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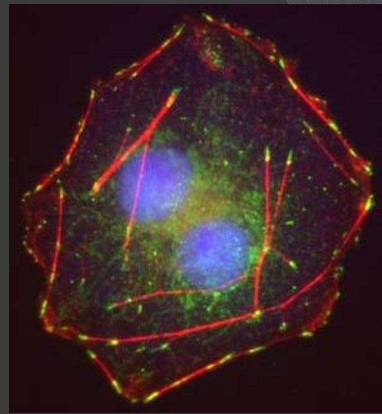
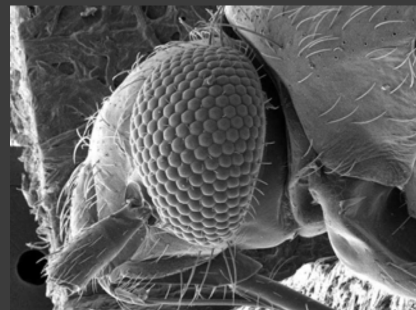
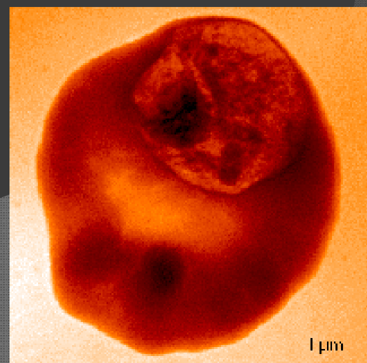
DETECTORS FOR COHERENT DIFFRACTIVE IMAGING

Imaging small things

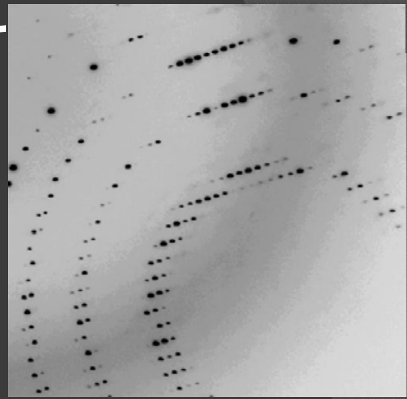
- Light microscopy
  - limited by penetration
  - Limited by wavelength (100s nm)
- Electron microscopy
  - Has to be done under vacuum
  - Exquisite resolution (0.2 nm)
- X-ray microscopy
  - Difficult to focus the x-rays
  - 15 nm is a very good resolution







Crystallography and coherent diffractive imaging (CXDI)



- X-ray crystallography
  - Details down to 0.1 nm…but only with crystals.
- CXDI - Microscopy without lenses
  - Use the *coherence* of the illuminating light to obtain structural information.
  - All the advantages of x-ray microscopy, but much higher resolution (<10 nm)

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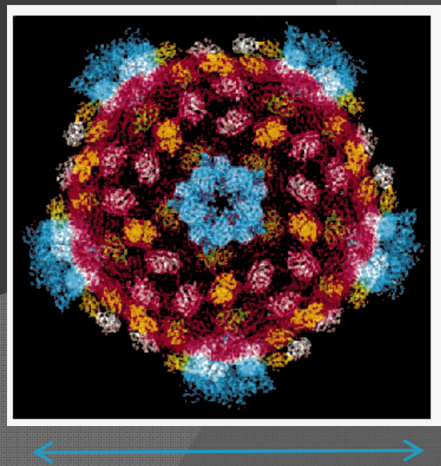
The Goals of CXDI

- Imaging single (large) proteins
- Eventually use an x-ray free electron laser
- Collect an image of the sample (protein)…before it is blown apart.

- More modest goals…small biological entities (cells).



CXDI ...how does it work?

Axioms:

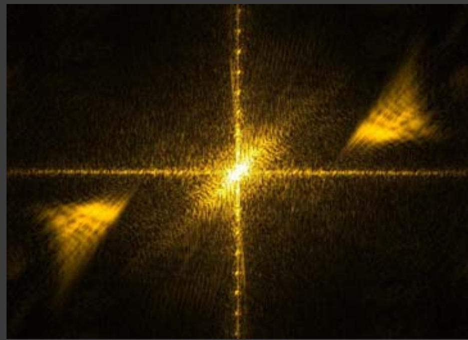
- If the waves incident on the object are plane waves. Then in the far field, after interacting with the object the wave represents a Fourier Transform of the object.
- To get back to an image of the object you simply need to perform an inverse Fourier transform.
- In light optics the lens does this.

