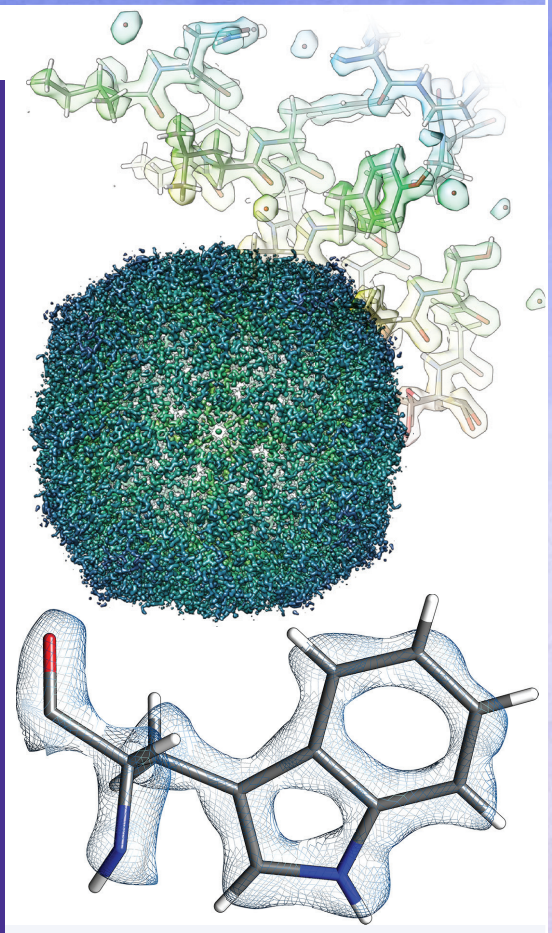
APOLLO CAMERA

Ultra-Fast Electron Counting For Cryo-EM

Delivering Bigger | Better | Faster | Cameras For Electron Microscopy

NEXT-GENERATION DIRECT DETECTOR FOR ELECTRON COUNTING

- Our novel direct detection device (DDD®) delivers ultra-low noise and extraordinary resolution for nearly any beam current for cryo-EM.
- Electron counting *in hardware* is elegant, fast, easy-to-use, and more cost effective.
- Change the paradigm for cryo-EM by removing camera limitations.
- On-chip CDS and digital output of detected events minimizes noise.
- 4k × 4k (16.8 million) physical pixels with larger 8 µm pixel size to maximize resolution.
- Super-resolution 8k × 8k (67.1 MP) counted movies saved to the computer for motion correction, dose filtering, etc.
- Integrated with SerialEM, Leginon, etc., for automated acquisition.
- Generate better results than you've ever achieved before.



1.46 Å resolution cryo-EM structure of apoferritin (EMD-33707) from Apollo on a JEOL CRYO ARM 300 II, acquired at 12 e-/physical pixel/s (eps).

DETECTOR APPLICATION:

Biology

Direct Electron®

INNOVATION PROPELLING DISCOVERY

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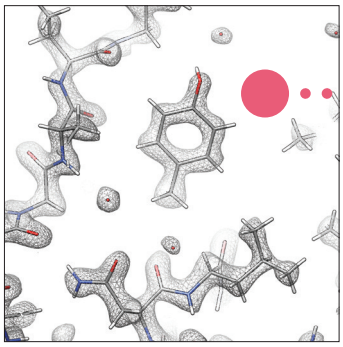
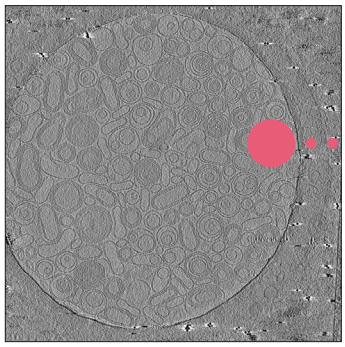
OPTIMIZED FOR DEMANDING TEM APPLICATIONS



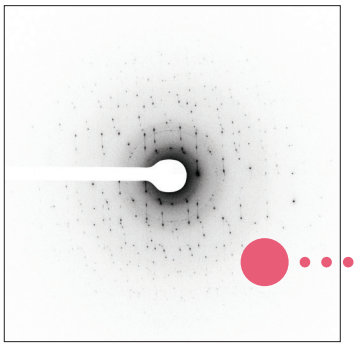
High-Resolution Single-Particle
Ultra-large search mode images without montaging

