

Early CMOS development project 2005-2008

- LMB, FEI, MPI-Biophysics and MPI-Biochemistry sponsored a pre-commercial project with RAL named TEMAPS.
- Goal was to maximise DQE for 300keV electrons in an integrating detector, and to make it more-or-less a straight replacement for film and phosphor/CCD detectors.
- Many parameters were optimised.

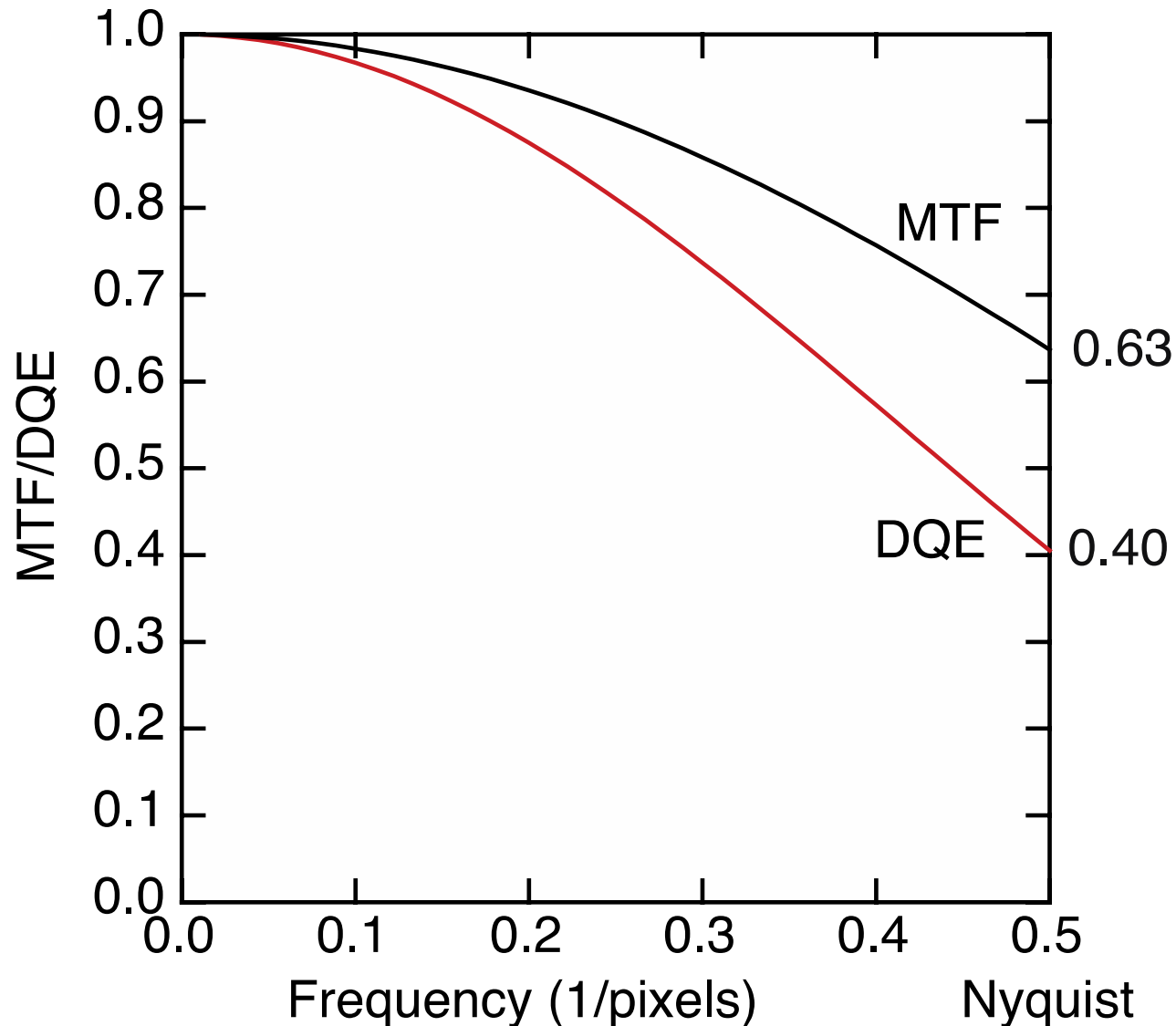
FEI Falcon CMOS direct electron detector is a product

- Use same beam intensity, same exposure time as for SO-163 (12' in D19).
- e.g. 1 sec exposure at 59,000x, with exposure meter set to 1 sec (emulsion 1). This gives 17el/Å²/sec at specimen, 17 Hz frame rate, 1.71 Å pixel, 3 el/frame/pixel, 50 el/pixel/sec.
- Vary dose by varying exposure time or magnification (keep same intensity at detector).
- To do better than Falcon in integrating mode, must go to counting mode.