Detection and reconstruction

- If we can detect the complex far field wave we can do the FT^{-1} with a computer.
- The problem is that our detectors only detects intensity. No phase information is measured directly.
- However, the phase can be estimated then refined by iteration.

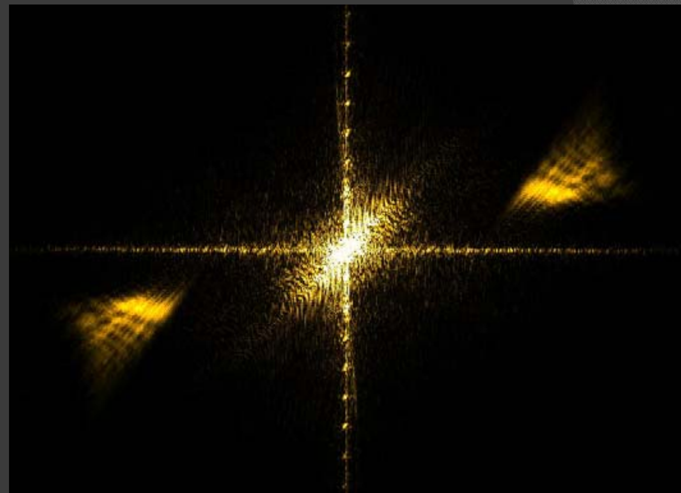
Fourier transforms

$\mathcal{F}$



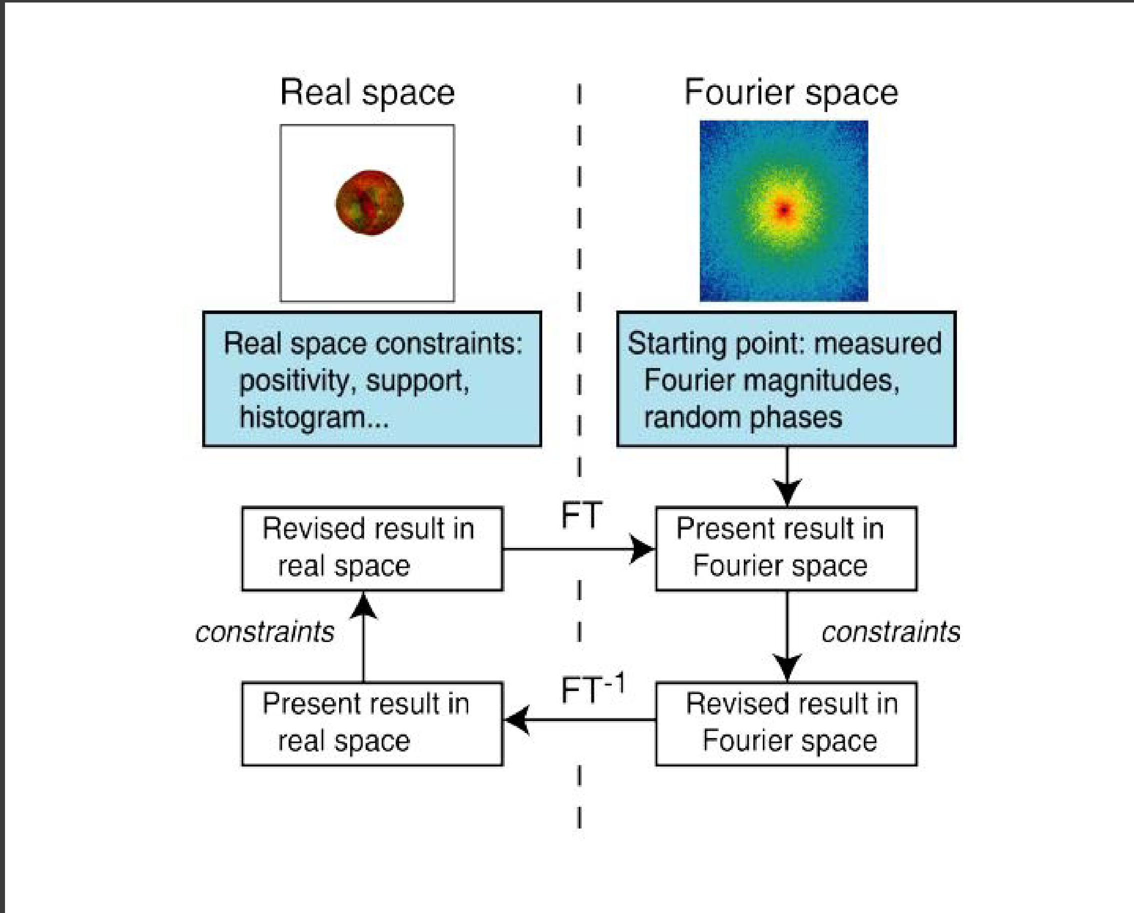
Frequency

Phase



Intensity

Gershberg-Saxton (and family)



