1982)

Collins *Nature* 298, 49 (1982)

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Input Output Algorithm's

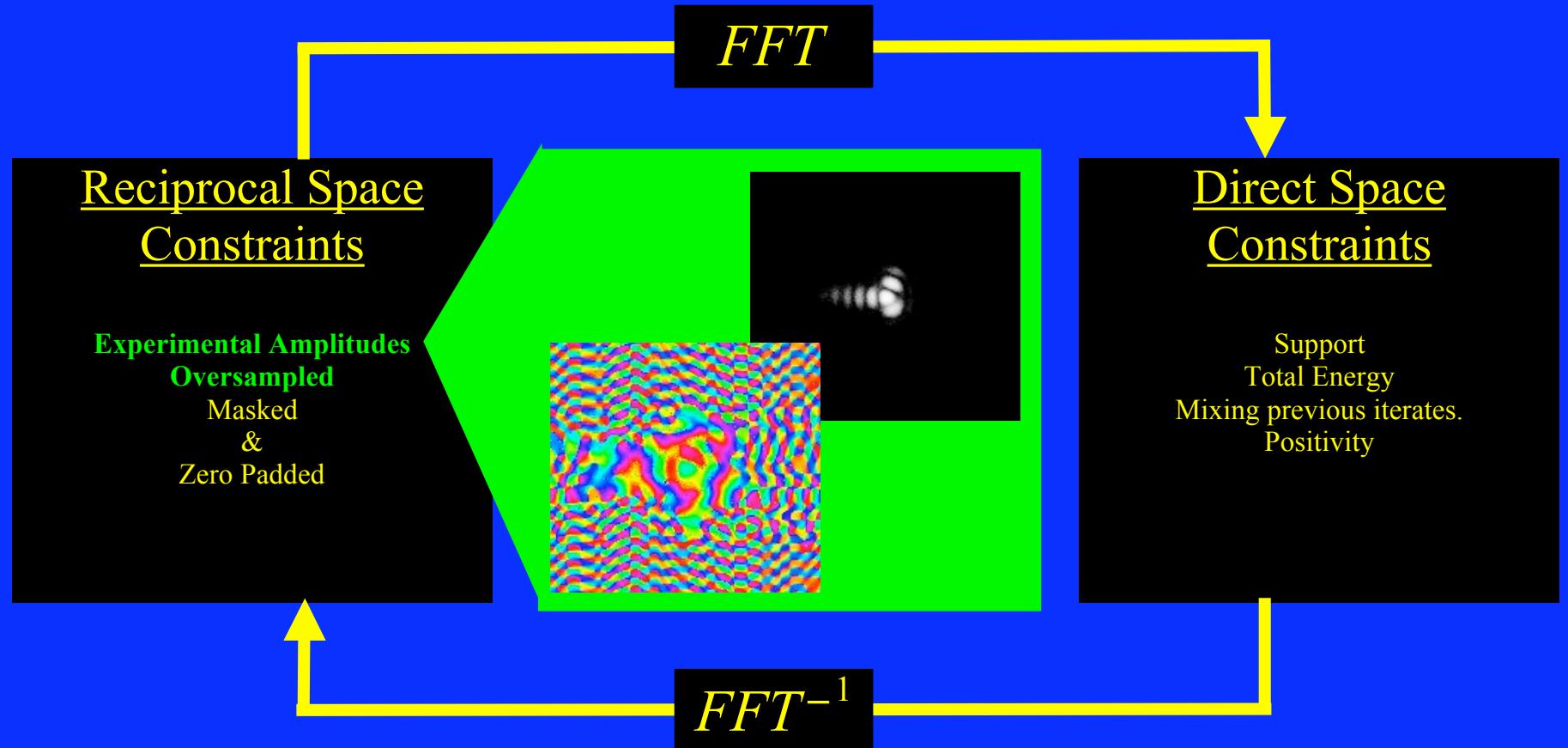


J. R. Fienup *Appl. Opt.* 21 2758 (1982)

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Input Output Algorithm's

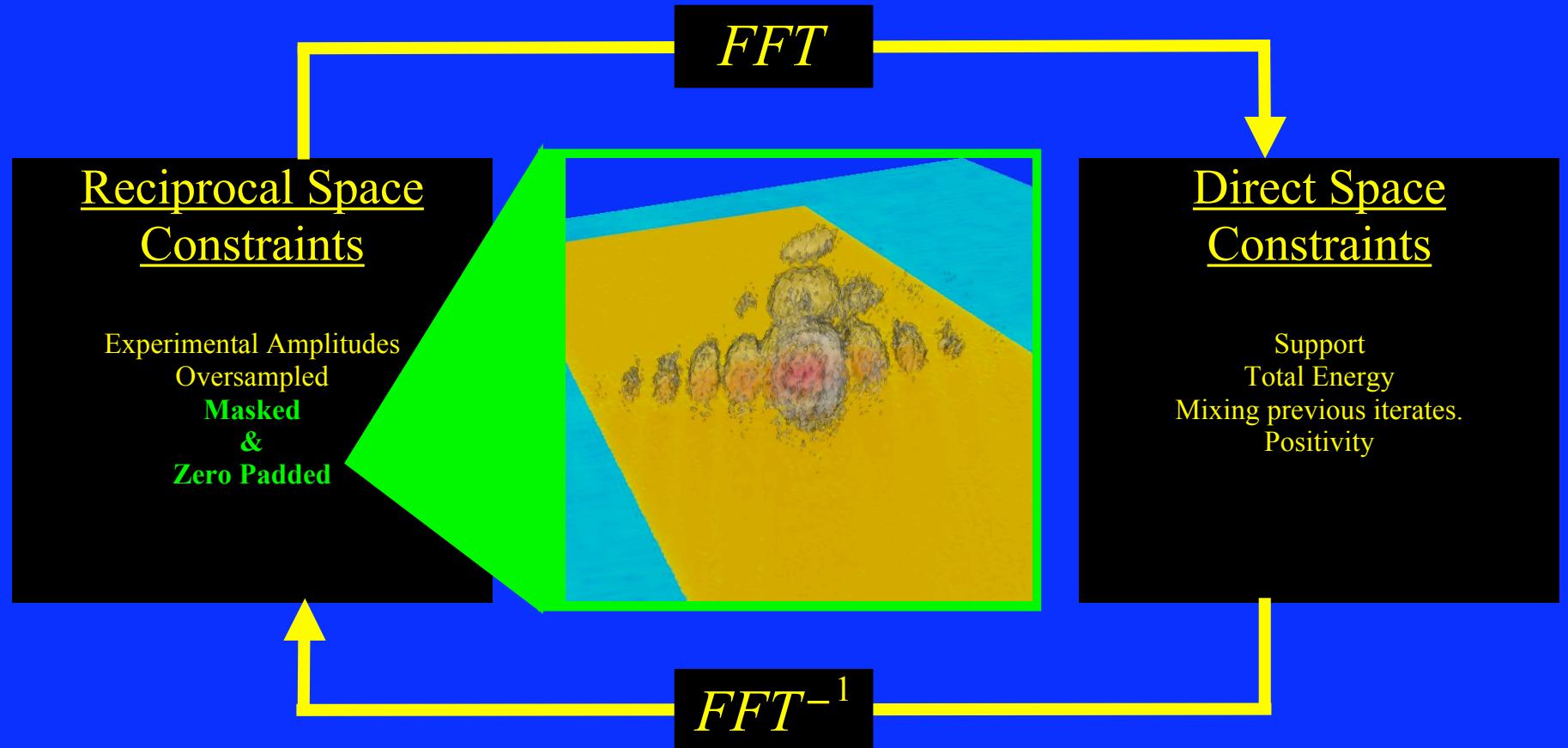


J. R. Fienup *Appl. Opt.* 21 2758 (1982)

Collins *Nature* 298, 49 (1982)