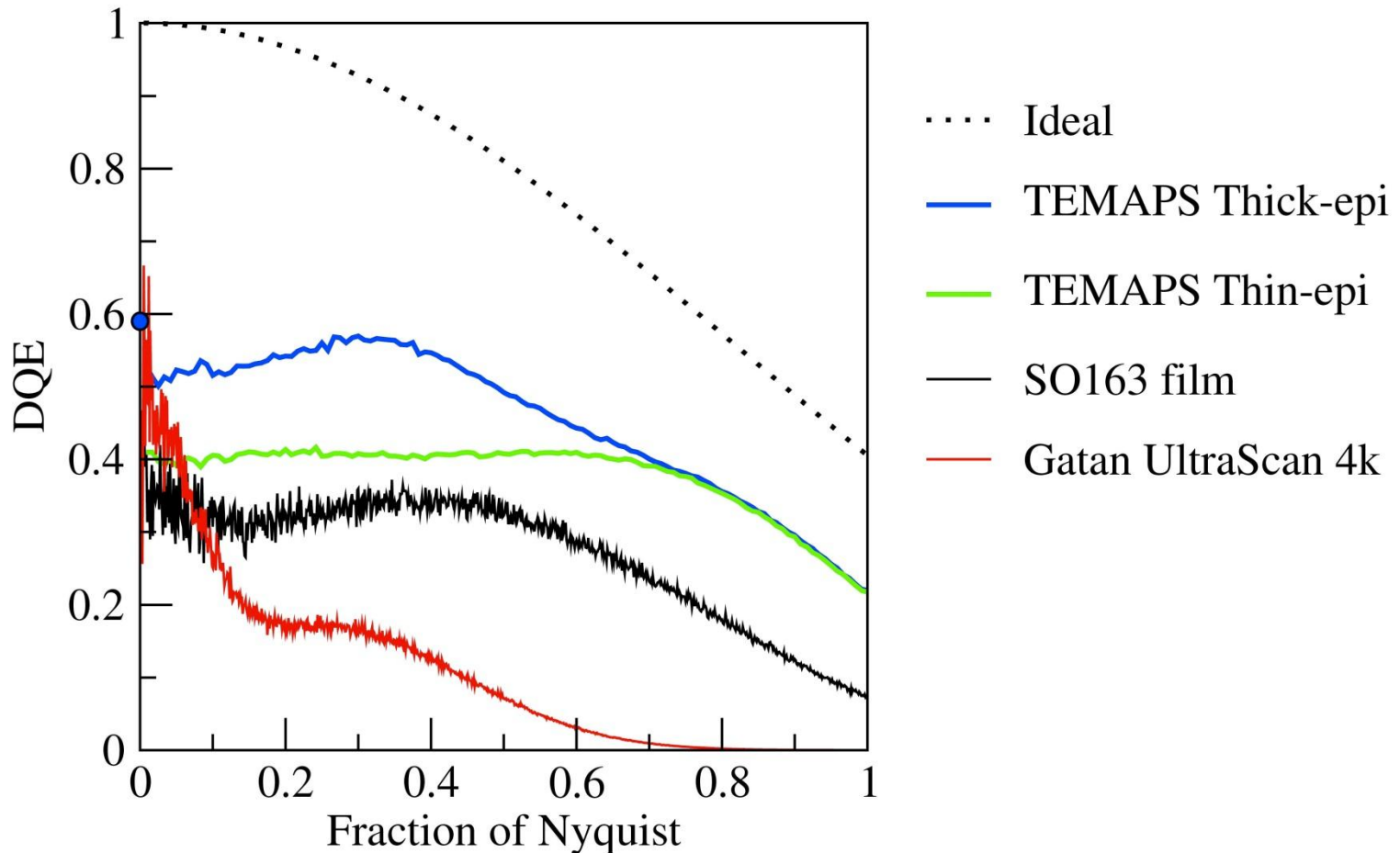
$$DQE(\omega) = DQE(0) * MTF^2 / NTF^2$$

Meyer & Kirkland (2000)
De Ruijter (1995)

Perfect detector MTF and DQE

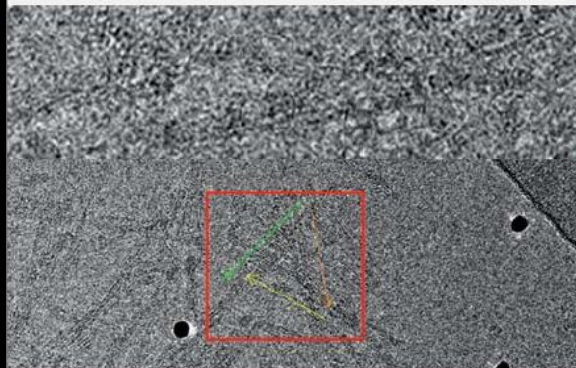


Comparison of DQE for various detectors at 300 keV (Pre-Falcon)