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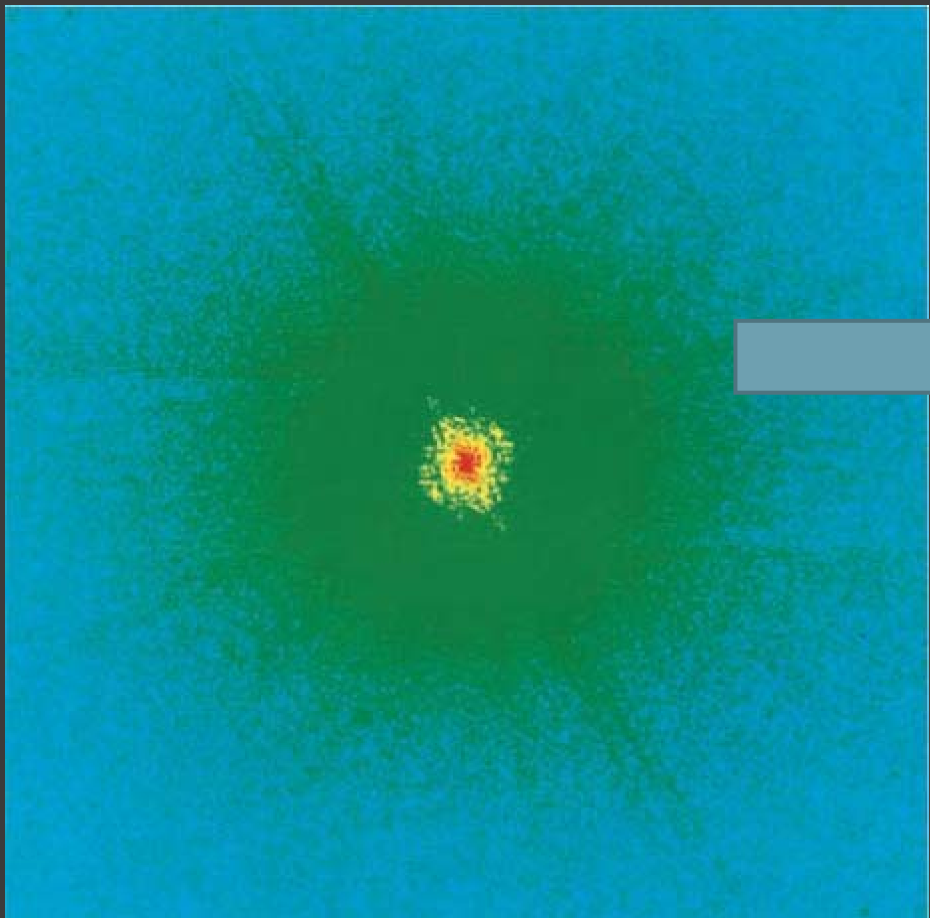