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Input Output Algorithm's



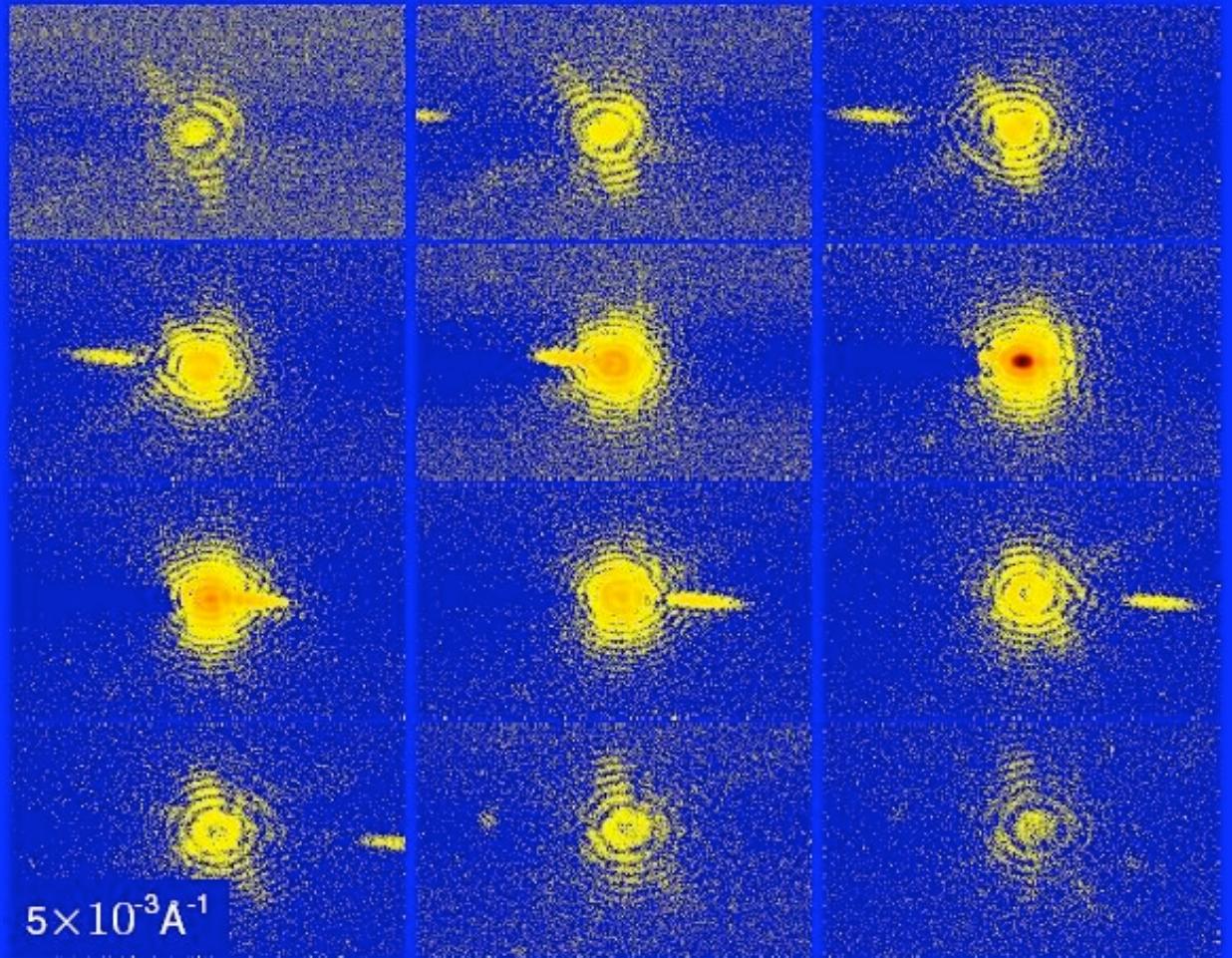
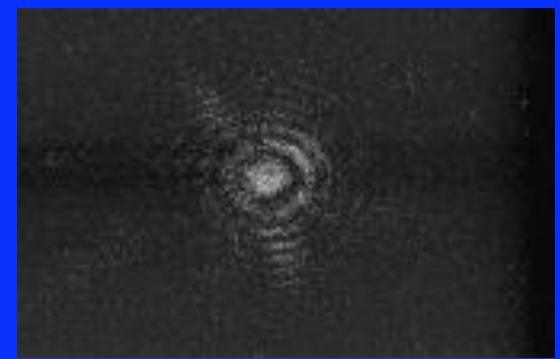
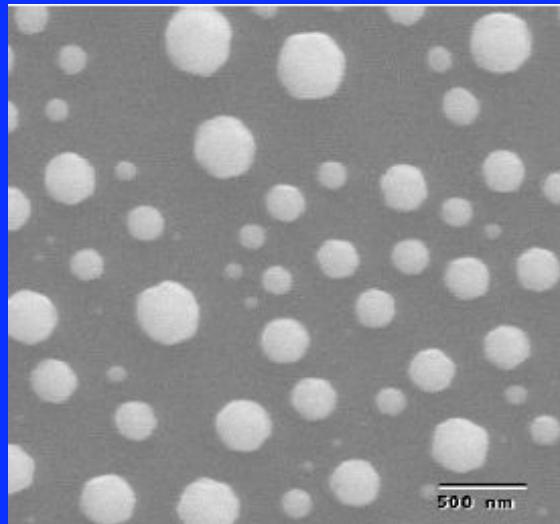
J. R. Fienup *Appl. Opt.* 21 2758 (1982)

Collins *Nature* 298, 49 (1982)

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

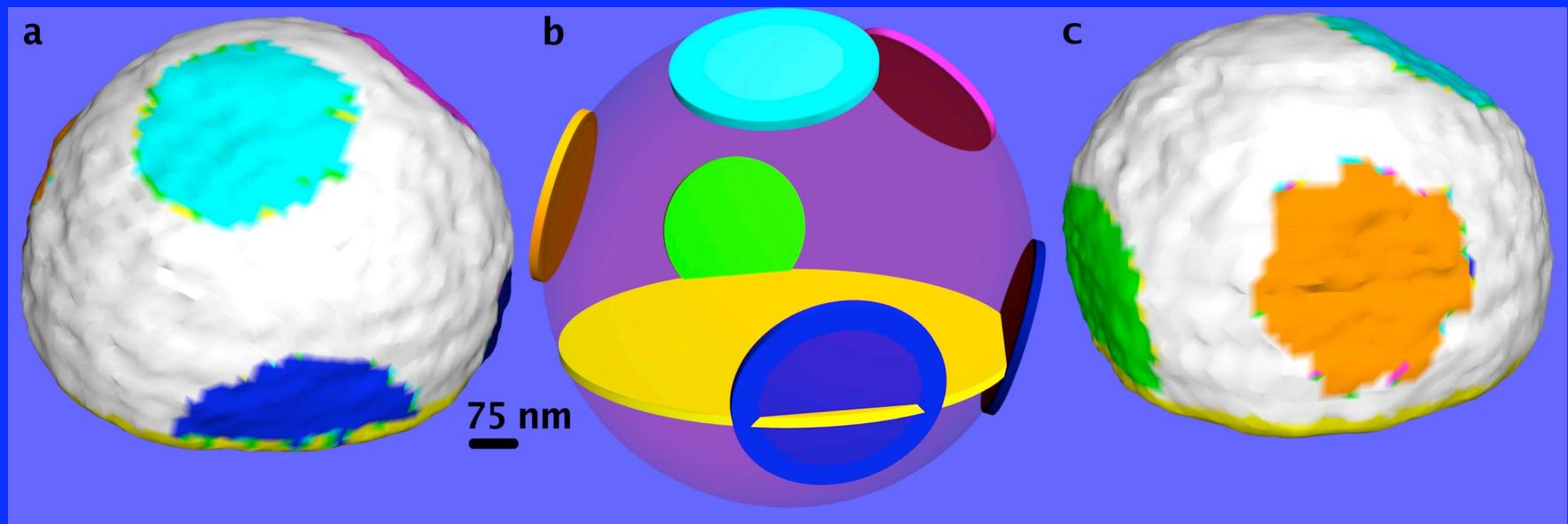
Hot Science! (T=573K)

