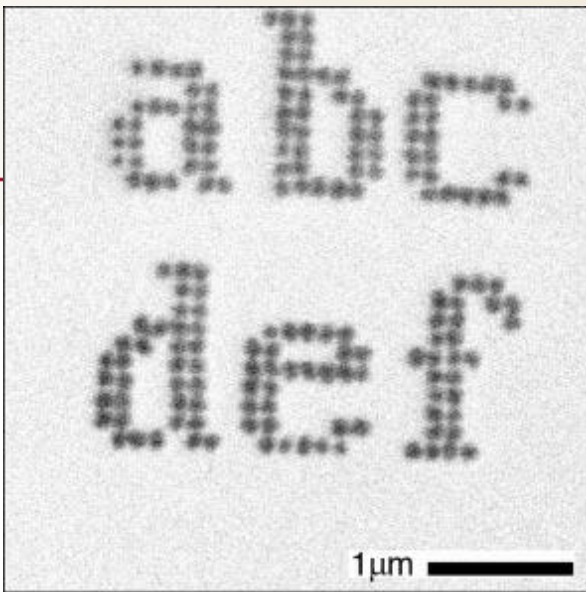


Coherent Diffraction Imaging (lensless imaging)

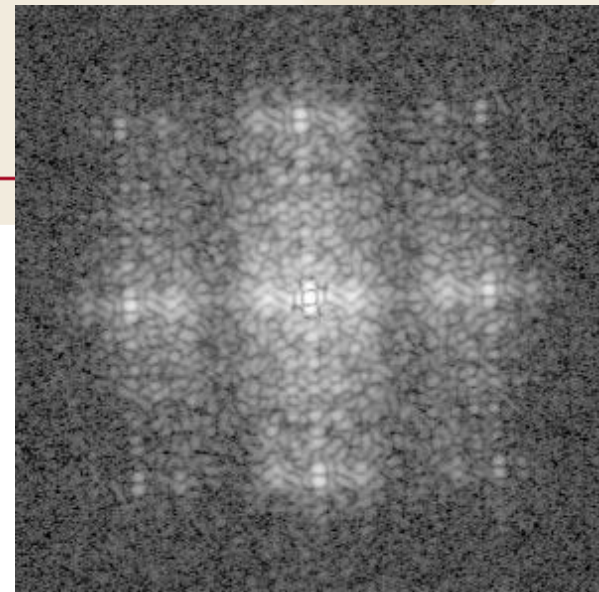
Eric Welch, Sara Mohamed, Ling Zeng, Weilun Qin

August 7, 2015

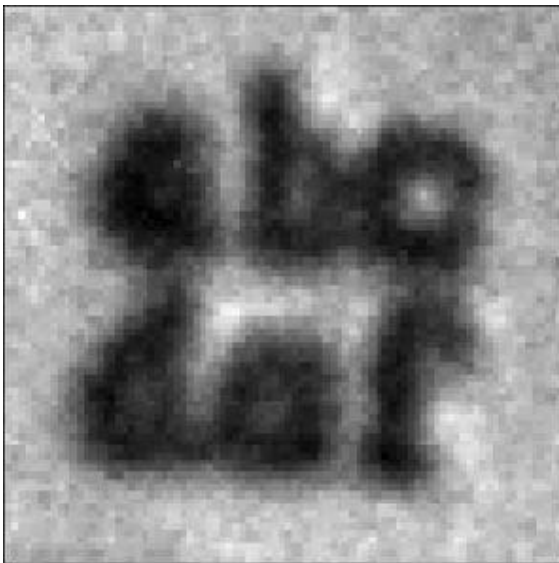
- Introduction of CDI
- CDI methods and applications
 - plane wave
 - scanning
 - Bragg
 - Fresnel
- Summary



1- A scanning electron microscope image of the specimen



2- Diffraction pattern of the specimen (using a logarithmic intensity scale)