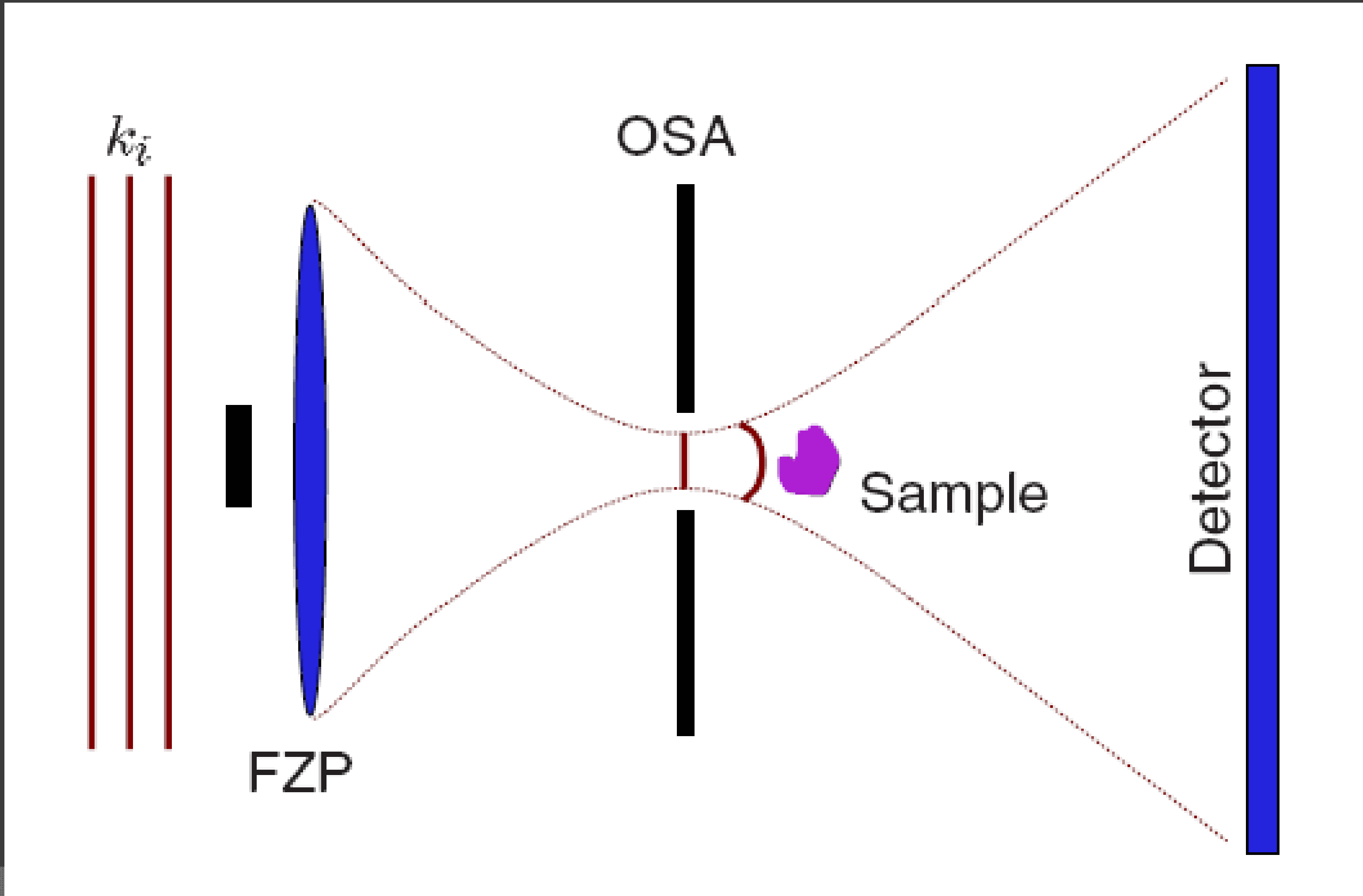
CXDI for real

