Celeritas Camera

ultra-fast 4D STEM and *in situ* TEM

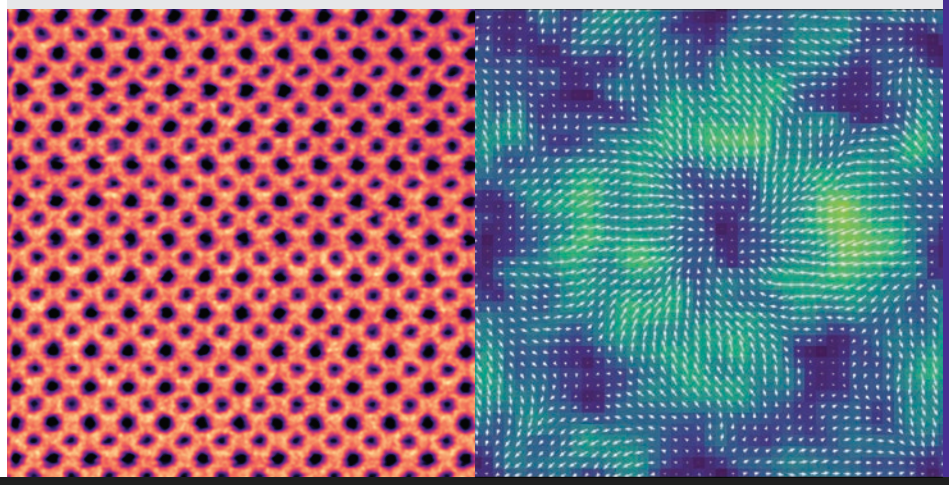
delivering | bigger | better | faster | cameras for electron microscopy

Direct Electron®
INNOVATION PROPELLING DISCOVERY

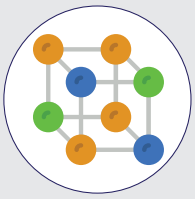
4D STEM at the Speed of Conventional STEM

- Direct detection device (DDD®) delivers **ultra-high speed**, **extraordinary resolution**, and **ultra-low noise**.
- Orders of magnitude faster than other detectors (**up to 87,000 fps**).
- **1k × 1k** (1 million) seamless pixels for a broad range of TEM/STEM methods.
- **On-chip CDS** minimizes noise.
- **Global shutter readout** option eliminates rolling artifacts present on other cameras.
- **Simultaneous HDR** readout delivers more than an order of magnitude higher dynamic range.
- Patented **HDR counting** automatically performs electron counting in sparse regions while maintaining linearity in bright regions.
- **Hardware** synchronization with our DE-FreeScan scan generator and other third-party scan generators.
- DE-FreeScan scan generator enables **a variety of scan patterns**, including conventional raster, serpentine, spiral, subsampled, and custom user-defined scan patterns.

90° rotation symmetry STEM (*left*) and zoomed-in electric field map of [100] $SrTiO_3$, acquired at 49,000 fps. *Courtesy of Paul Voyles, University of Wisconsin.*



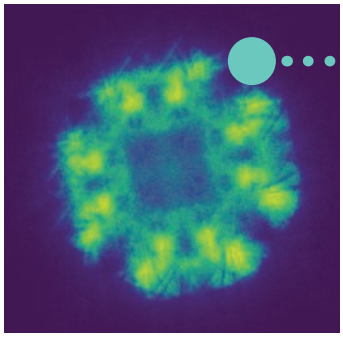
Applications



MATERIALS

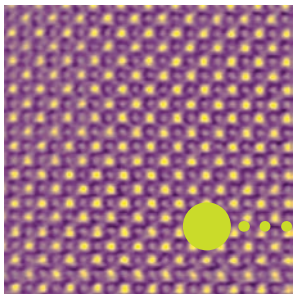
BIOLOGY

Versatile & Ultra-Fast for a Wide Range of TEM/STEM Applications



Position-Averaged CBED (PACBED)