3D Diffraction From Lead

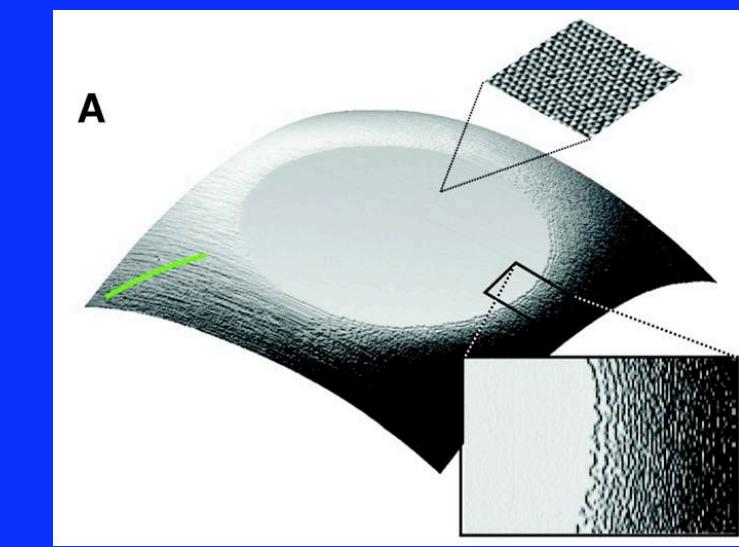


Nature, Vol. 442 p. 63 (July 6 2006)

3D Reconstruction of Lead

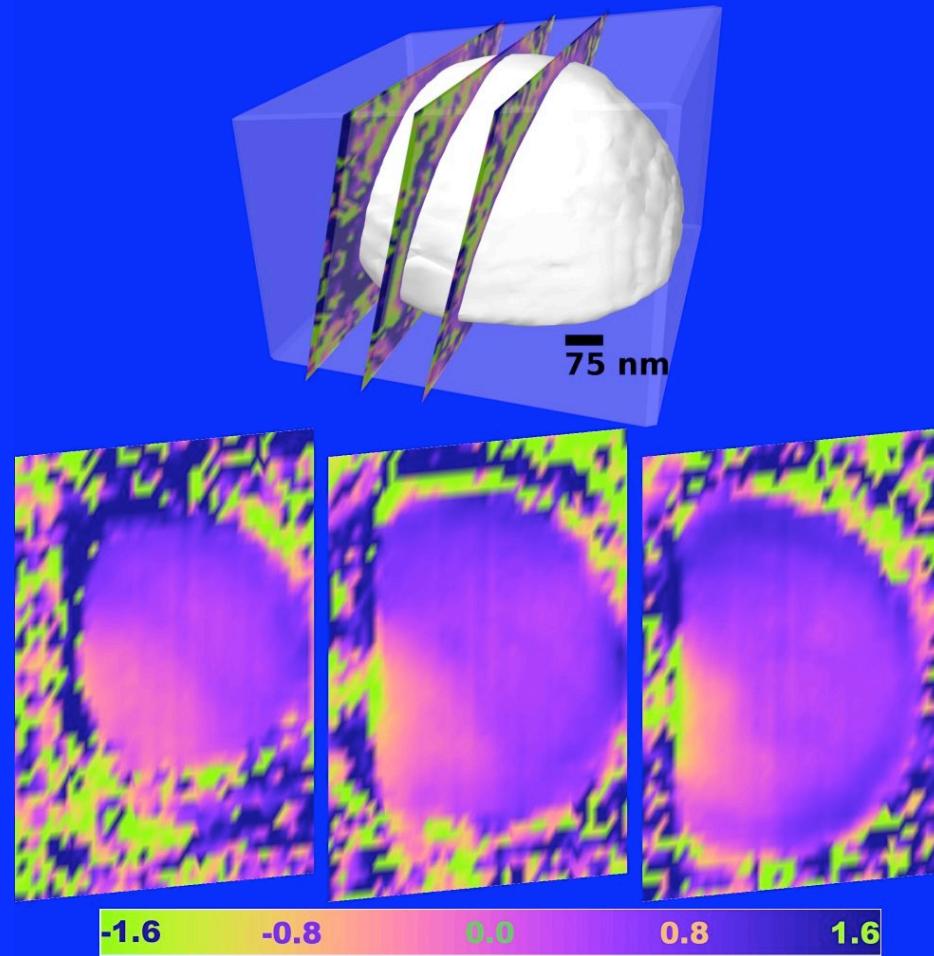


Nature, Vol. 442 p. 63 (July 6 2006)