High-Throughput Automation
Ultra-fast electron counting enables short exposure times

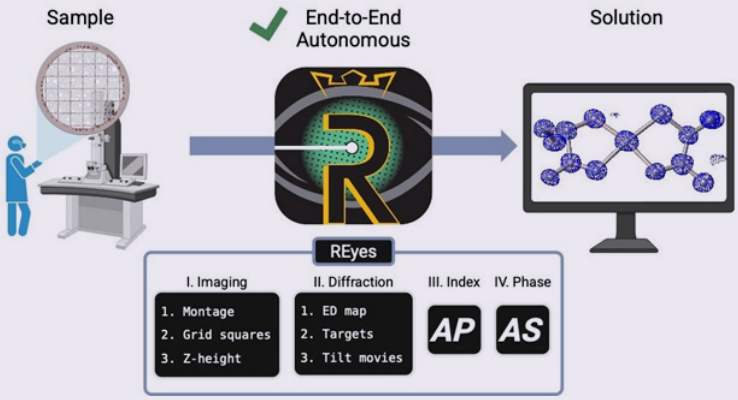


Cryo-Tomography
Large field-of-view and high contrast

Continuous Rotation & *in situ*
Real-time counting enables dynamic applications



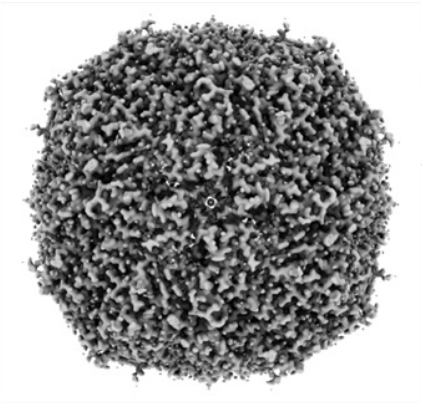
MicroED (Diffraction)
High dynamic range & large area for crystallography

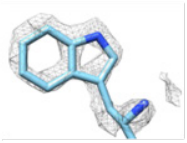


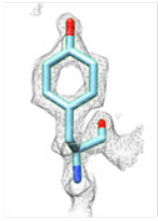
IMPACTFUL RESULTS

Researchers from Caltech have recently developed 'Reciprocal Eyes', a program that works with Serial EM to survey a TEM grid, acquire Micro-ED data and calculate the structure. It is not a screening tool, or a rough estimate. It provides the high resolution structure completely autonomously. The program is free for academic use, and compatible with all major TEMs. The developers found that Apollo produced the best resolution and highest throughput.

When single particle data was collected from the same apoferritin sample by different cameras on the same microscope, the results were striking. Apollo's superior counting rate enabled a much higher resolution reconstruction using much less particles [2].