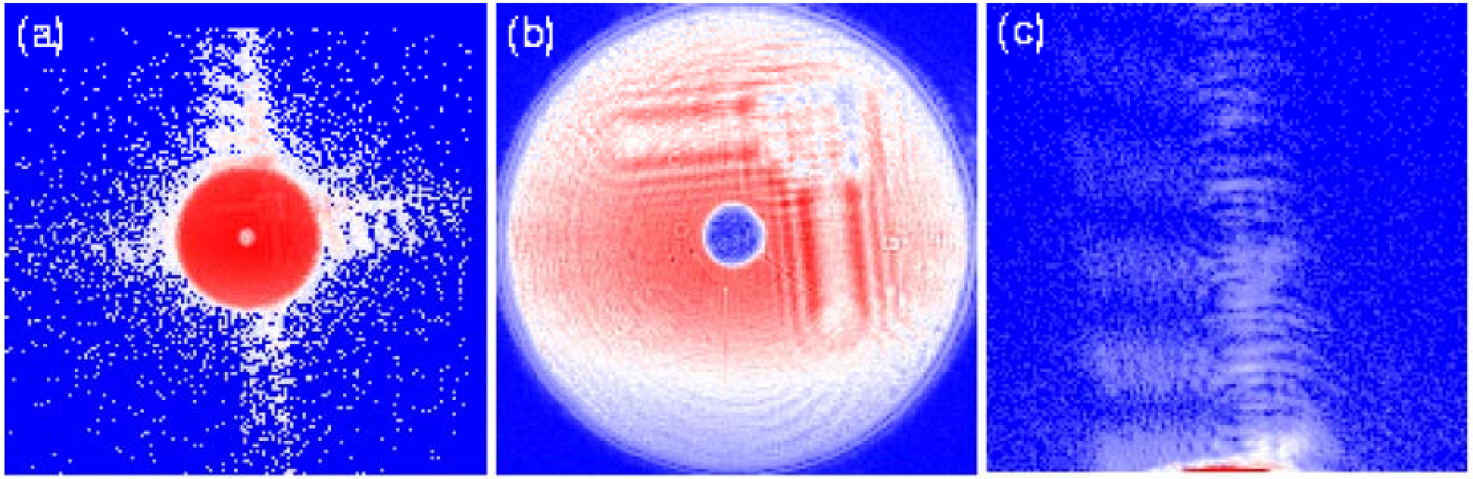


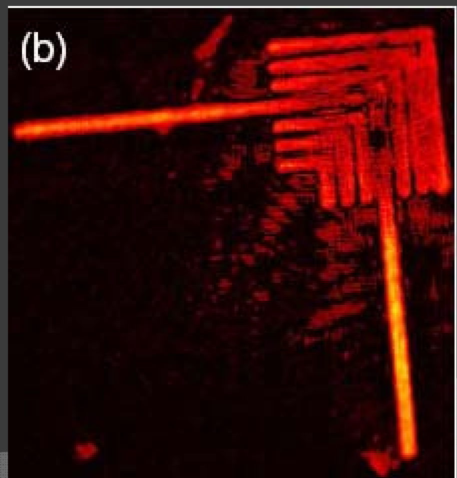
J. Miao, K. O. Hodgson, T. Ishikawa, C. A. Larabell, M. A. LeGros and Y. Nishino, Proceedings of National Academy of Science of the USA 100, 110-112 (2003)

Fresnel CXDI



From Williams, Quiney, Peele and Nugent, PRL (2006).





CXS

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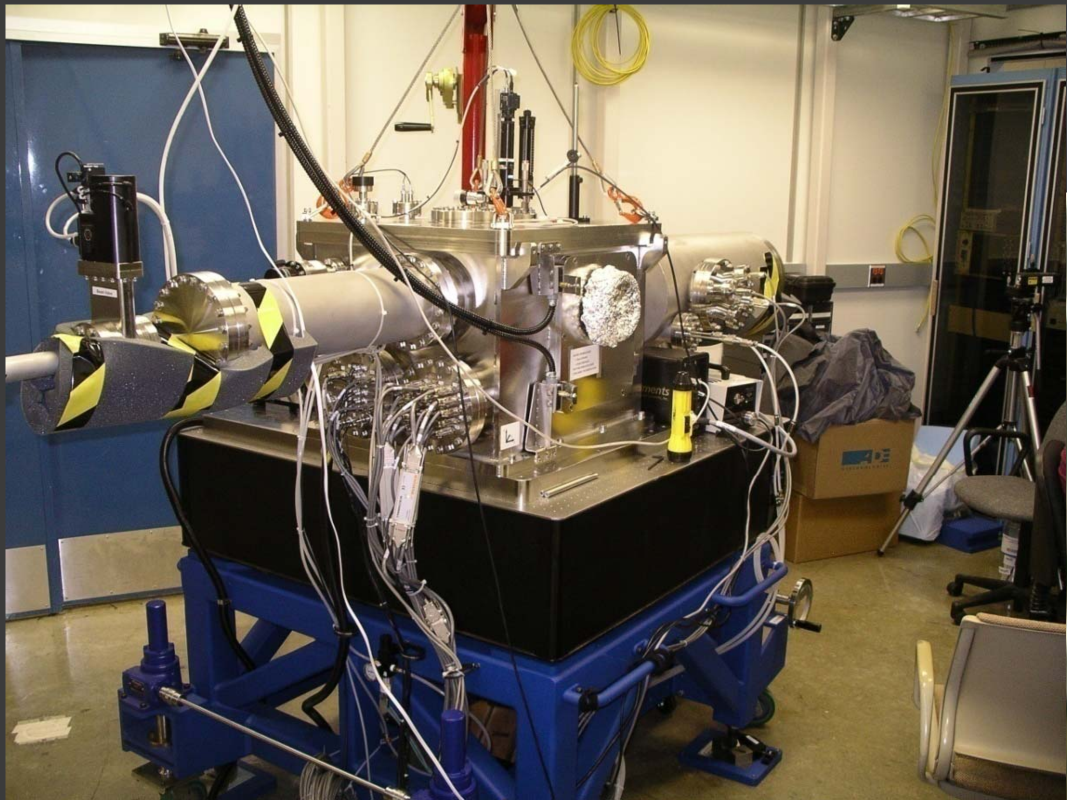