McMullan et al (2009a, 2009b, 2009c) Ultramicroscopy

From FEI Falcon brochure



Falcon II™

16 Megapixel TEM Direct Electron Detector
with Back-Thinned Sensor Technology

Specifications Falcon II™	
Operating voltage	Up to 300kV
CCD field of view	5.7 x 5.7 cm ²
CCD size	4096 x 4096 pixels, 14 x 14 μm ²
Binning	1x, 2x, 4x
Mounting position	On-axis TEM bottom, retractable
Magnification on detector with respect to film	1.3 – 1.5x
Peltier cooling	-20 °C (regulated)
DQE (300kV, 10e ⁻¹ /px)	> 0.4 at ½ Nyquist at 300kV
Readout noise	< 0.05 pe/px (input referenced units = primary electron beam)
Readout area	Full, half or quarter
Acquisition time	2.5 sec/image @ binning 1
Radiation hardness	Electron Dose: 500Me ⁻¹ /px
Targeted lifetime	5 years under standard low dose conditions (~ 50 M images of 1 sec exp time)
Bit depth	16 bits
Safety	SW protection against over exposures Second camera (CCD, 2672 x 2672 pixels, 9 x 9 x 14 μm ²) included for routine pre-screening
Software	FEI embedding (included)

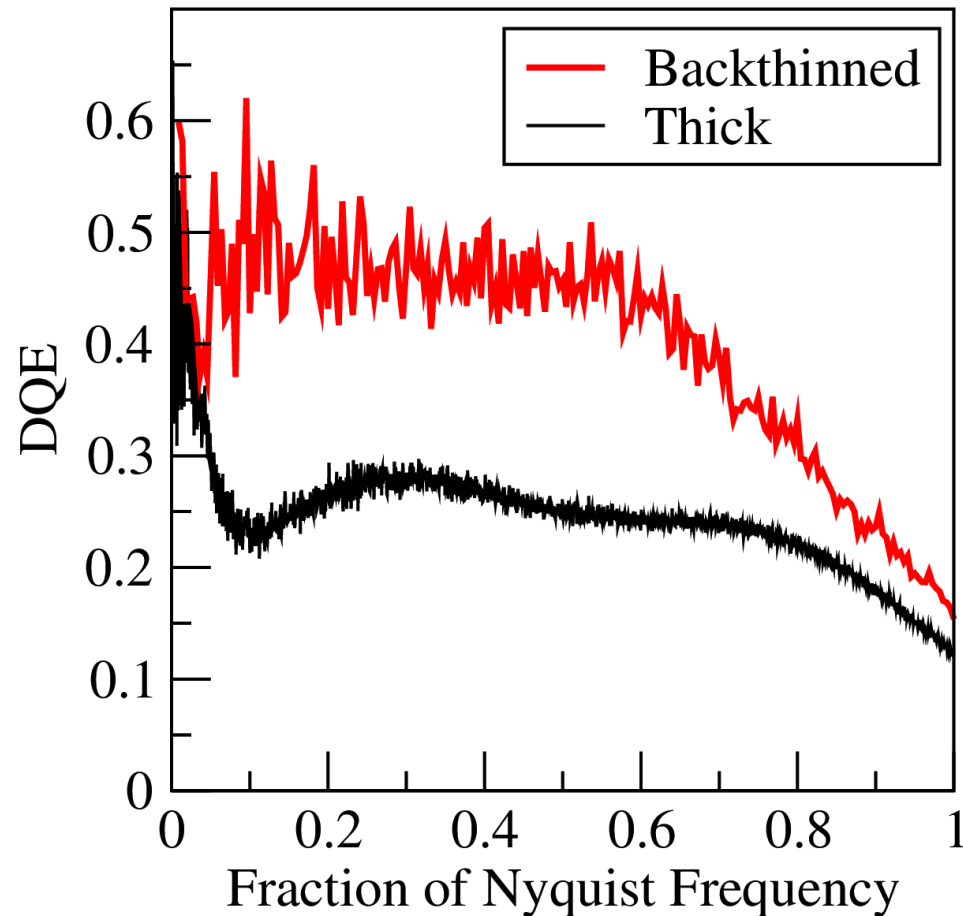
LMB Falcon mounting and single frame acquisition system – Greg McMullan