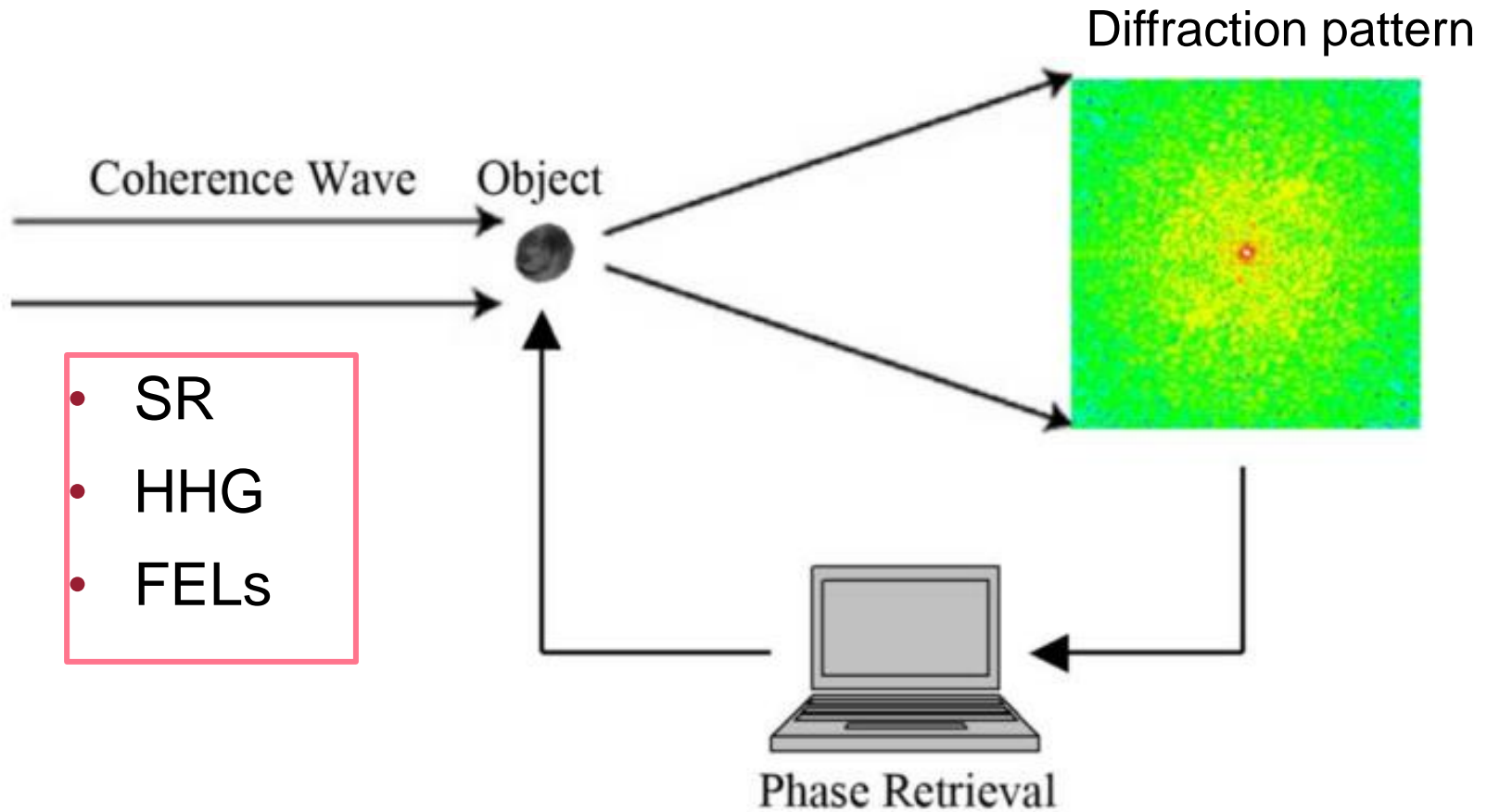


3- An optical microscope image of the specimen.

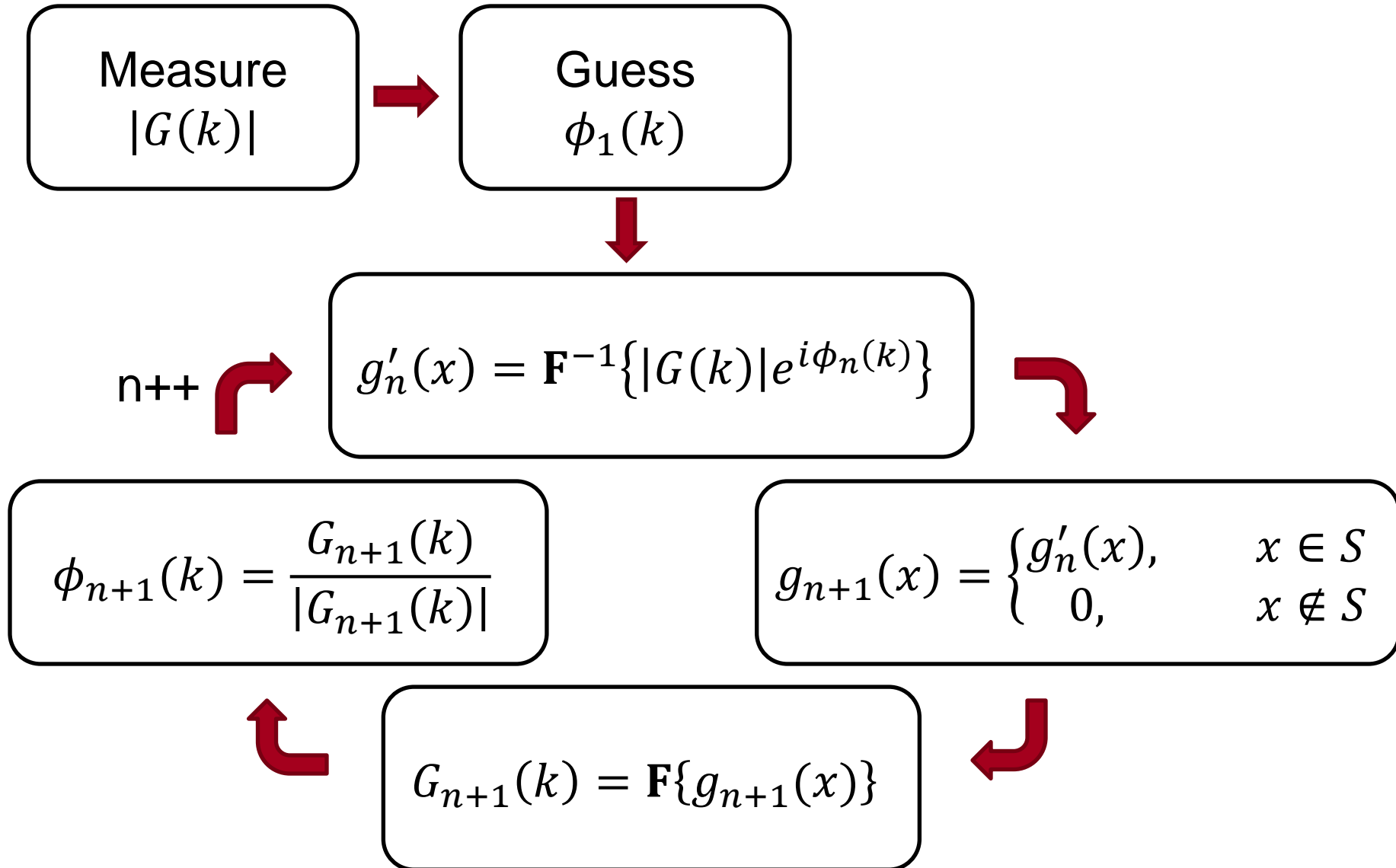


4- The specimen image as reconstructed from the diffraction pattern of Fig. 2.