large number of pixels reveals details unseen with smaller detectors

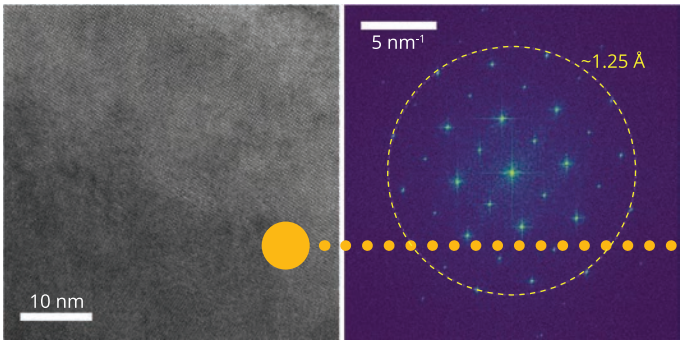


Ptychography

exceptional single-electron SNR enables low-dose

Wide-Range of 4D STEM Techniques

visualize light elements, electromagnetic fields, etc.



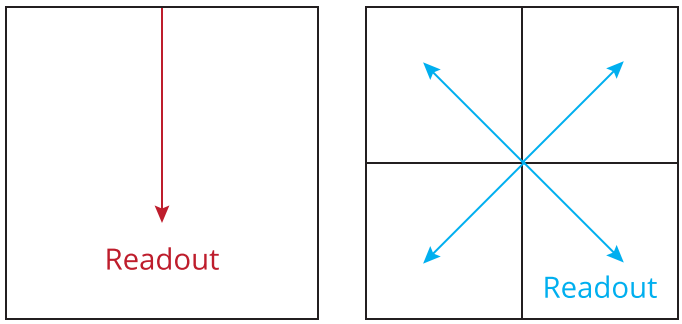
in situ TEM

high speed for visualizing fast specimen dynamics

High-Resolution Imaging (HRTEM)

high MTF & sensitivity yields exceptional images

Unique Readout Architecture to Maximize Speed

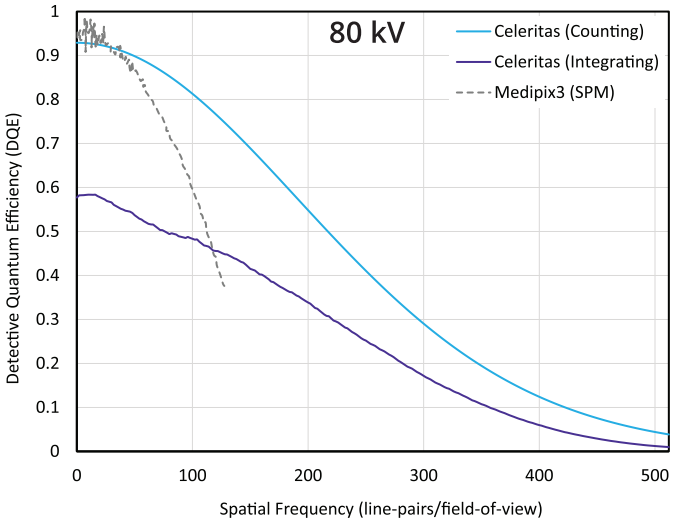


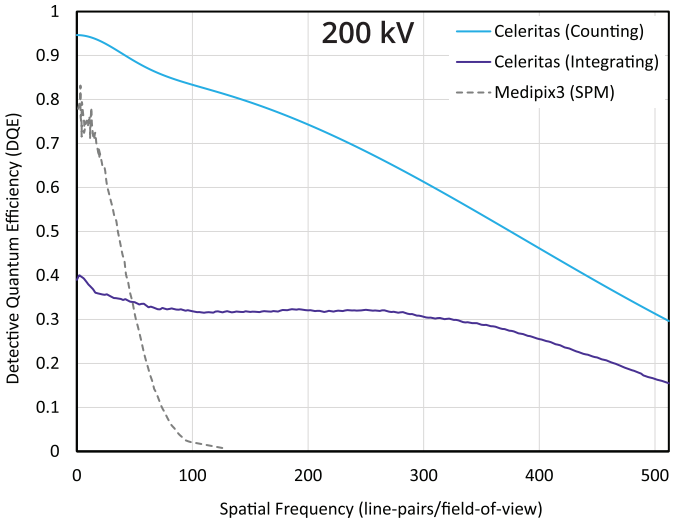
Conventional CMOS image sensors (including both scintillator-coupled cameras and direct detectors) output each frame as a series of rows, read out from top to bottom. While this strategy is simple, it results in **limited output speed**, especially for smaller ROIs. At best, the frame rate can scale with the Y dimension.