LMB report on backthinned Falcon May 2011

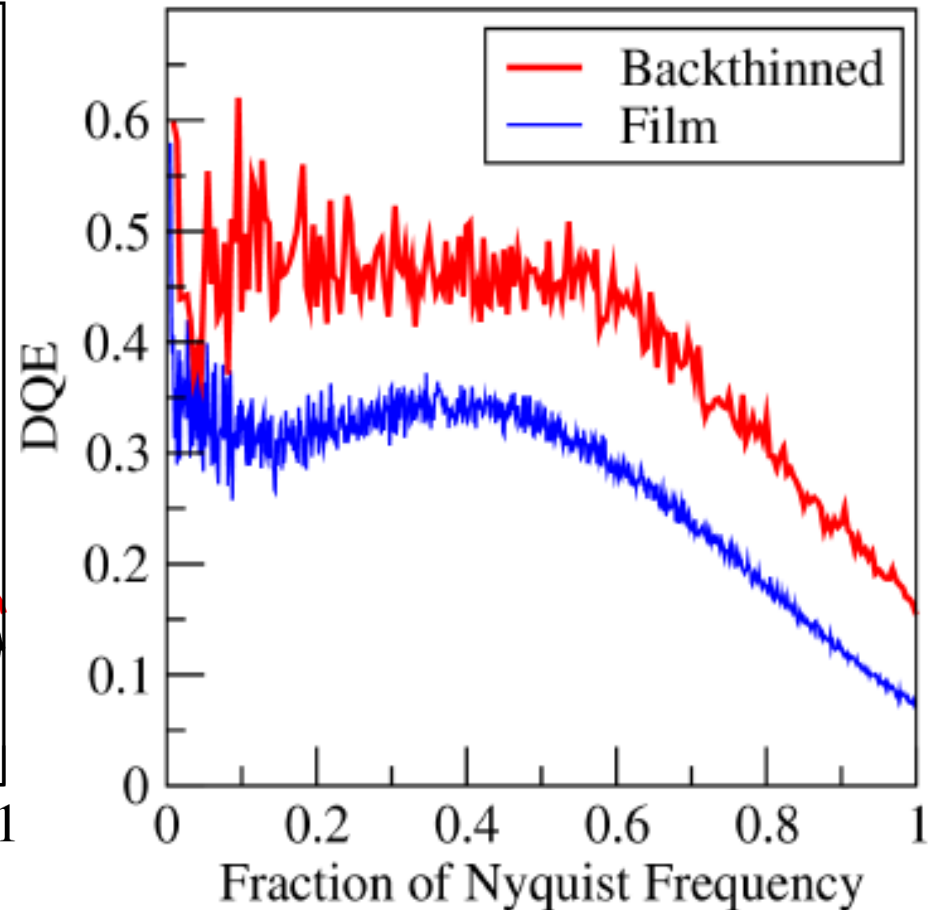
Effect of backthinning

300 keV



Falcon versus film

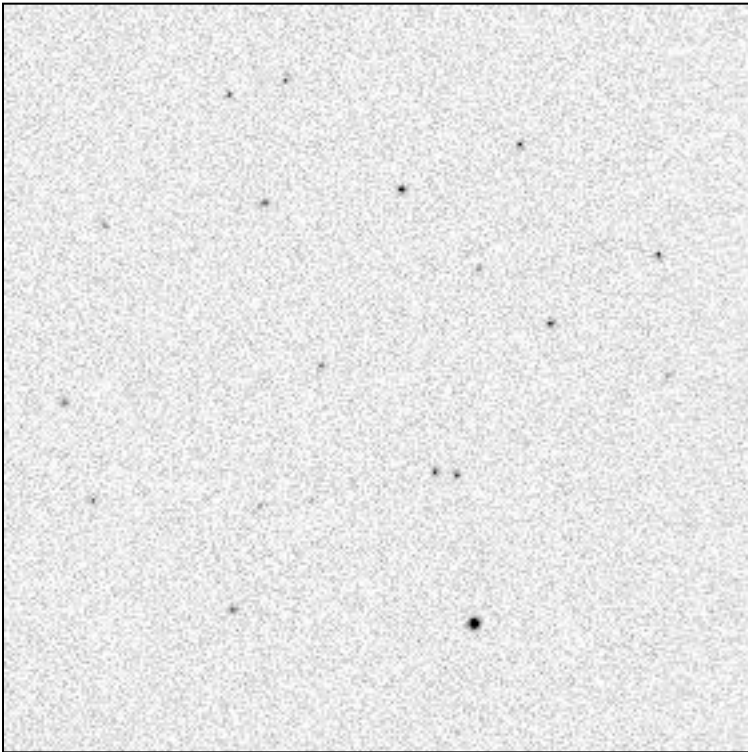
300 keV



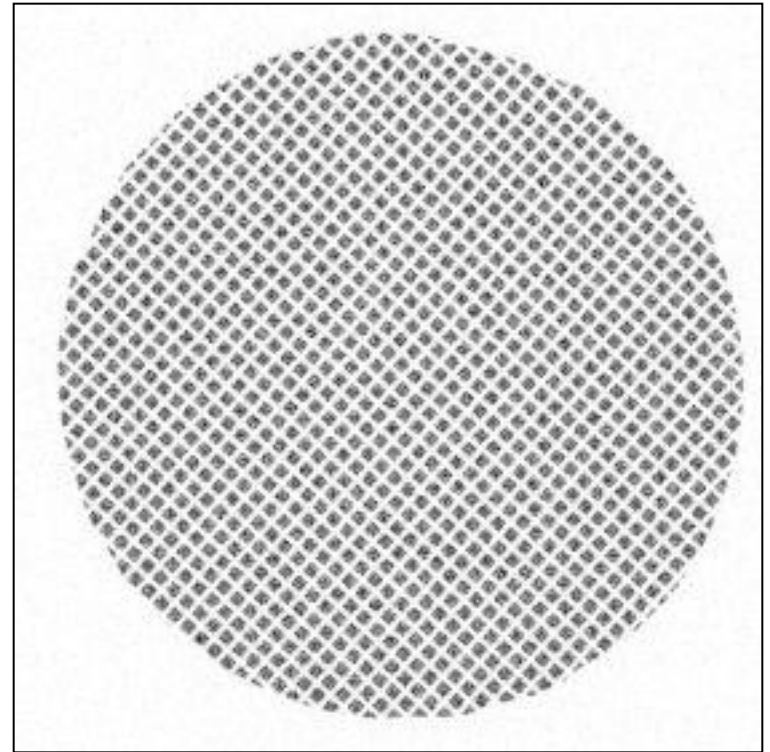
Electron counting with Falcon

Single electron event processed images – backthinned Falcon