Coherent diffraction imaging



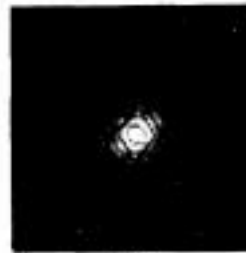
Iterative Algorithm



Phase retrieval of simulated image



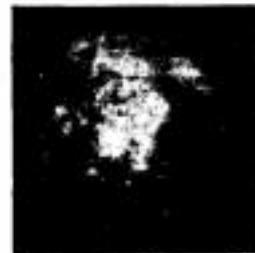
(a)



(b)



(c)



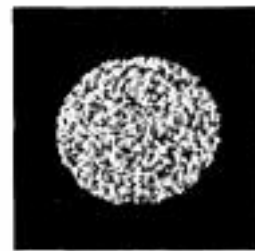
(d)



(e)



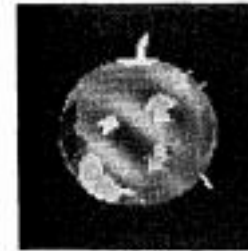
(f)



(g)



(h)



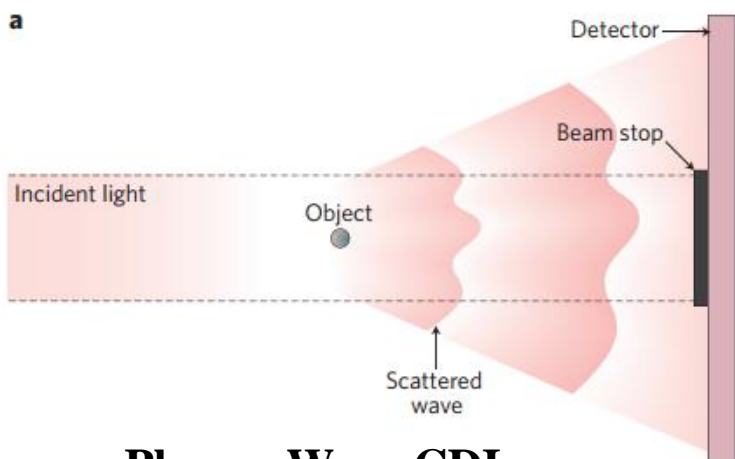
(i)

Challenges of realizing CDI experiment

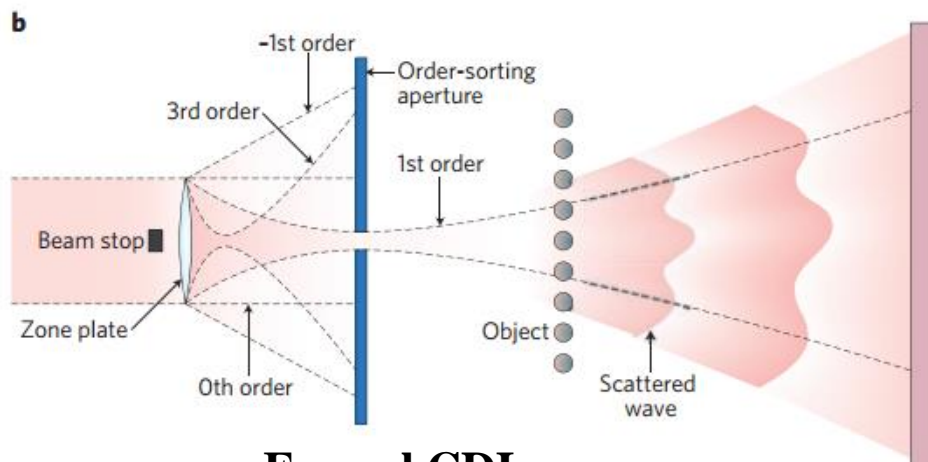
- **Radiation damage of sample (ultrafast process 10s fs)**
- **Radiation damage of detector**
- **Poor signal-to-noise ratio**

- **Use of ultrashort pulses**
- **Beam stop / beam dump**
- **Brighter beam / multiple shots**