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

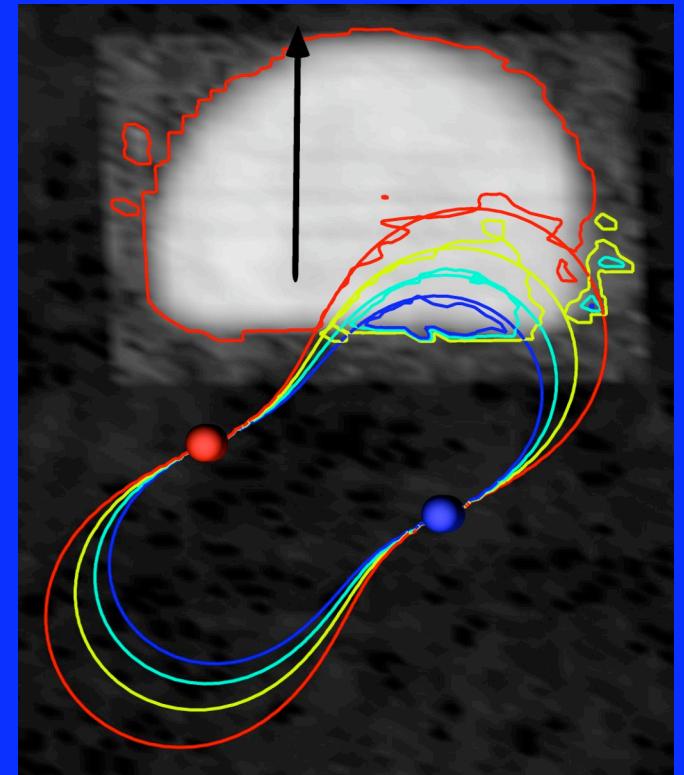
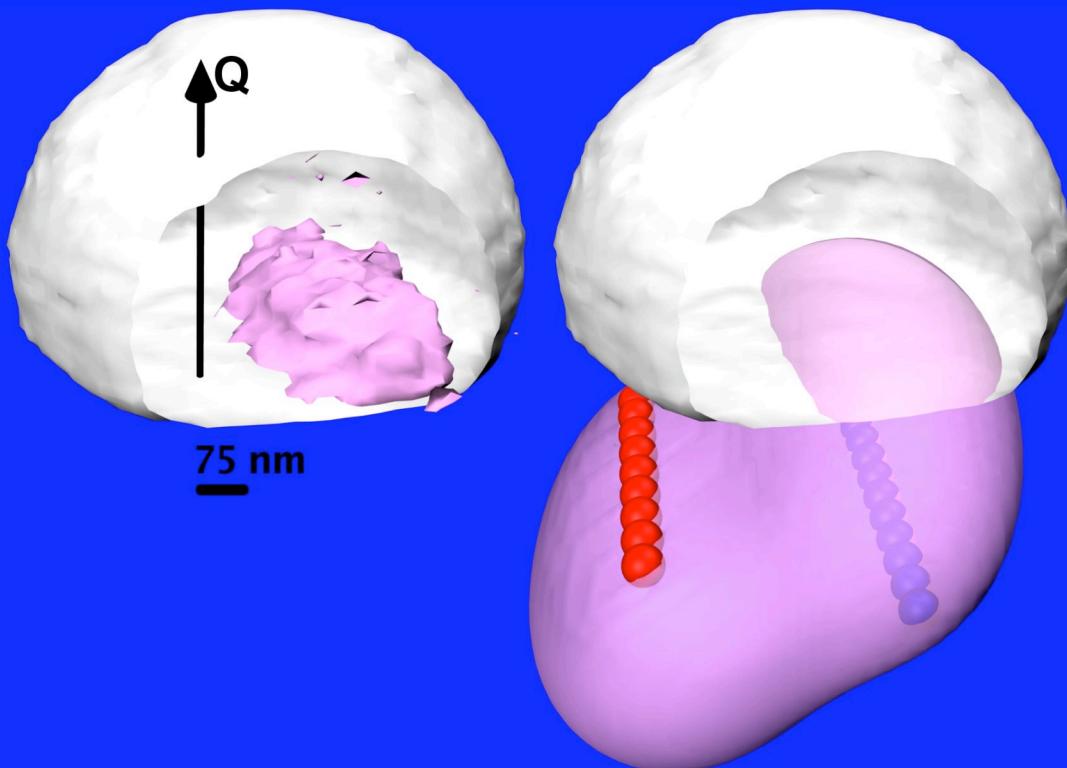
3D Reconstruction of Lead



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

3D Strain Map in Lead

$$E(Q) = C \int \sum_n^{unitcell} \rho(\mathbf{r} - \mathbf{r}_n) * \sum_{m=-\infty}^{\infty} s(\mathbf{r}) \delta(\mathbf{r} - \mathbf{r}_m - \mathbf{u}(\mathbf{r}_m)) e^{iQ \cdot \mathbf{r}} d\mathbf{r}$$
$$E(Q) \approx F(Q) \sum_{m=-\infty}^{\infty} s(\mathbf{r} + \mathbf{u}(\mathbf{r}_m)) e^{iQ \cdot (\mathbf{r} + \mathbf{u}(\mathbf{r}_m))}$$
$$E(Q) \approx F(Q) \sum_{m=-\infty}^{\infty} s(\mathbf{r}) e^{iQ \cdot \mathbf{u}(\mathbf{r}_m)} e^{iQ \cdot \mathbf{r}_m}$$

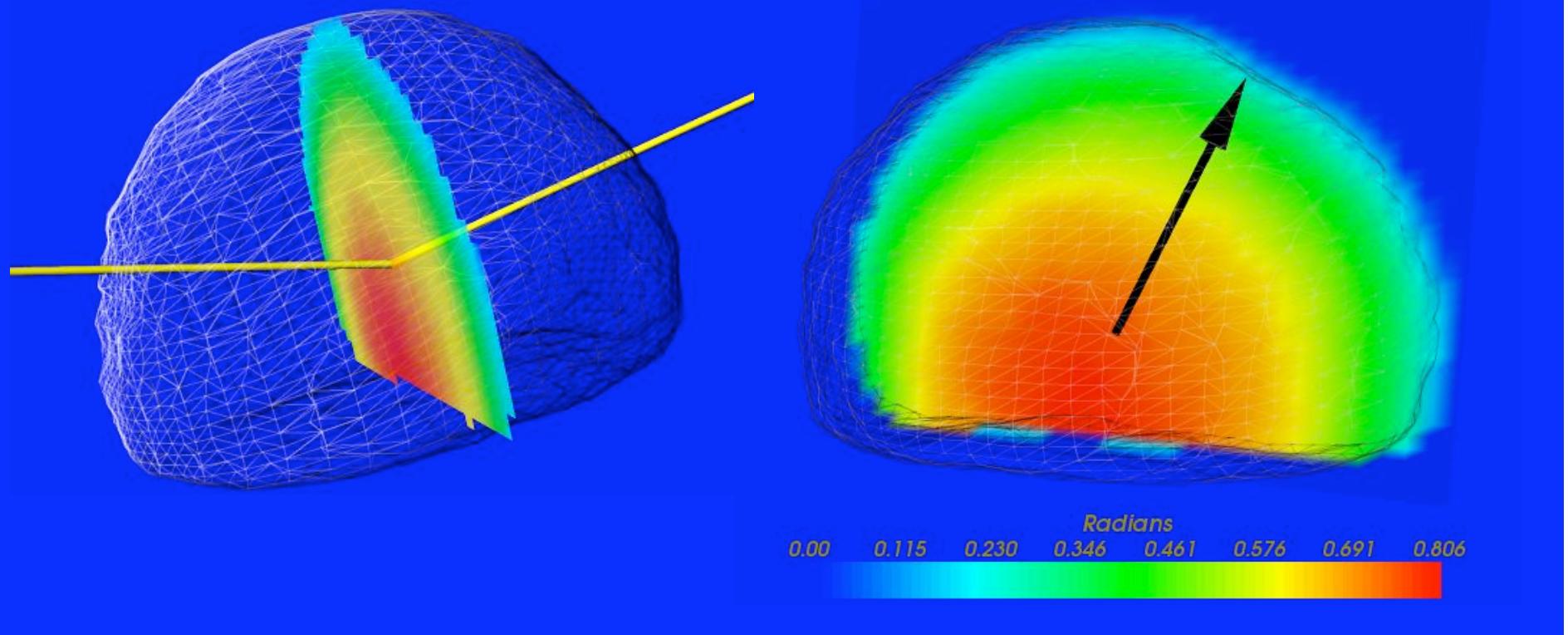


Nature, Vol. 442 p. 63 (July 6 2006)