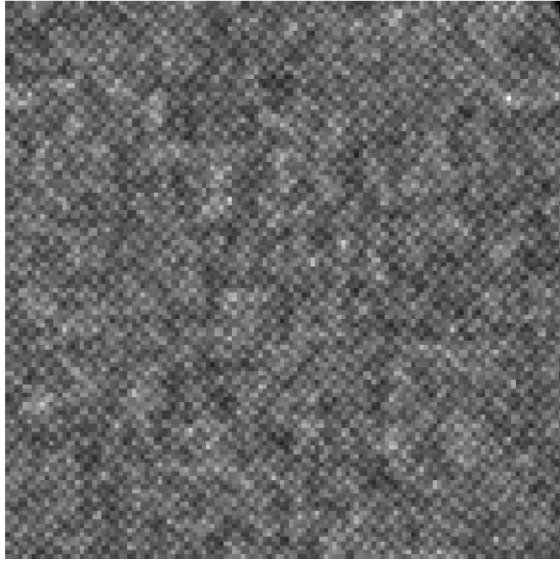
Best region, area of 280x280 pixels
single frame



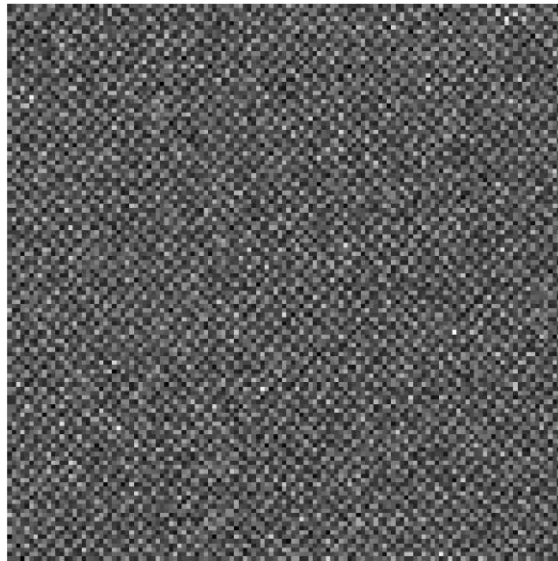
sum of 26,000 frames



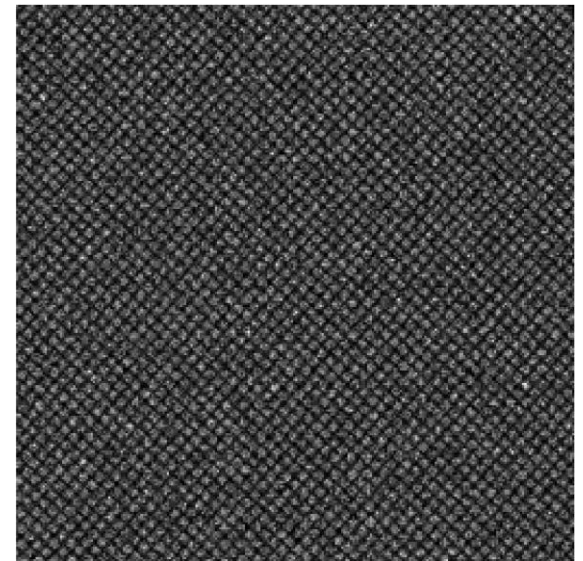
Backthinned Falcon - 1000 mesh grid shadow pattern – single electron comparison