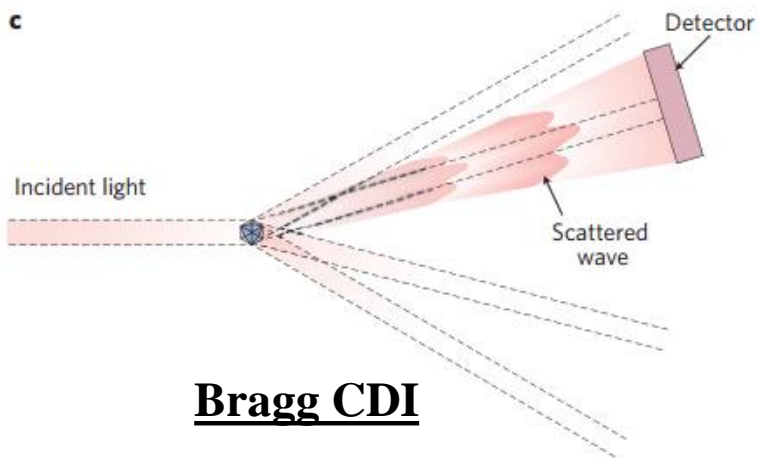
CDI methods



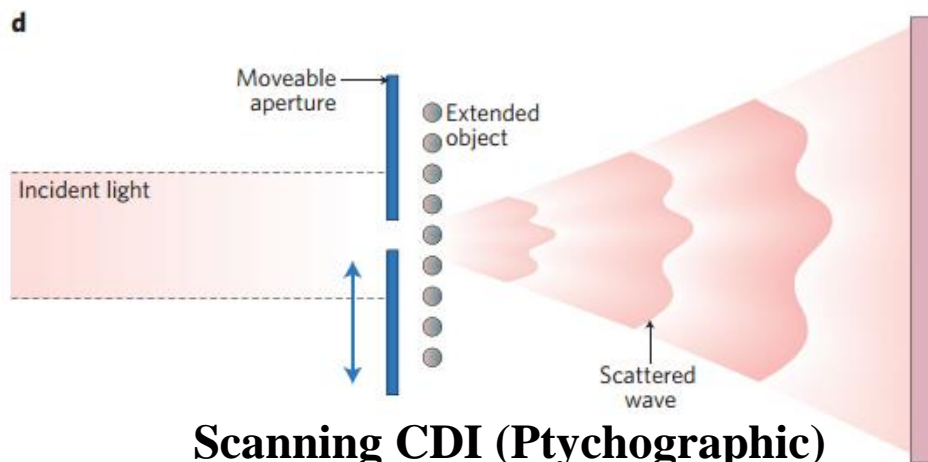
Plane – Wave CDI



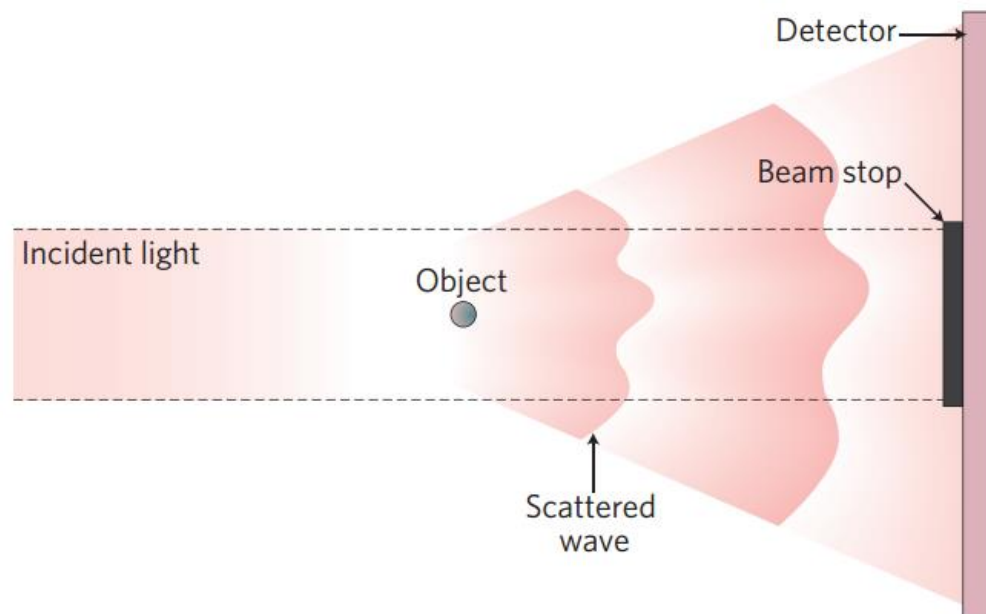
Fresnel CDI



Bragg CDI



Scanning CDI (Ptychographic)

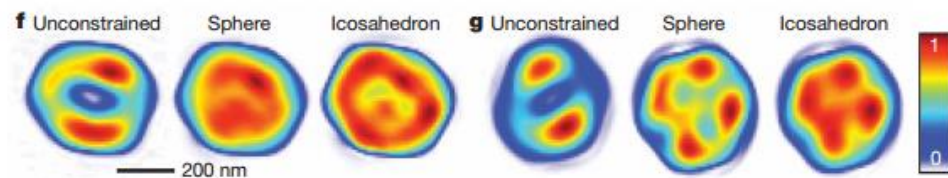
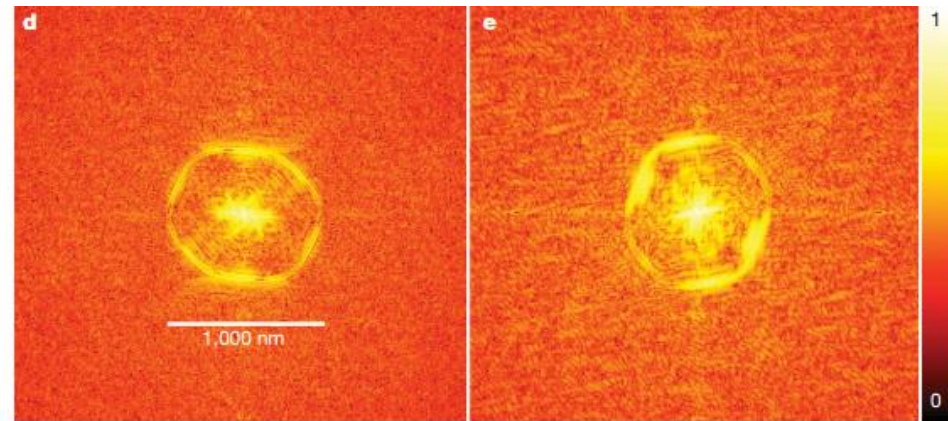
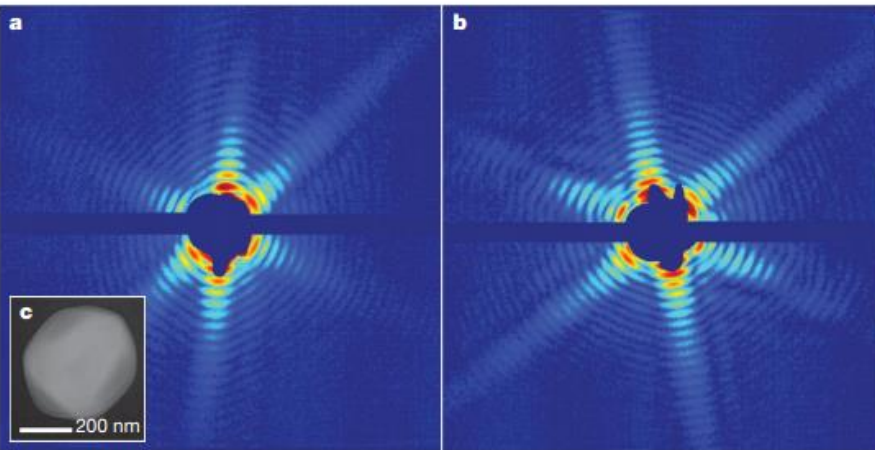
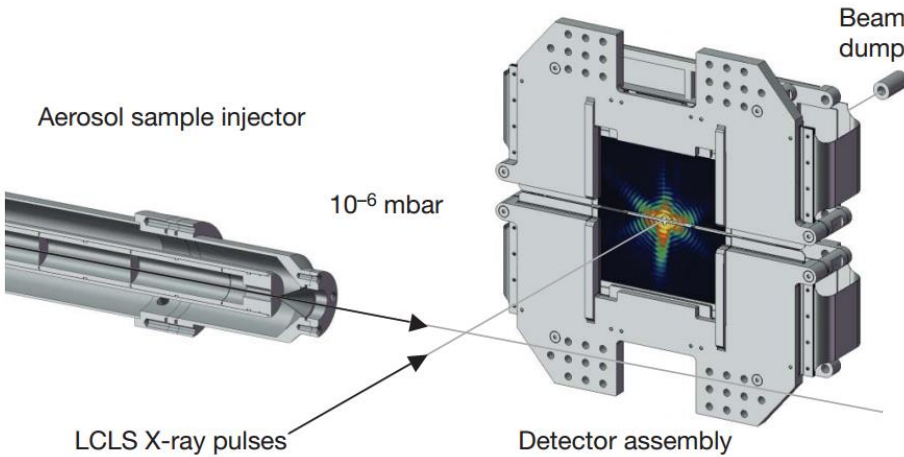


