Study Meeting 3: Electron detectors

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• Two weeks ago

• Today
Summary of Electron lenses

• Two different types:
  1. Electrostatic lenses
  2. Electromagnetic lenses

• Lens aberrations
  1. Spherical aberration
     • Hexapoles, etc
  2. Astigmatism
     • Careful beam alignment / Stigmators
  3. Chromatic aberration
     • Energy filters, FEGs
Film & CCD Cameras

- Electrons cause exposure of film
- CCD never had large impact
- Mismatch between scintillator and fiber optics

Ruijter (1995)
Micron, 26(3):247
Electrons cause exposure of film

CCD never had large impact

Mismatch between scintillator and fiber optics
Direct Electron Detector
Why are DEDs so much better?

- No scintillation layer
- Reduced shot noise
- Backscattering
- Faster readout → Motion correction
- Electron counting → Reduce coincidence loss → Landau problem

Reducing backscattering

300 keV electrons

Si

35 μm

350 μm

McMullan et al. 2009
Ultramicroscopy 109:1144
Backscattering

- Thick back layer in early DED
Motion Correction

Single frame

(A) Direct alignment

(B) MotionCor1

(C) FFT of B

(D) FFT of C
MotionCorr2

- Does global and local (patch) alignment

Zheng et al. (2017)
Nat. Meth. 14(4):331
K2 counts each electron rather than the charge of each pixel which eliminates the Landau noise (as each pixel could be a sum of different electrons)

8 $e^-$/px/s is really 10 $e^-$/px/s
Camera performance

- Modulation Transfer Function (MTF)
  - Envelope function of the camera
- Detector Quantum Efficiency (DQE)

\[
DQE = \frac{(S/N)^2_{\text{OUT}}}{(S/N)^2_{\text{IN}}}
\]
How to measure the MTF

- Platinum or gold knife
- Has a sharp edge
- A perfect optical system would produce a step function
How to measure the MTF

- Cameras are made of pixels\(^{(\text{cit. needed})}\) so an atomic width edge does not produce a perfect step function.
How to measure the MTF

McMullan, Chen, Henderson, Faruqi (2009)
Ultramicroscopy. 109:1126
How to measure the MTF

McMullan, Chen, Henderson, Faruqi (2009)
Ultramicroscopy. 109:1126
Calculating the DQE

- Complicated
- Partially related to the MTF
DQE

- Measures how strong the signal will be relative to the noise at a certain spatial frequency.

The DQE relates the level of instrumentation noise to the level of inherent shot noise in the image. It is therefore the tool to quantify detector instrumentation noise. The noise in the recorded image follows by

Ruijter (1995)
Micron, 26(3):247
$$\text{DQE} = \frac{(S/N)_{\text{OUT}}^2}{(S/N)_{\text{IN}}^2}$$

McMullan et al. (2014)
Ultramicroscopy, 147:156
Summary

• DED are better
  – Shot noise
  – Back thinning
  – Motion correction
  – Coincidence loss

• MTF: the camera envelope function

• DQE: Input SNR to output SNR
Next session

• Image formation / CTF