Refraction effects in Lead @8.9keV

$$\delta = 2.23 \times 10^{-5}$$
$$\beta = 2.19 \times 10^{-6}$$

Phase accumulation due to
refraction along scattering path

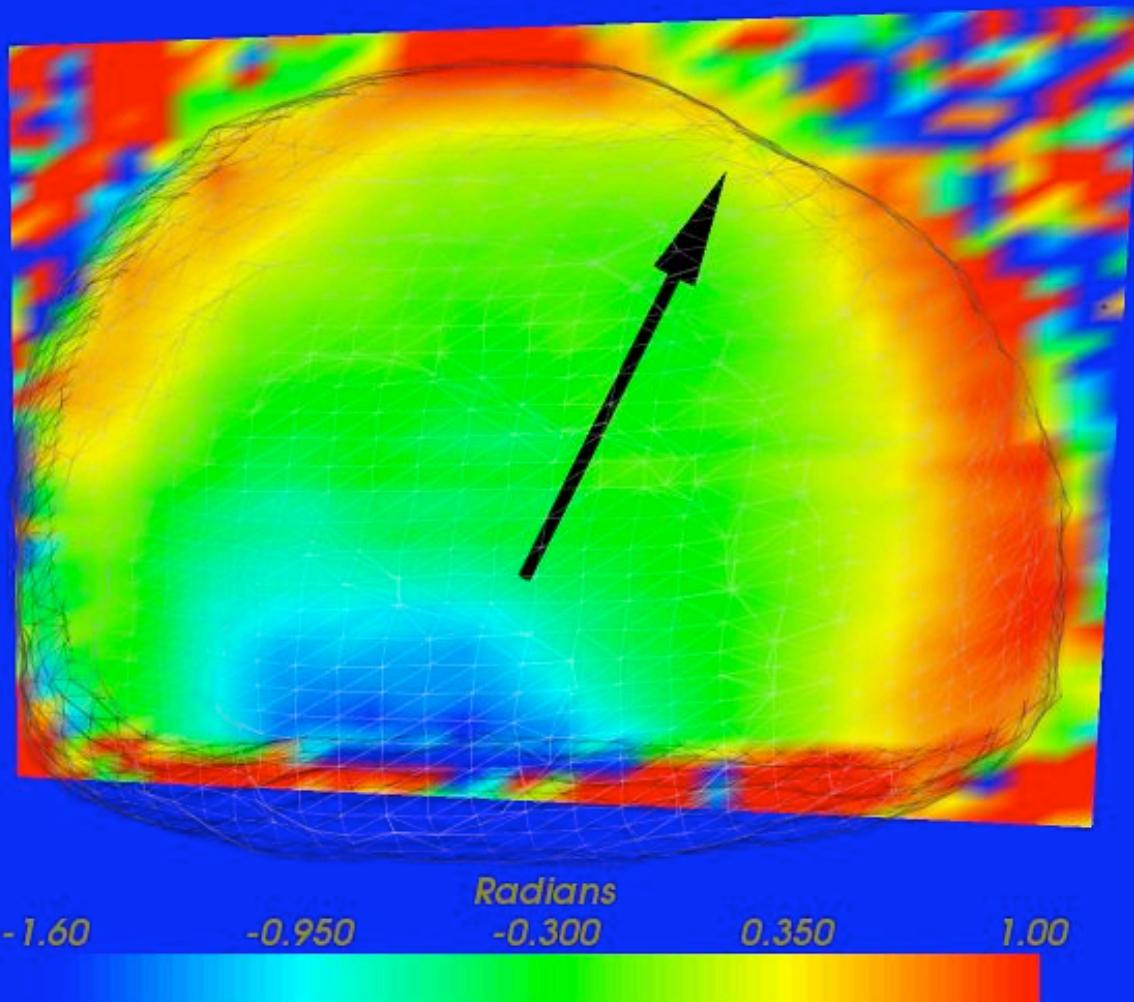


“Anomalous” Thermal Expansion

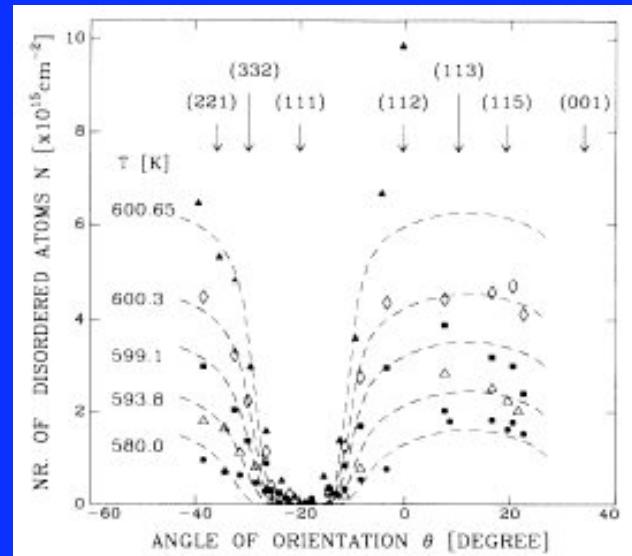
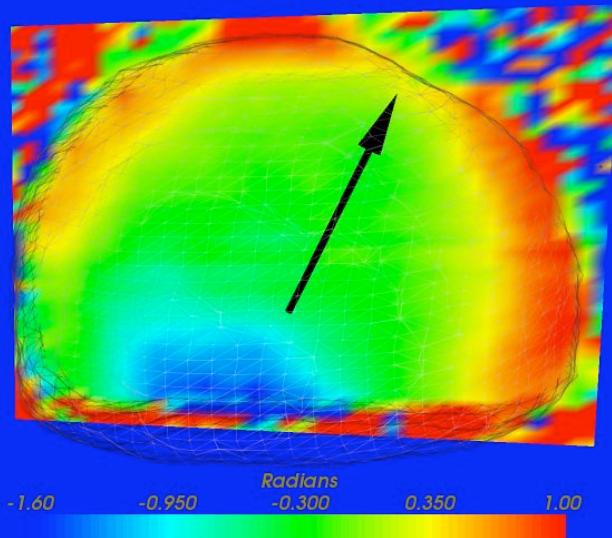
Refraction corrected phase map.

Max phase = 1.15rad
= 0.052nm

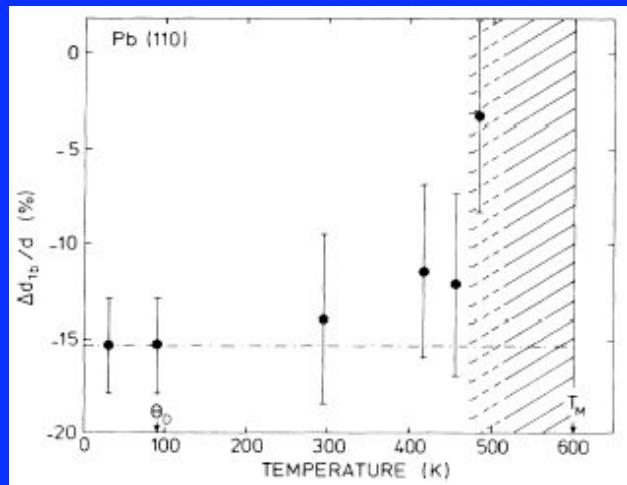
Phase on the (111) facet:
= 0.47 rad
= 0.02nm



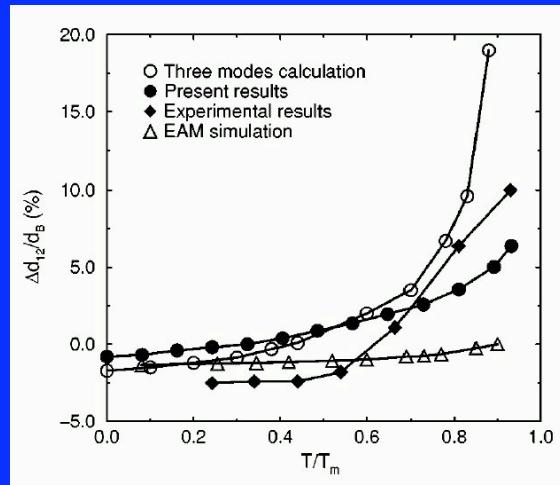
“Anomalous” Thermal Expansion (of Surfaces)