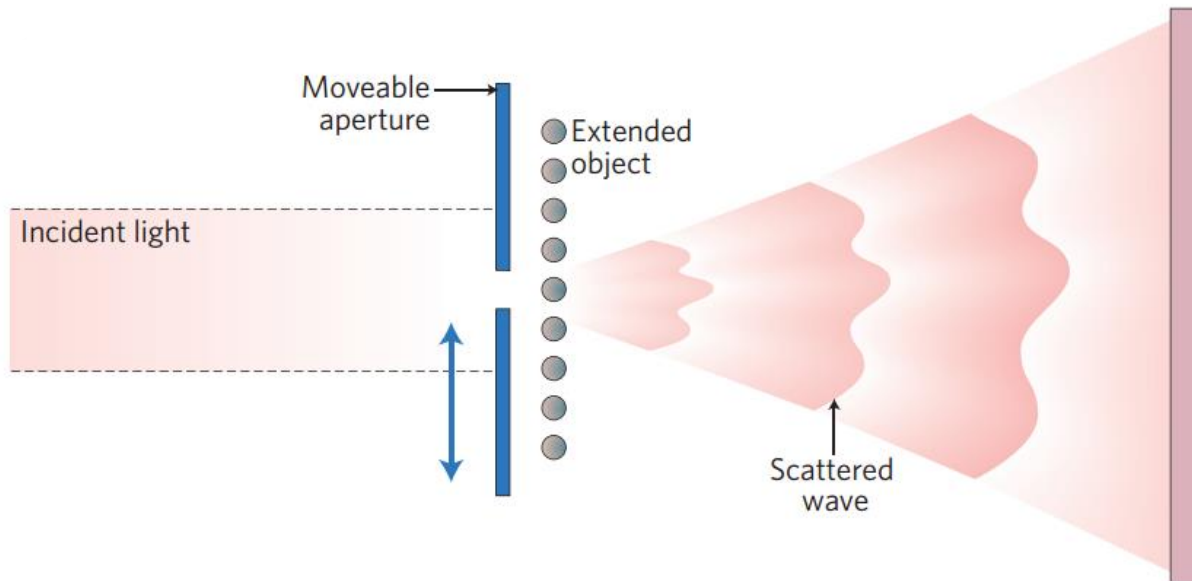
- Insensitive to sample vibration
- Easy to get 3-D datasets and reconstruction
- Can be implemented in single-shot experiments