Apollo
1.6 Å
65,516 ptcls

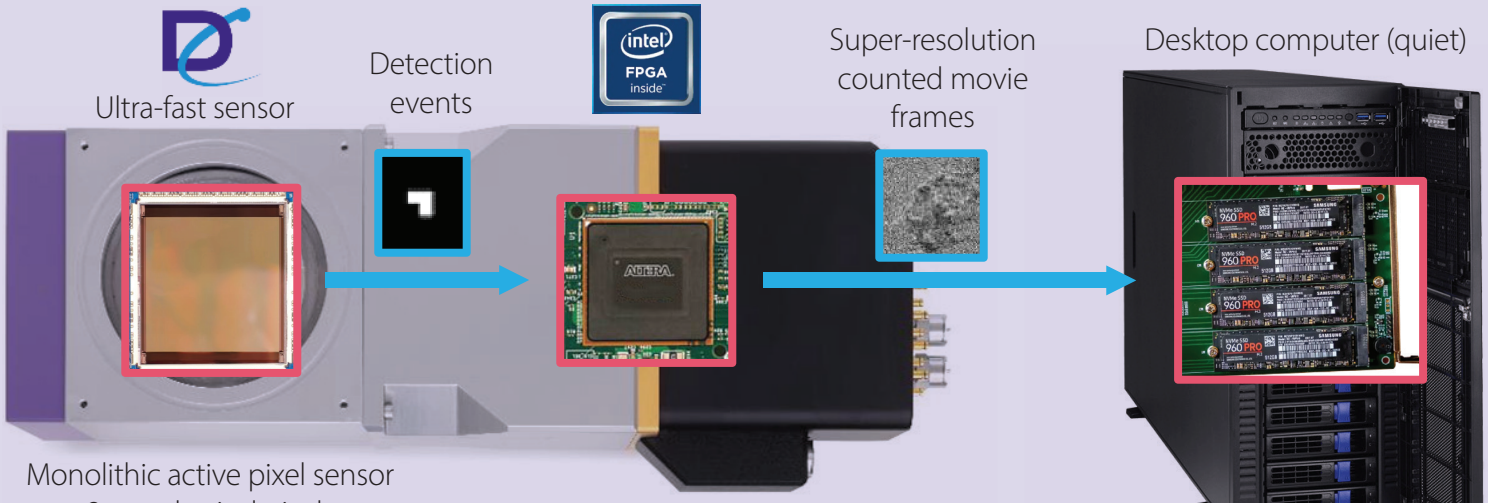
DE-64
2.5 Å
197,315 ptcls

K3 + GIF
2.5 Å
440,421 ptcls

300 kV
Titan Krios G1

1. Nakane, T. et al. Single-particle cryo-EM at atomic resolution. Nature 587, 152–156 (2020).
2. Peng, R. et al. Characterizing the resolution and throughput of the Apollo direct electron detector. Journal of Structural Biology: X 7, 100080 (2023).
3. Sun, M. et al. Practical considerations for using K3 cameras in CDS mode for high-resolution and high-throughput single particle cryo-EM. Journal of Structural Biology 213, 107745 (2021).

A NEW STRATEGY FOR ELECTRON COUNTING: EVENT DETECTION IN HARDWARE

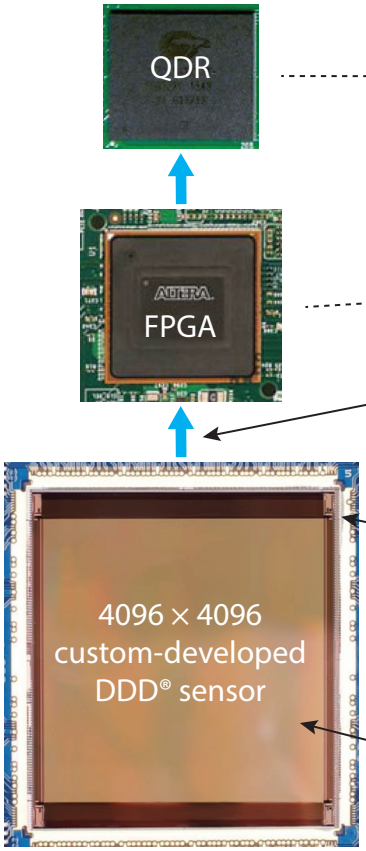


Monolithic active pixel sensor
8 µm physical pixels
4096 × 4096 physical pixels
On-chip CDS
On-chip thresholding
On-chip event detection
Event encoding

Field-programmable gate arrays
Sensor control
Real-time event processing
Super-resolution centroiding
Generation of output frames

User interface
TEM automation
Data storage/transfer
Post-processing

NEXT-GENERATION REAL-TIME ELECTRON COUNTING



US patent #10,616,521

Digital output of event blocks

Integrated circuitry on the top and bottom edges of the sensor (shielded from the electron beam)