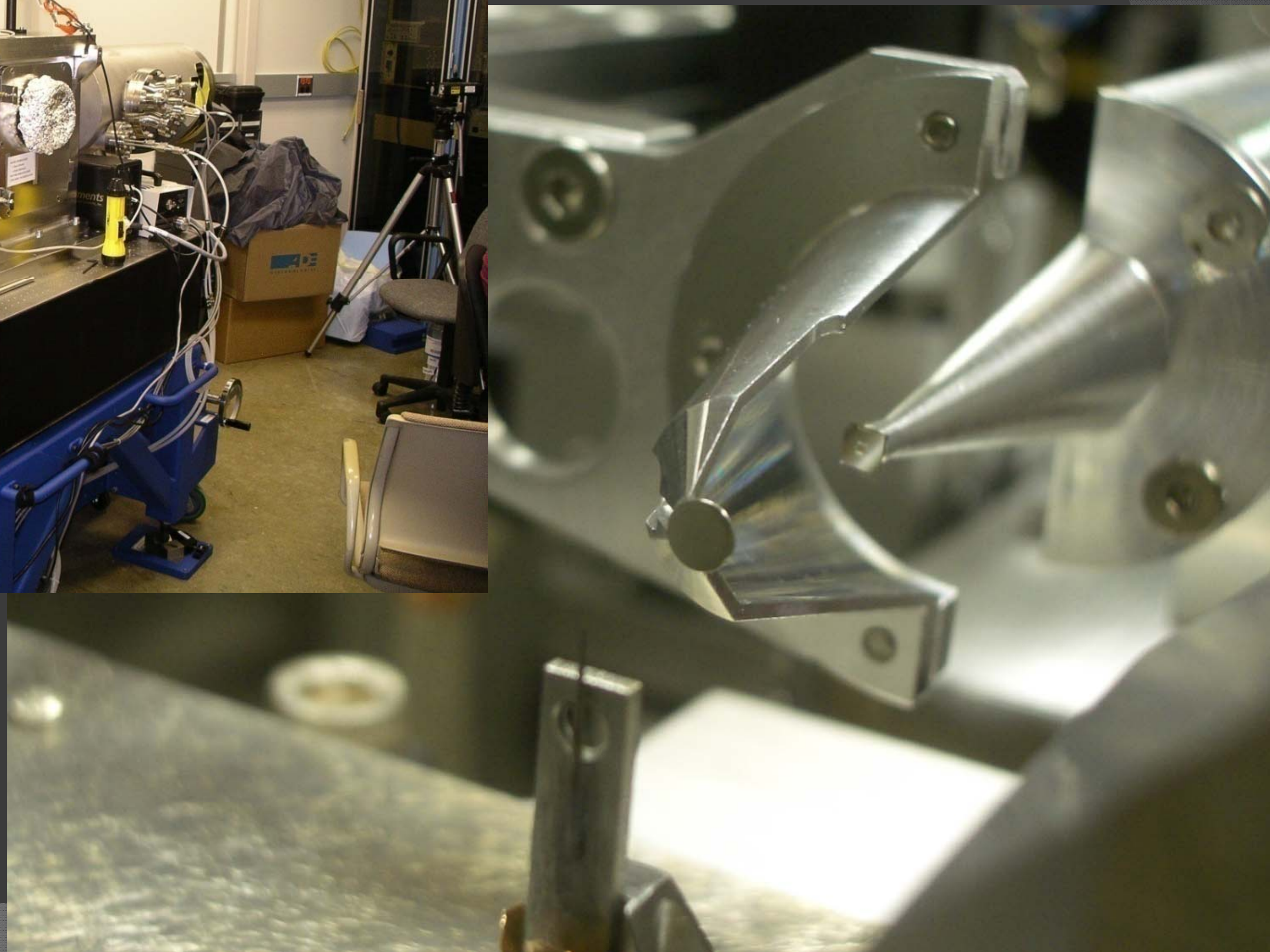

Where will it happen

APS, Illinois, USA

AS, Victoria, Australia

CXS

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So, what are the current detector requirements?