Plane-wave CDI

Imaging single mimivirus particles

- LCLS, 30 Hz, 1.8 keV, <70 fs pulse, 8×10^{11} photons/pulse
- 32 nm resolution

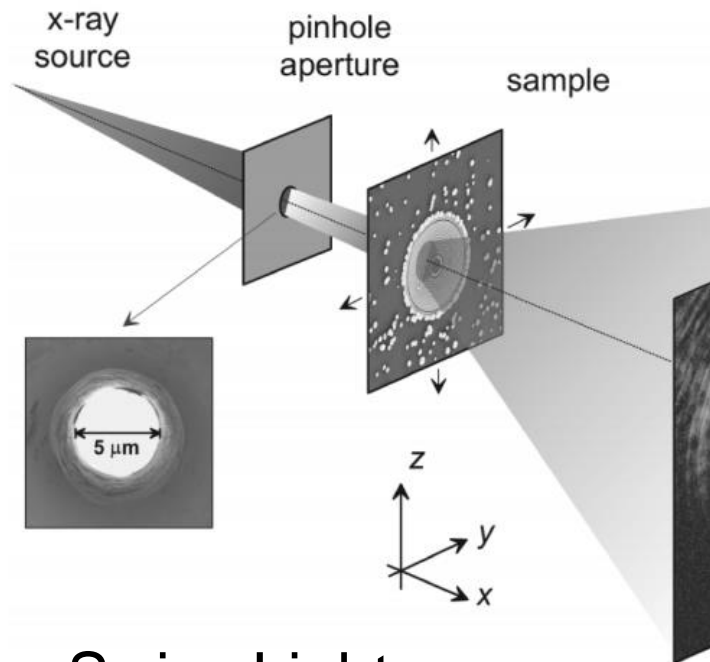




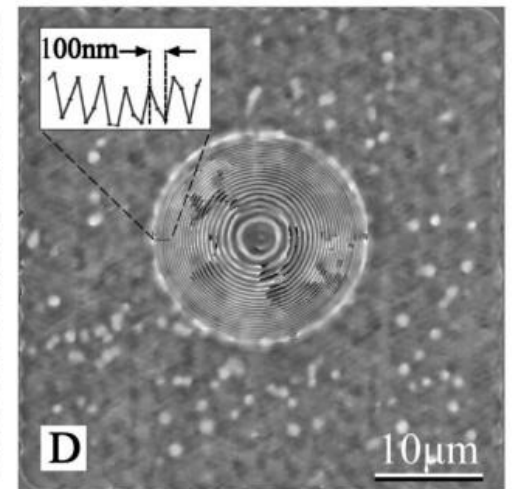
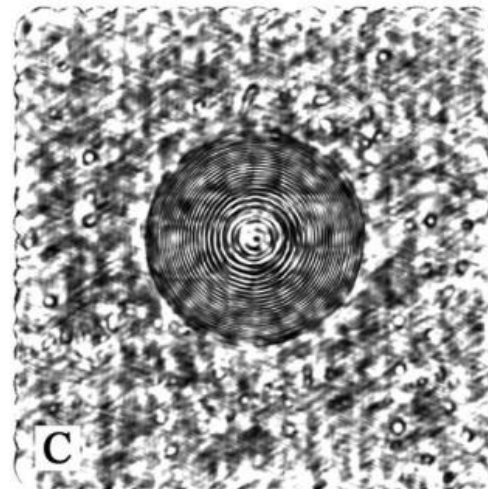
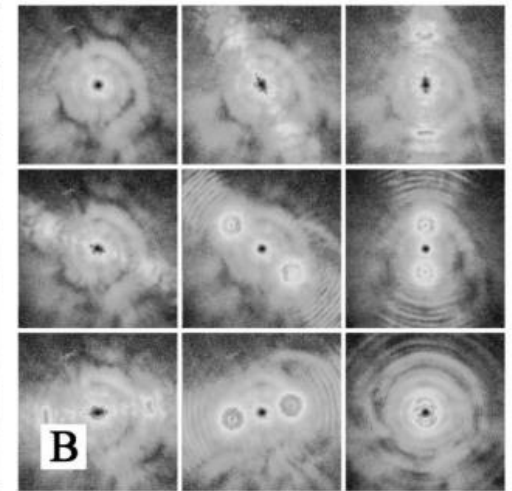
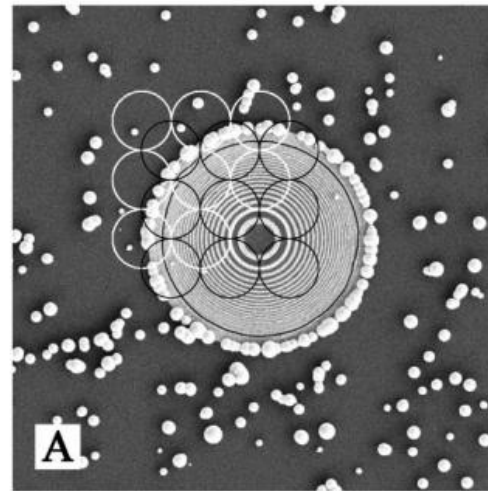
- Applied to extended objects
- Utilizes curved wave front
- Fast convergence of the phase retrieval algorithm

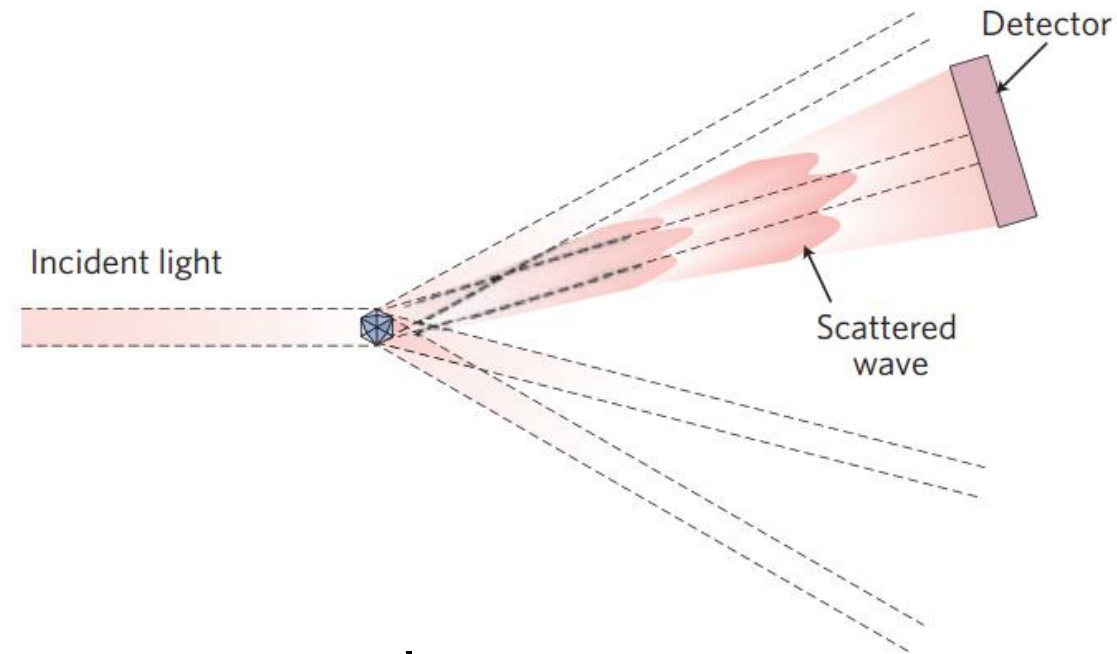
Scanning CDI

Imaging of a sample



- Swiss Light source
8 keV x-ray
- Gold plate and balls
- 50 nm resolution



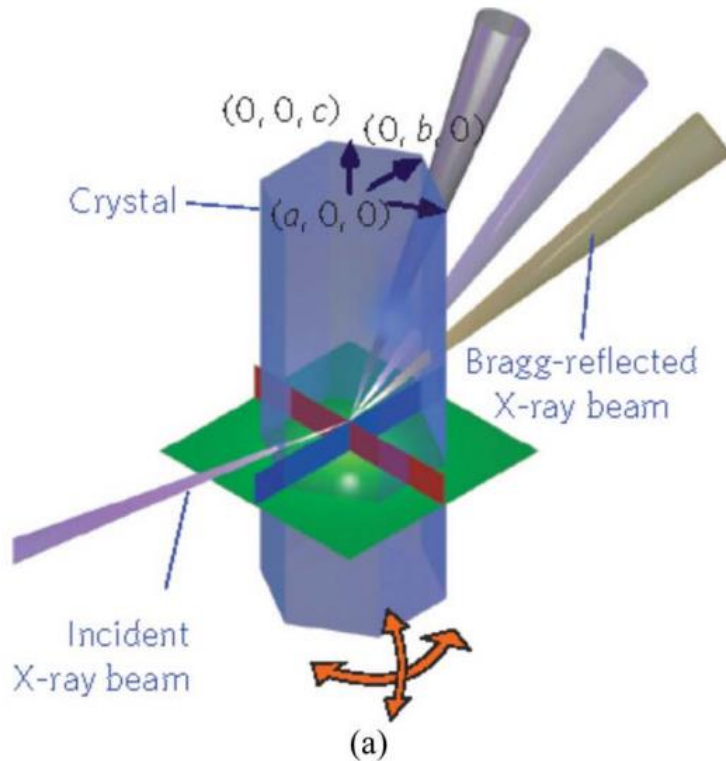


- Applied to nanocrystals
- Able to determine the 3D strain tensor and ion displacement