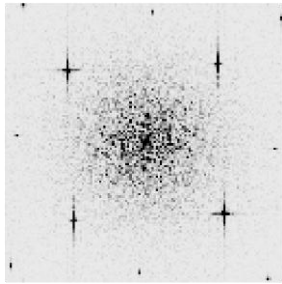
integrating mode



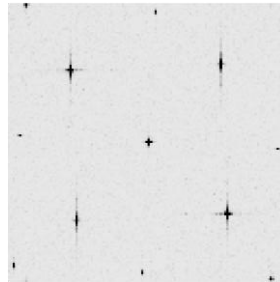
centre-of-gravity



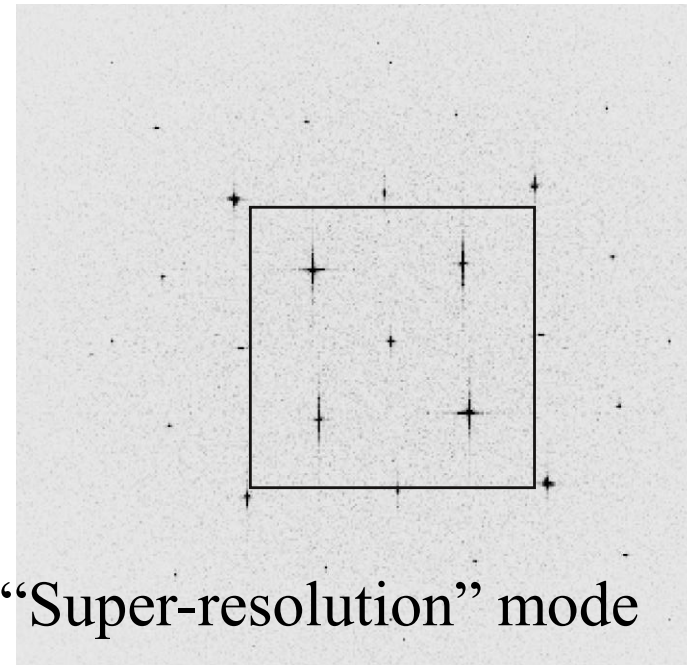
centre-of-gravity interpolated