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



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

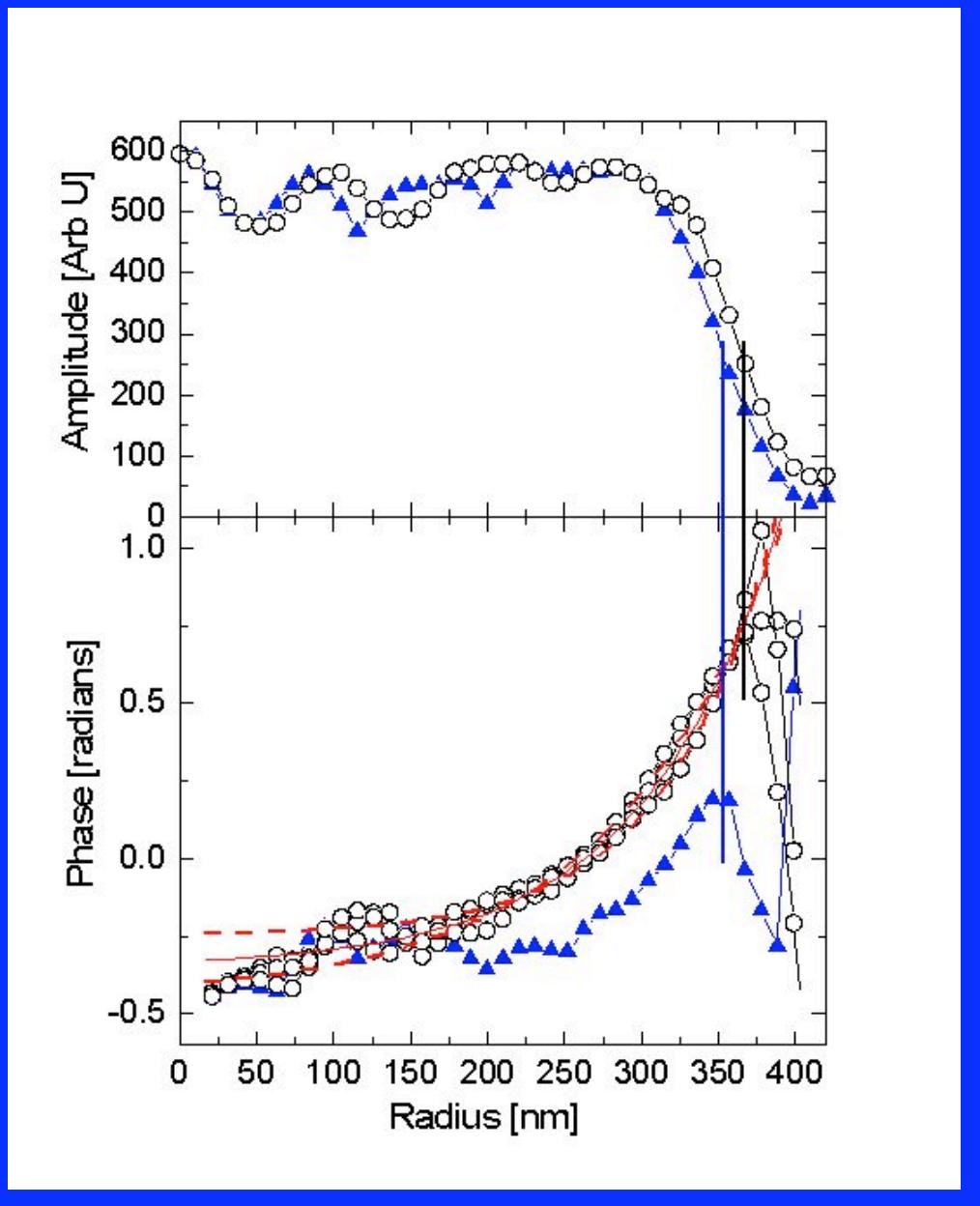
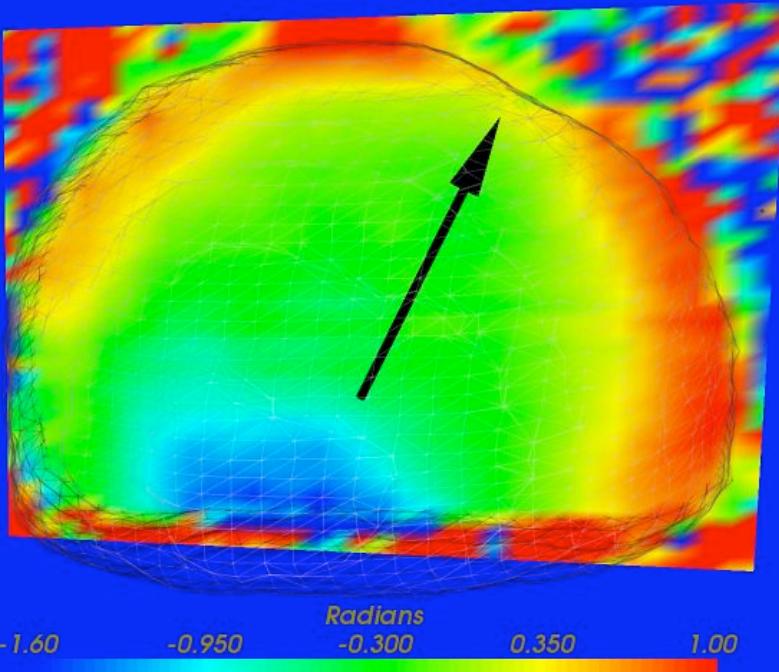


Ag(111) theory J. Xie (Scheffler group)
PRB 59 970 (1999)

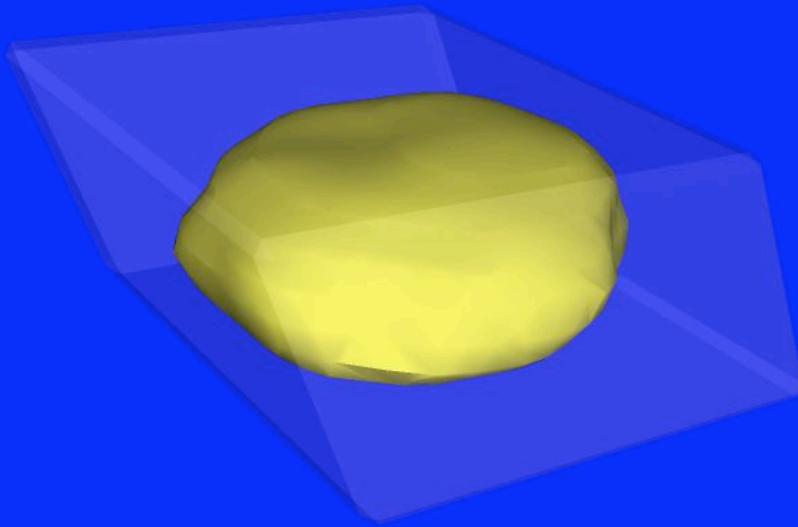
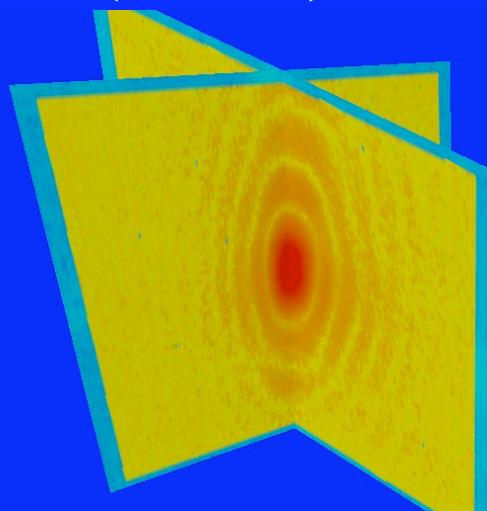
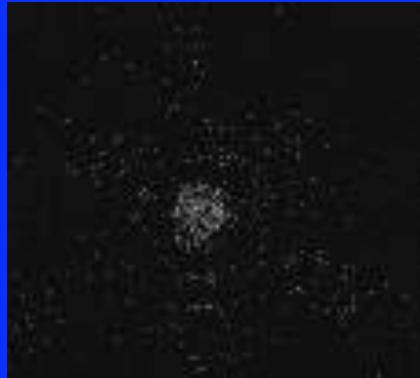
Depth Variation of Distortion