Bragg CDI

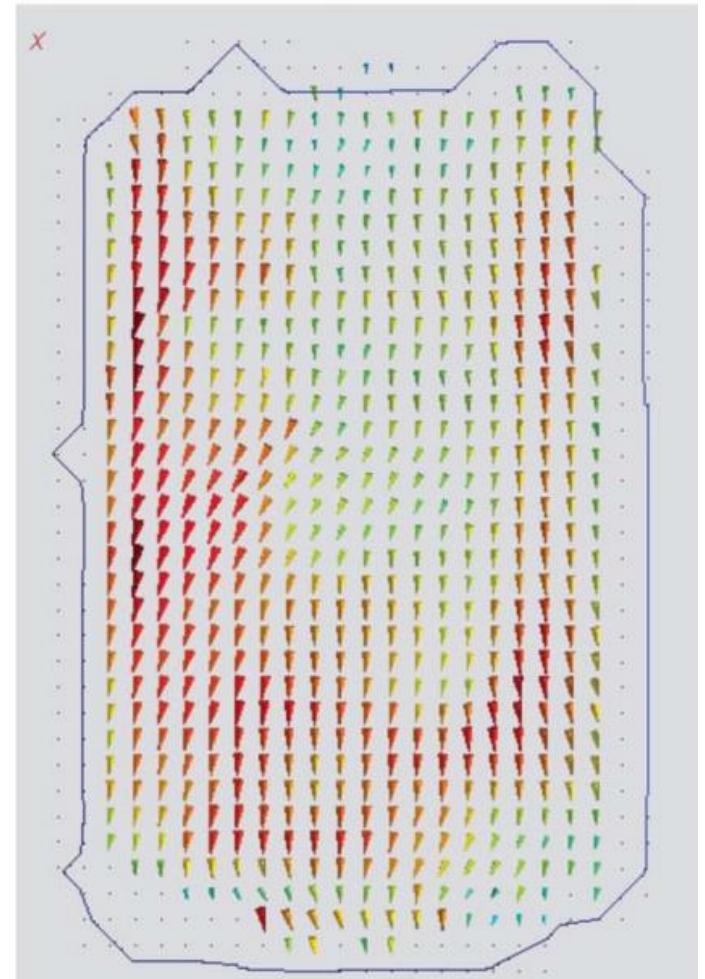
3-D Imaging of Strain Inside ZnO Nanocrystals