Integrating mode

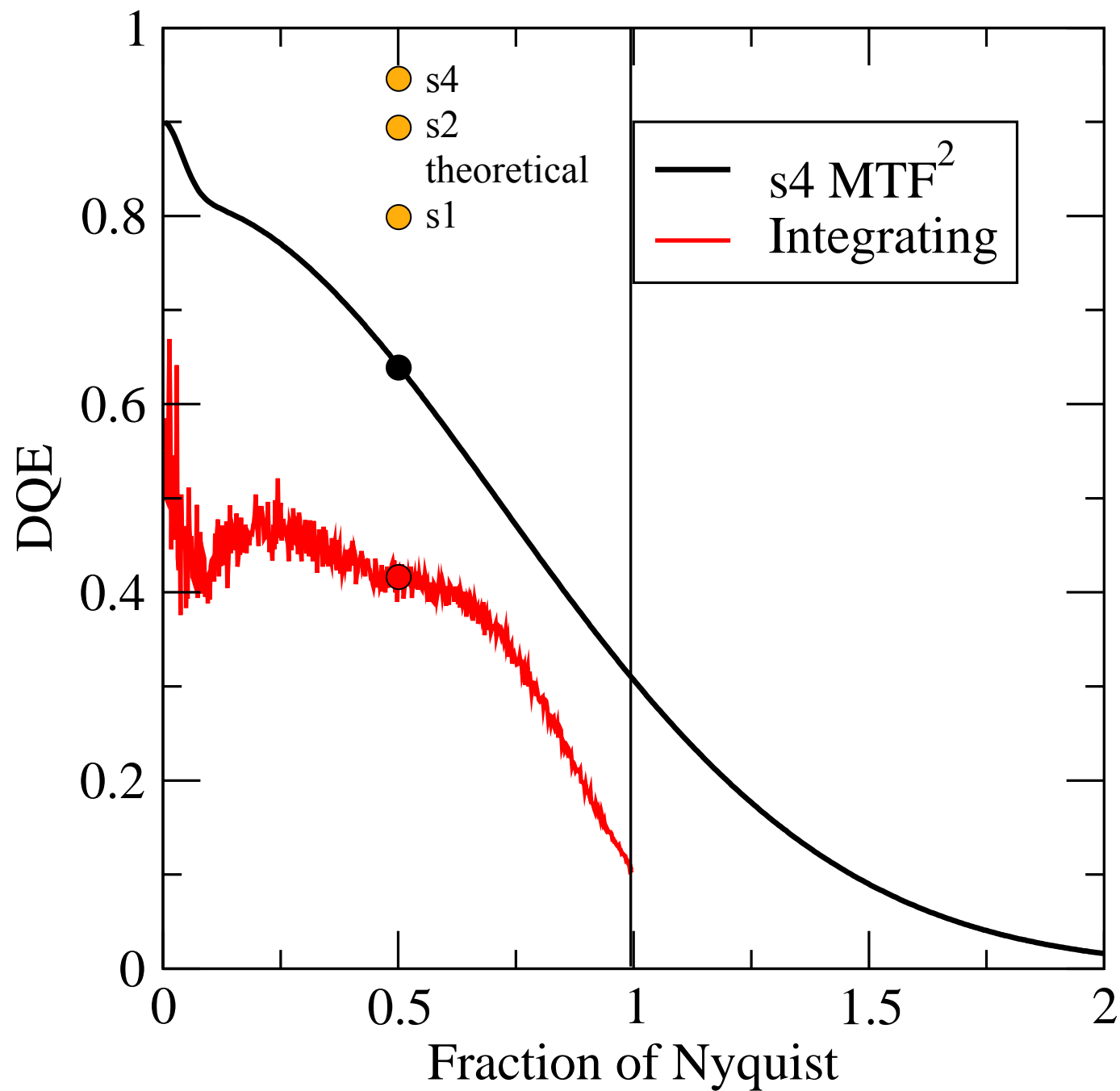


Counting mode

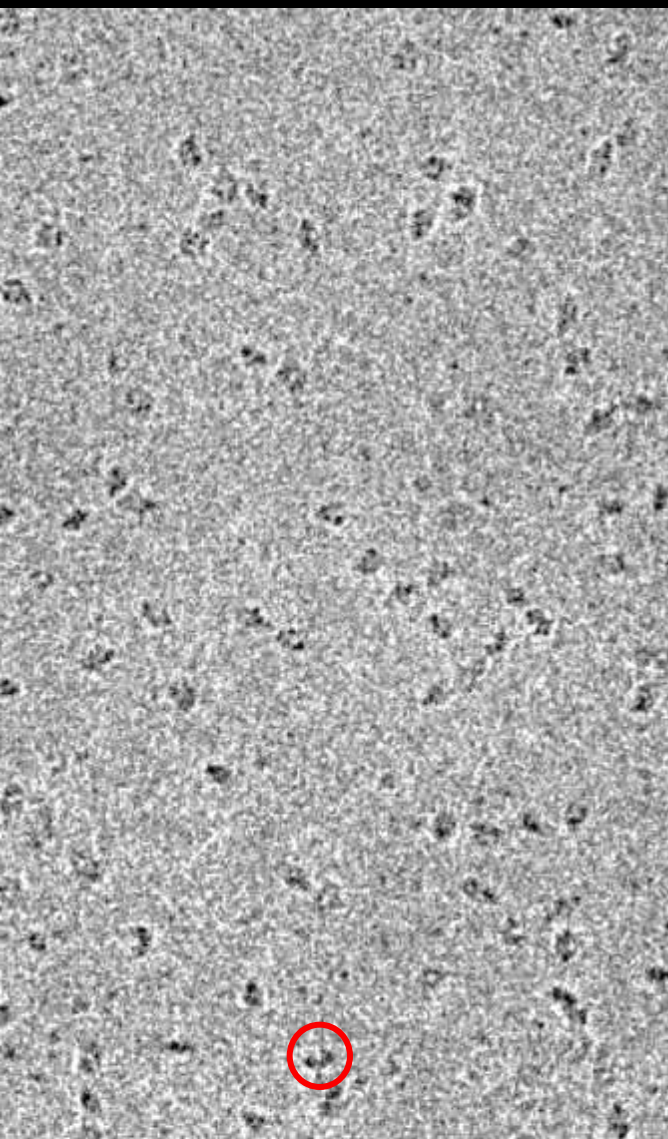


“Super-resolution” mode

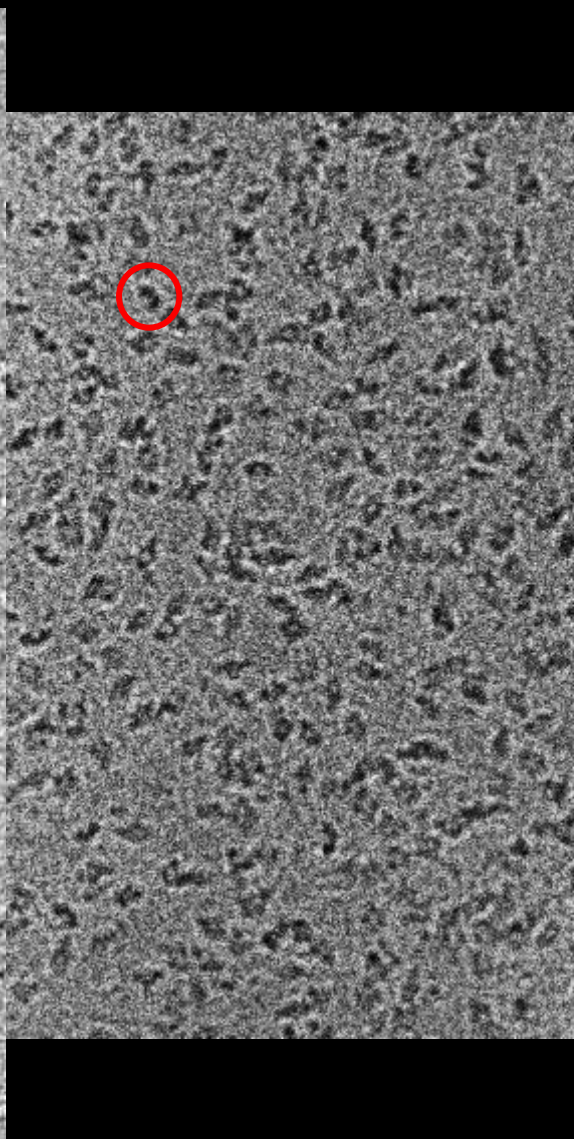