In the geometry used now:

Energy range for > 50% DQE = 0.5 – 4 keV
Dynamic range in image (noise to saturation) $>10^7$
Pixel size ideally < 25 μm
Pixel number >1024 x 1024
Maximum local count rate 10^4 per pix per second

CXS

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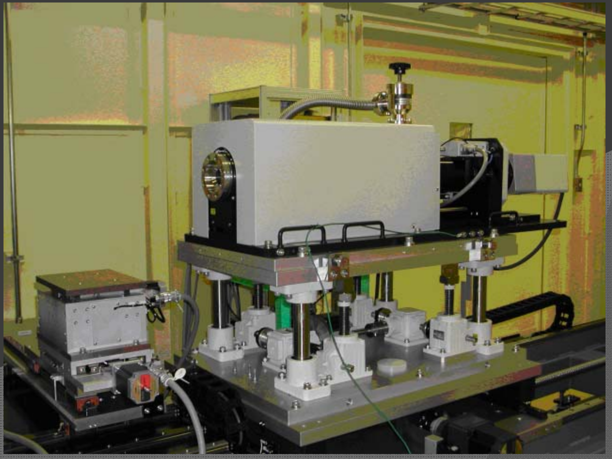
Trade study

	Criterion	Essential	Desirable
1	Dynamic range	10^4	10^7
2	Pixelation	2048 x 2048	>4096 x >4096
3	Pixel Size	<100 μm	< 50 μm
4	Energy Range	0.5 keV to 3 keV	0.5 keV to 3 keV
5	Detective Quantum Efficiency	10%	50%
6	Rate Capability	> 10^4 / pixel/ second	> 10^6 / pixel/ second
7	Frame rate	1 Hz	1 kHz
8	Vacuum compatibility	10^{-4} bar	10^{-6} bar
9	Dead time fraction	10%	1%
10	Parallax error	< 1 pixel at 20 degrees	
11	Gaps in FOV	Acceptable	None

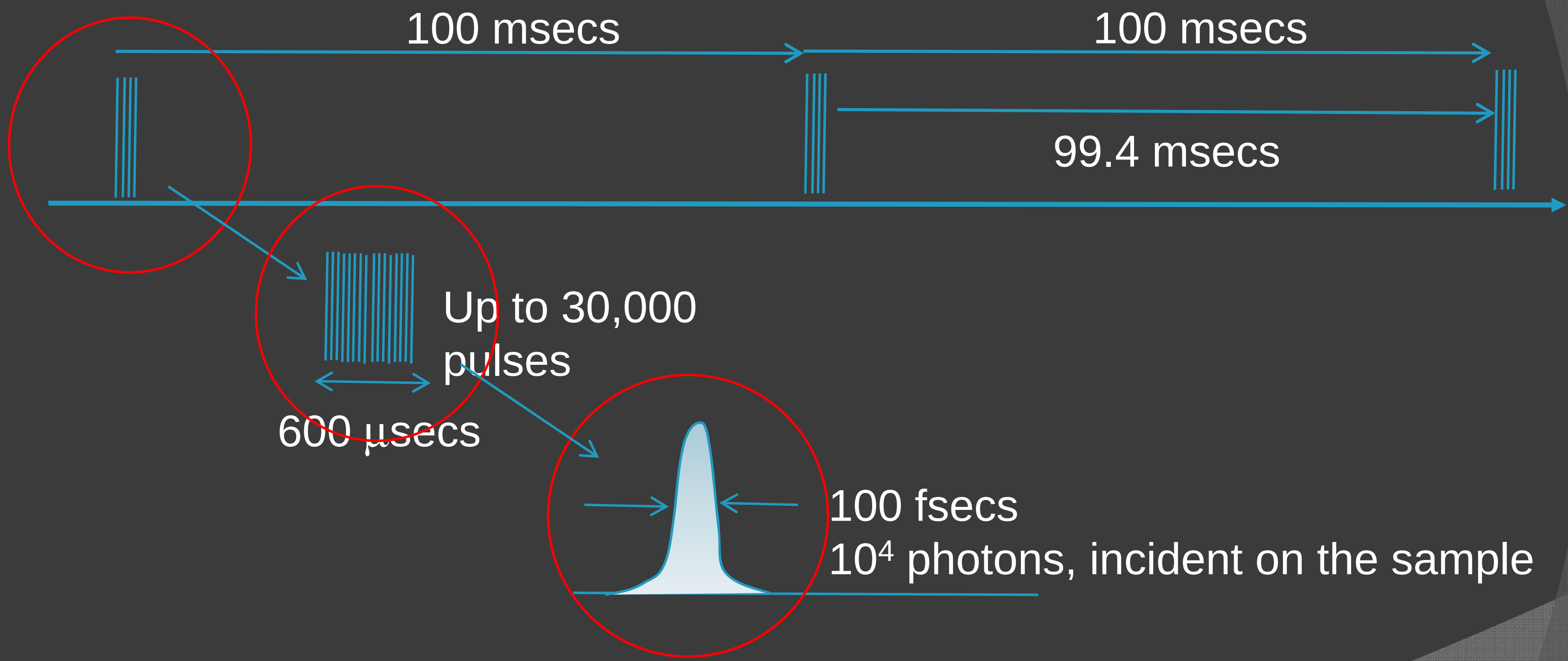
Commercially available detectors

- Easy option, but…
- Not designed for our purposes



XFEL pulse structure



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Dr. Garth Williams (Melbourne University)
Dr. Mark Pfeiffer (La Trobe University)
Evan Curwood (Monash University)
Mr. Andrew Berry (Monash University)
Dr. Wilfred Fullagar (Monash University)