Facets subtend 18.6deg \pm 2.6
ECS predicts 14deg

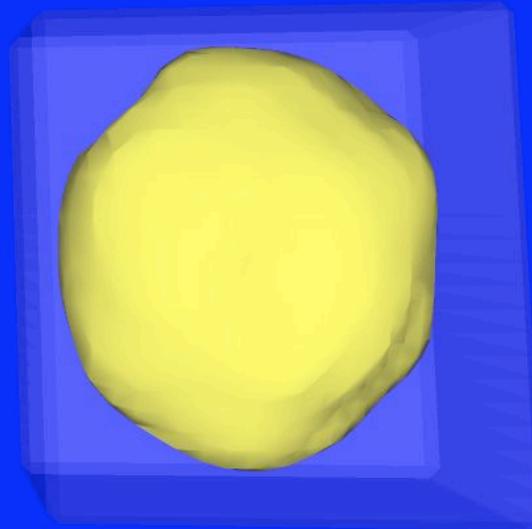
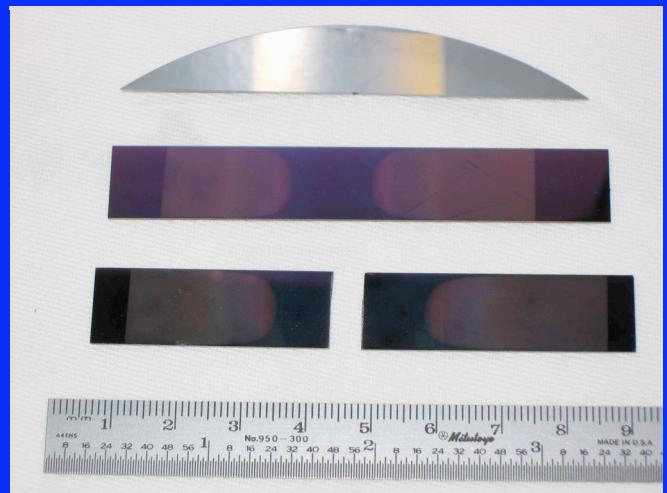
Depth measured 90nm \pm 20
Theory says 75nm



3D Au crystal (7/06)



XFD-OFM Chian Liu, Ali Khounsary



CXD GaP nanowires

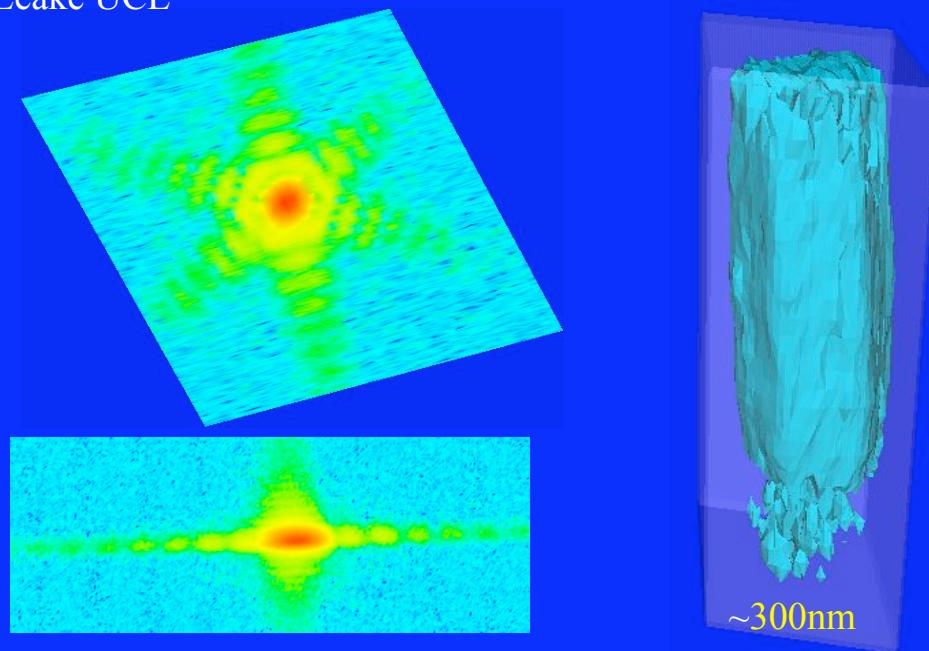
Lund University (from Thomas Martensson & Linus Froberg)

GaP(111)