The Celeritas sensor is **seamlessly** segmented into quadrants, operating in parallel and read out from the center of the sensor. **This advanced architecture enables ultra-fast output**, scaling with ROI in both the X and Y directions.

Experiment	Other Detectors (~1000 fps)	Celeritas XS (87,000 fps)
512 × 512 4D STEM acquisition	4.4 minutes	3.0 seconds
4096 × 4096 4D STEM acquisition	4.7 hours	3.2 minutes
128 × 128 *in situ* 4D STEM acquisition	16 seconds/scan	<0.2 seconds/scan

High Performance & Large Field-of-View

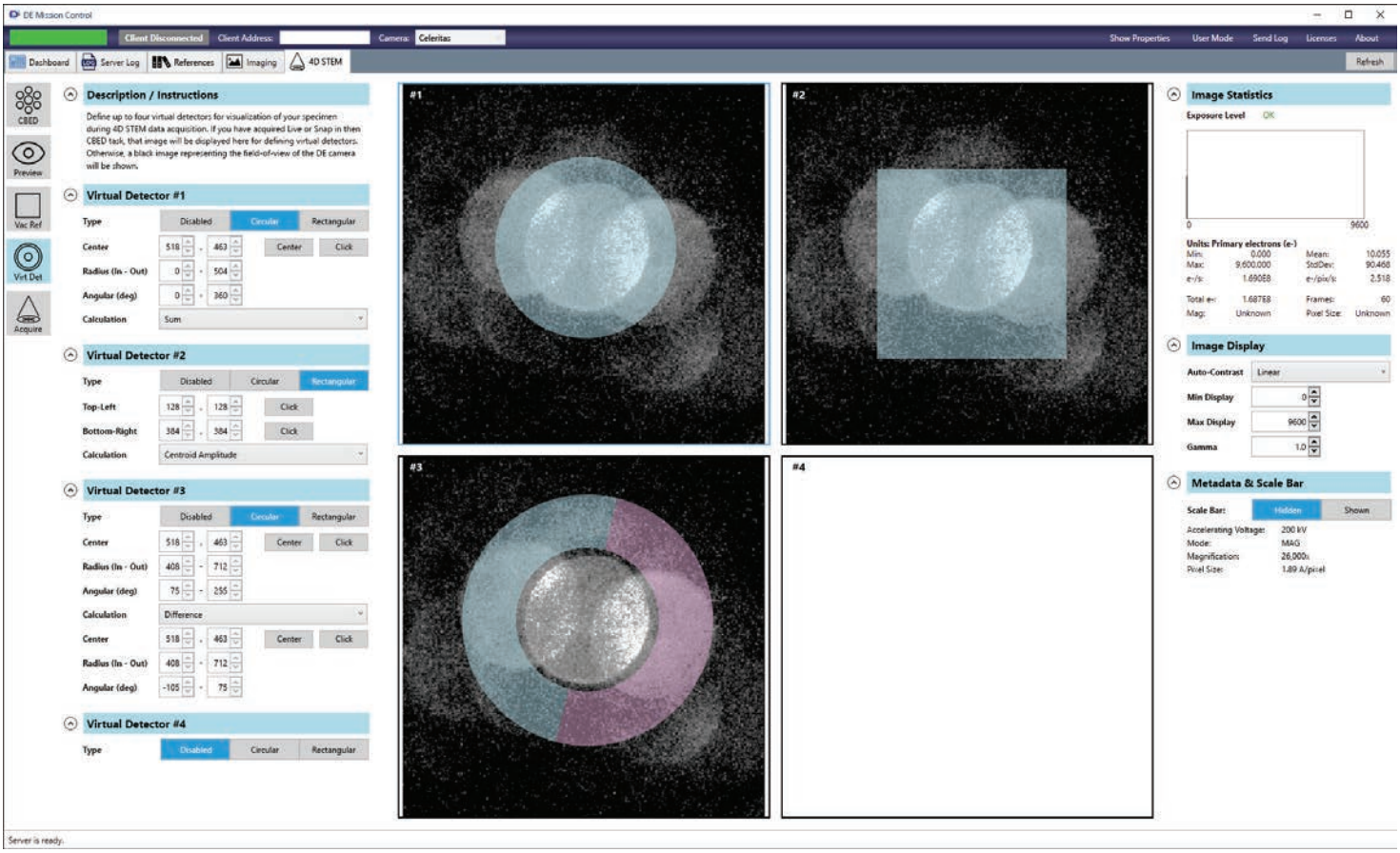




Dimension: Powerful, Easy-to-Use Software for 4D STEM

DE Mission Control + *Dimension* software includes integrated control of Celeritas and the DE-FreeScan scan generator, real-time virtual image generation and visualization, and data output in formats directly compatible with popular data analysis software. Performing 4D STEM experiments has never been easier.

Plus, DE Mission Control enables imaging experiments, such as HRTEM or dynamic *in situ* TEM. The software also includes an API for integration with custom software.



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TEM electron energy	sensitive to 60 keV – 1.25 MeV | optimized for 200 - 300 keV
pixel array specification	1024 × 1024 (1 million pixels) | 15 µm pixel pitch
single electron SNR	>50:1 (200 - 300 keV)
sensor design	custom-designed ultra-fast DDD® sensor on-chip correlated double sampling (CDS) | backthinned | radiation hardened
acquisition modes	integrating mode | electron counting mode HDR counting mode (US patent #11,252,339)