Backthinned Falcon -300 keV



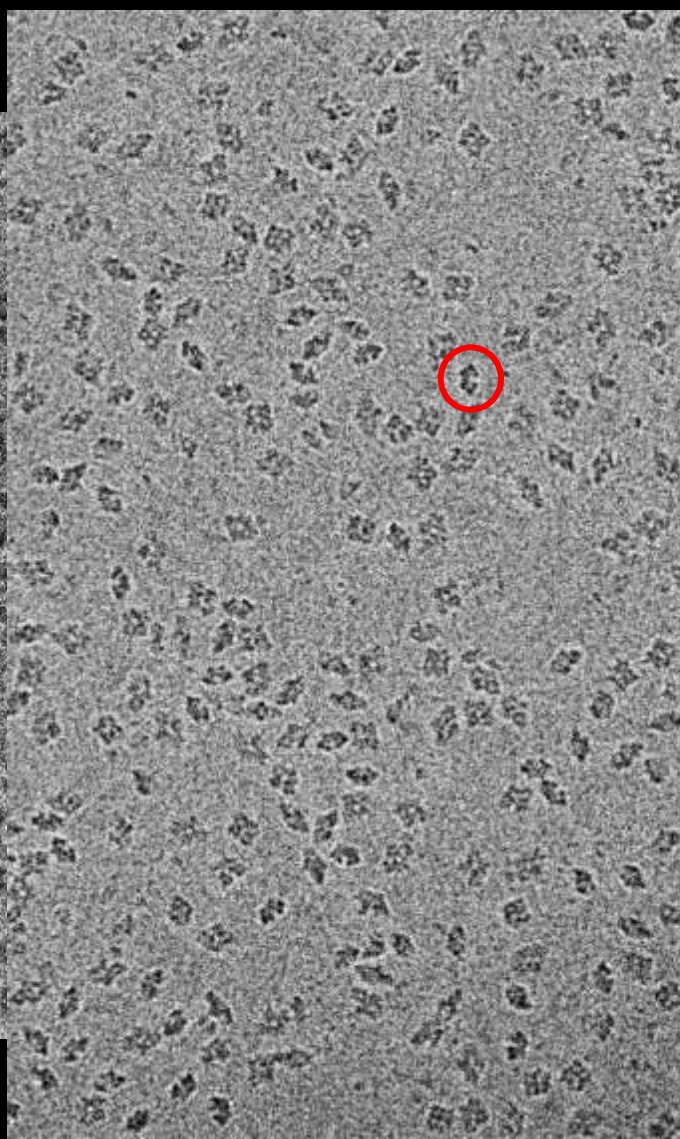
T12/SO-163
120kV



Krios/Eagle
80kV



Polara/BT-Falcon
300kV



Acknowledgements

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