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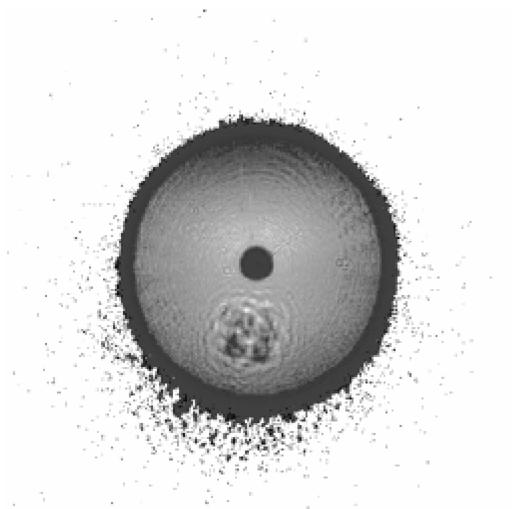
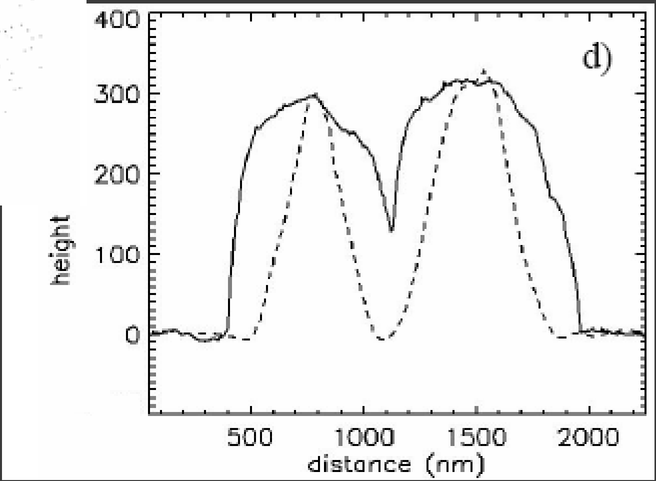
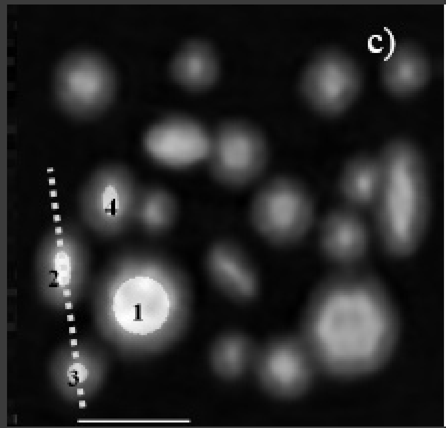
Thank you for your attention

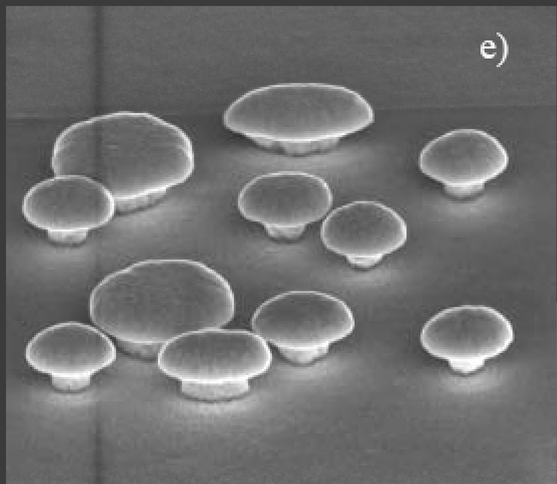
[redacted]

Results so far









Gold blobs on Si_3N_4 substrate

Specifications for the CXS End Station apparatus

- Includes a 4 axis laser Doppler displacement meter which provides:
  - Positioning of sample w.r.t beam of 30 nm
  - Resolution in closed loop feedback of 0.2 nm
  - =>Stability of sample w.r.t. beam of 2 nm