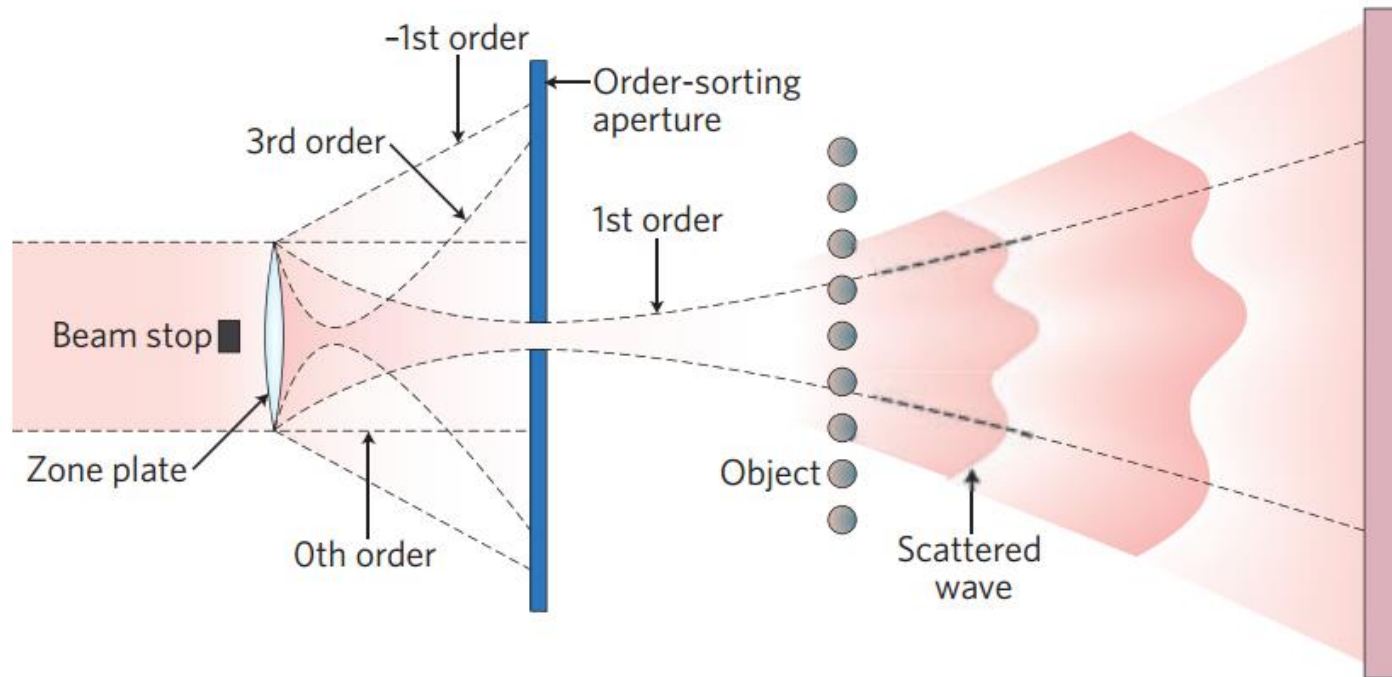
SLAC



- Advanced Photon Source
9 keV x-ray
- 40 nm resolution

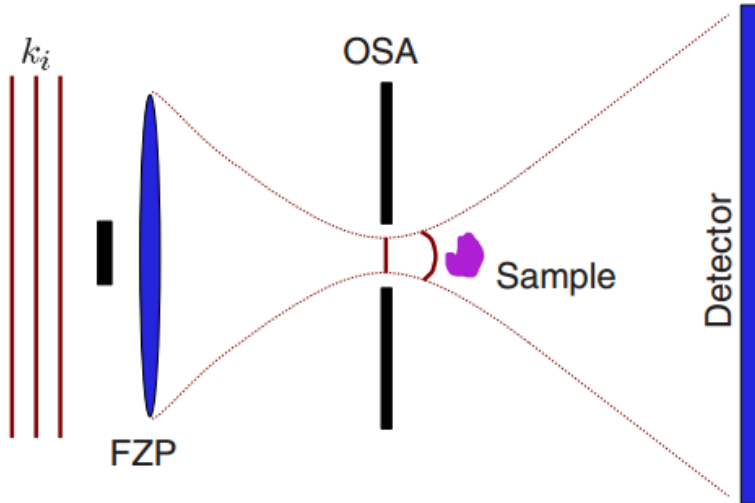
Ion displacement pattern



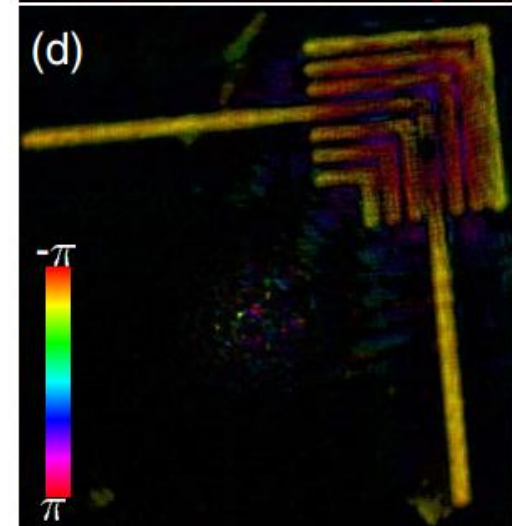
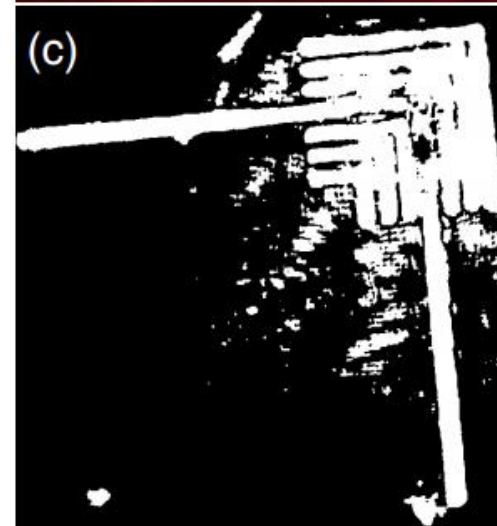
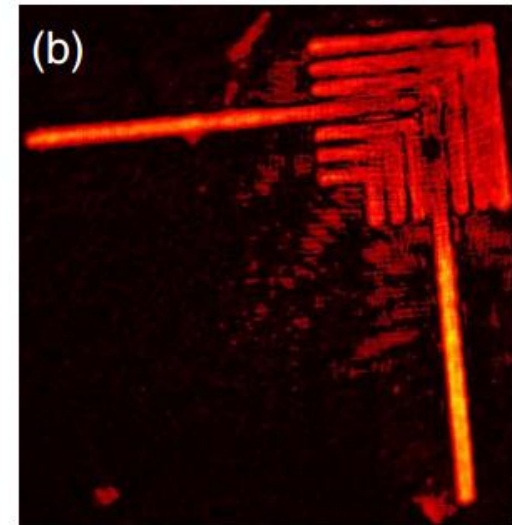
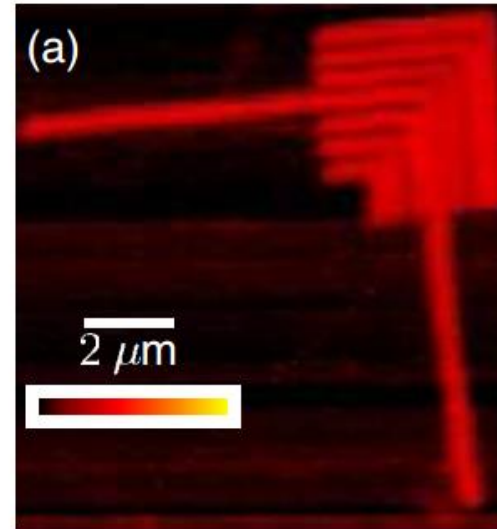


- Rapid convergence due to curvature
- the ability to image a subregion in an extended sample with a single view
- Higher resolution

Fresnel CDI Imaging nonperiodic Au sample



- APS 1.8 keV x-ray
- 24 nm resolution



- CDI is a novel form of lensless X-ray imaging
 - Ideally suited for non-periodic objects or nanocrystals
 - Resolution limited by radiation damage to sample
 - Need shorter, brighter pulses
-
- Best experimentally-achieved resolutions with CDI:
 - ~2 nm for inorganic materials
 - ~10-20 nm for organic materials

References

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- ⊕ M. Seibert et al., *Nature*, 470, 78 (2011).
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- ⊕ Williams, G. J., et al. "Fresnel coherent diffractive imaging." *Physical Review Letters* 97.2 (2006): 025506.
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- ⊕ Rodenburg, J. M., et al. "Hard-x-ray lensless imaging of extended objects." *Physical review letters* 98.3 (2007): 034801.
- ⊕ Miao, Jianwei, et al. "Extending the methodology of X-ray crystallography to allow imaging of micrometre-sized non-crystalline specimens." *Nature* 400.6742 (1999): 342-344.

THANKS FOR YOUR ATTENTION !