Monolithic active pixel sensor (MAPS) for direct detection of TEM electrons

QDR memory stores each movie frame until it is output

FPGA isolates and centroids each detection event

FPGA isolates and centroids each detection event

Sense amplifier checks pixel values against a threshold

Pixel array uses on-chip CDS to minimize noise

On-board functionality

On-chip functionality

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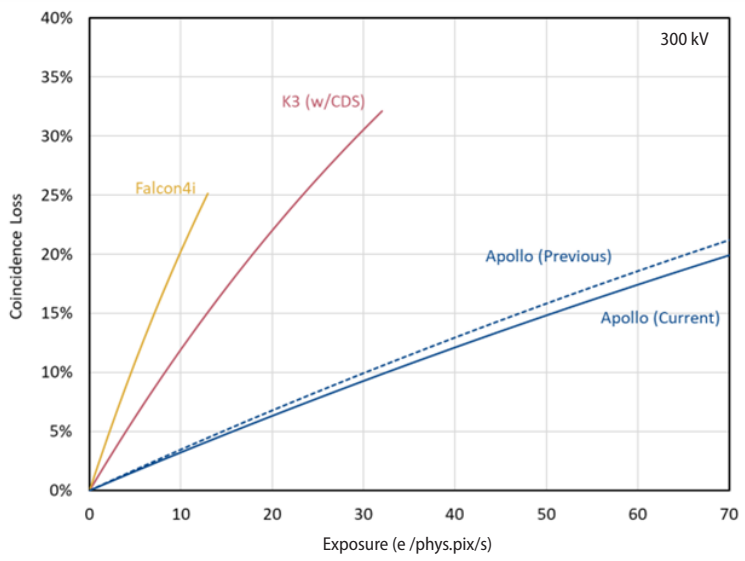
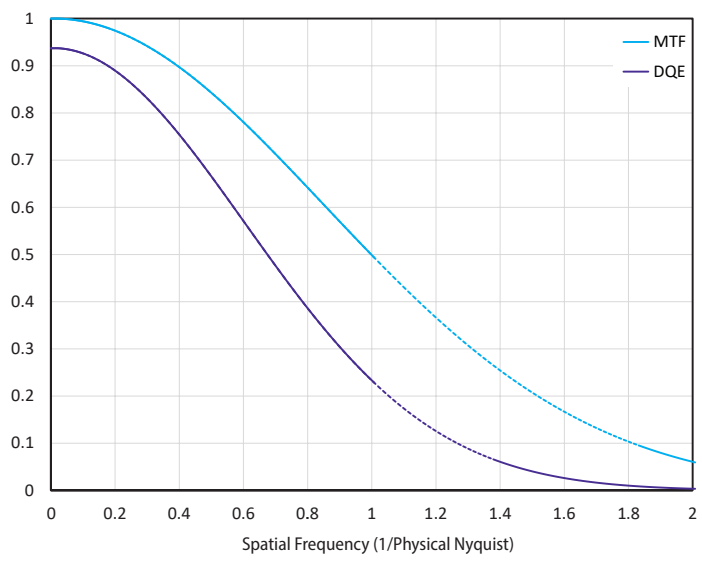
TEM Electron Energy	Sensitive to 80 keV – 1.25 MeV | optimized for 200 - 300 keV
Pixel Array Size	4096 × 4096 (16.8 million pixels) | 8 µm pixel pitch
Sensor Design	Novel event-based ultra-fast DDD® sensor on-chip correlated double sampling (CDS) | on-chip thresholding | digital readout backthinned | radiation hardened
Acquisition Modes	Event-based electron counting, *always*
Hardware ROI	2048 x 2048 hardware ROI available to increase counting speed even further
Detection Efficiency	>90% For 200 - 300 kV
Exposure Rate	~0.01 - 75 e-/pixel/second (ranging ~4 orders of magnitude)
Linearity	>95% linear up to ~15 e-/pixel/second
Dose Fractionation	8192 × 8192 (67.1 Million pixels) super-resolution counted movies flexible dose fractionation with electron event streaming format | or 8.3 ms minimum movie frame time.
TEM Compatibility	All major TEM manufacturers & models
Mounting Position	Fully retractable | compatible with a wide-range of configurations typically in TEM bottom port, pre- or post-energy filter, or in JEOL film drawer
Sensor Protection	TEM blanking/shuttering | failsafe software
Computer System	High-performance computer | Windows 10 | Nvidia GPU(s) | up to 55 TB storage
Image Format	Non-proprietary | MRC, TIFF, TIFF LZW or Event Streaming (EER –like)
Automation Software	SerialEM | Leginon | JADAS (JEOL) | open API (supporting Python, C, C++, C#, etc.)
Integrations	CEFID post-column energy filter (CEOS)





Left: Coincidence loss is a failure to detect electrons when the beam is too bright compared to the speed of the sensor. As you can see from the graph above, Apollo's ultra-fast counting is unmatched [1-3].
Right: DQE curves are shown for 300 kV electrons with Nyquist meaning the physical (non-super-resolution) Nyquist | Specifications and performance are subject to change.