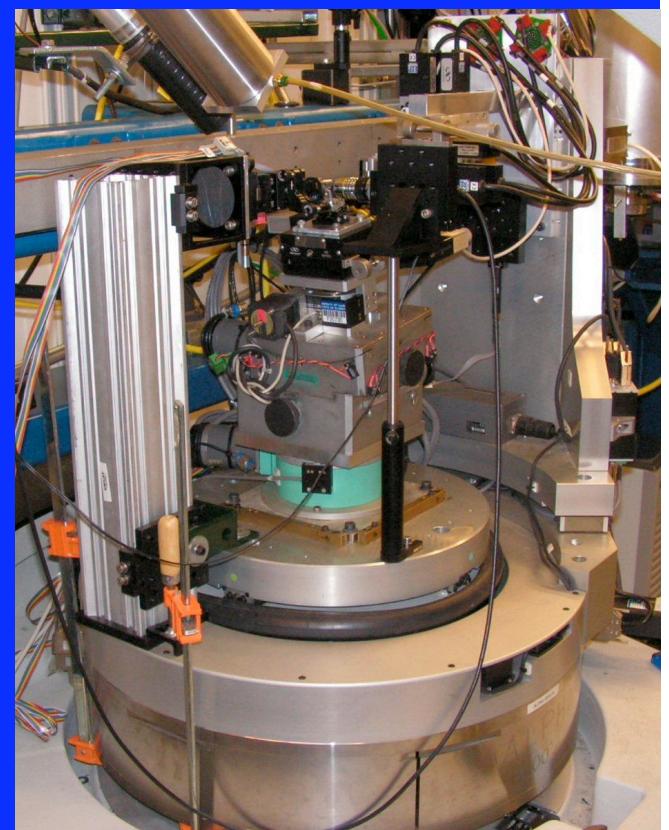
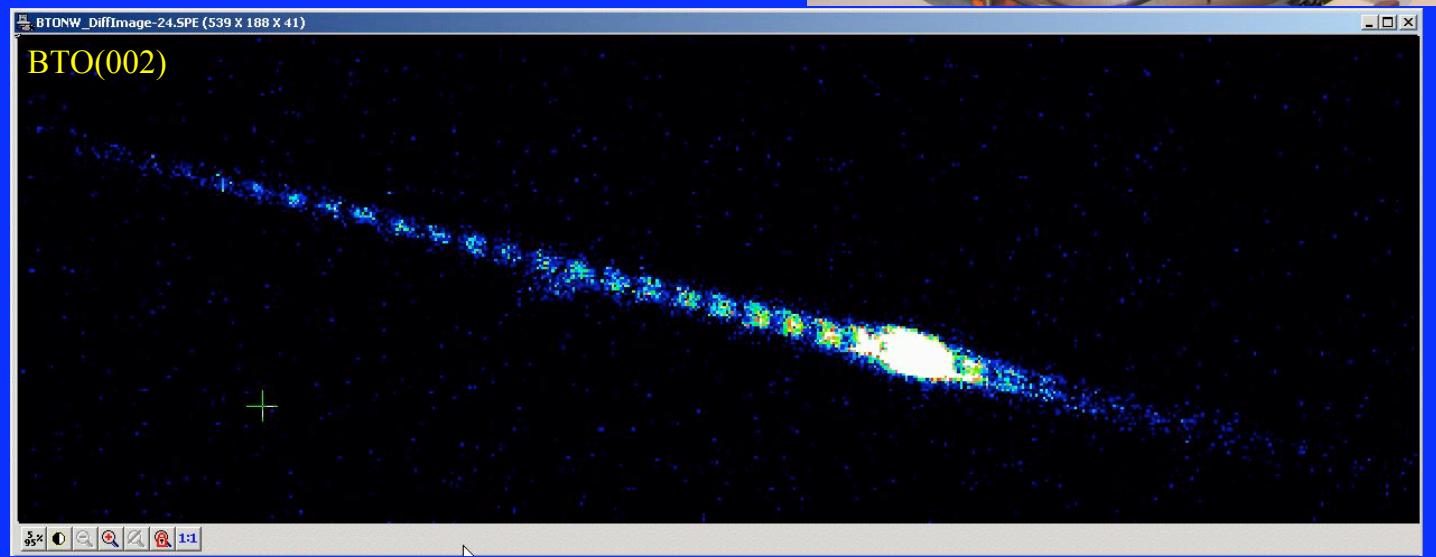
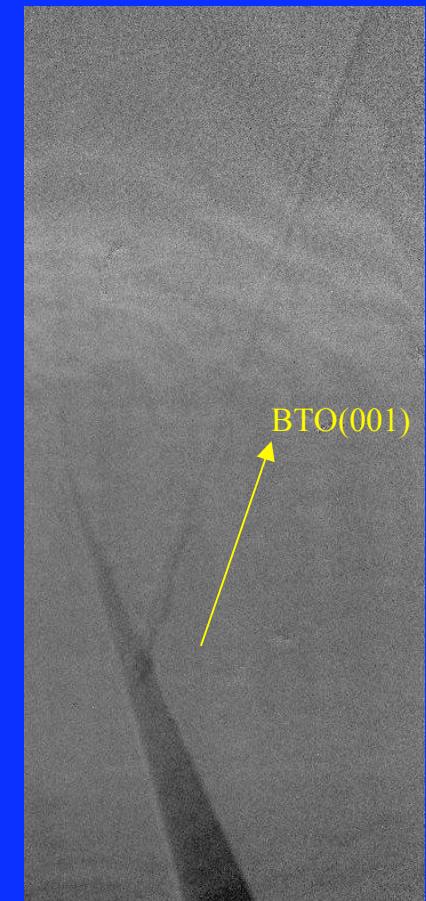
CXD ZnO nanowires

Steve Leake UCL

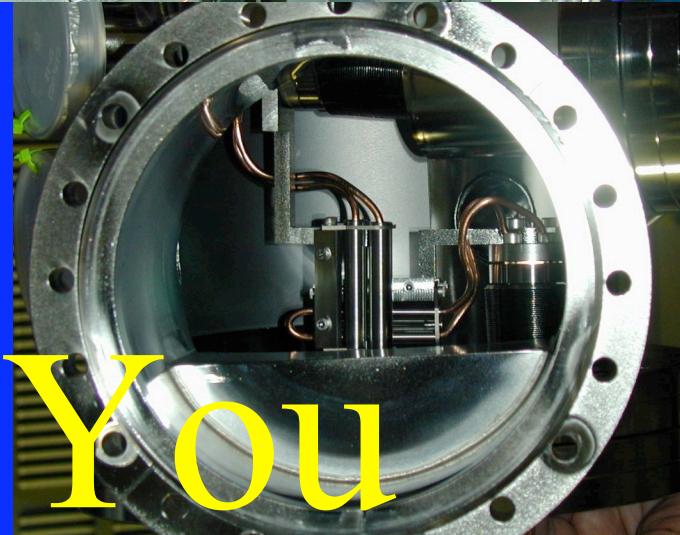
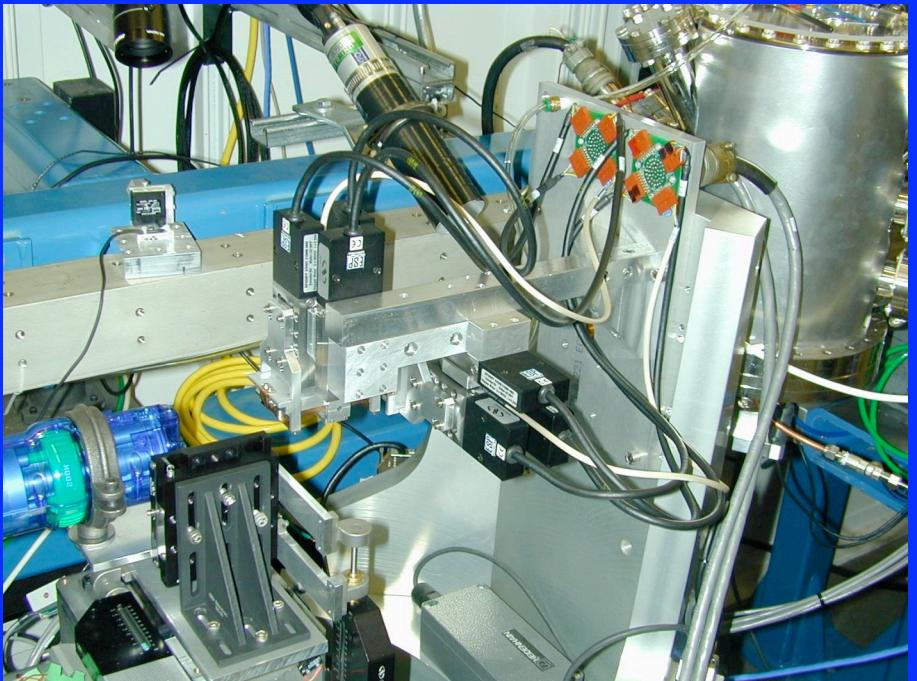


Simultaneous High Resolution Imaging & Coherent Xray Diffraction of BTO Nano Wire

Sample:Zhaoyu Wang
Microscope:Christoph Rau
Diffraction: Harder,Robinson



ID-34C Coherent X-ray Diffraction



Thank You