exposure rate	up to 10^7 e^-/pixel/second (300 keV, with selectable gain or simultaneous HDR)
TEM compatibility	all major TEM manufacturers & models | DE-FreeScan requires STEM capability
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	sensor protection shutter | TEM blanking/shuttering | failsafe software
computer system	high-performance computer | Windows 10 | Nvidia GPU(s) | up to 55 TB storage
image format	non-proprietary | HDF5, MRC, TIFF, or TIFF LZW compatible with ImageJ, LiberTEM, Hyperspy, Py4DSTEM, etc.
automation software	SerialEM | open API for custom integrations (with Python, C, C++, C#, etc.)
integrations	CEFID post-column energy filter (CEOS) | precession diffraction (Nanomegas)
scan control	DE-FreeScan scan controller (also includes 4 analog detector inputs) hardware synchronization signal (BNC) | selectable as either input or output

		Celeritas XS		Celeritas	
readout mode		rolling	global	rolling	global
CDS noise reduction		on-chip	optional	on-chip	optional
acquisition frame rate* (continuous)	**1024 × 1024**	1,960	1,900	1,000	*n/a*
	512 × 512	7,390	6,930	4,000	*n/a*
	256 × 256	26,400	22,400	16,000	*n/a*
	256 × 128	49,300	37,000	*n/a*	*n/a*
	256 × 64	87,000	54,900	*n/a*	*n/a*

Frame rates are rounded to three significant digits.
* Optional off-chip CDS and/or simultaneous HDR readout modes operate at reduced frame rate.

Specifications and performance are subject to change. | Medipix3 DQE curves are from Paton, et. al 2021 (https://doi.org/10.1016/j.ultramic.2021.113298)