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Subsampled Acquisition to Increase Speed and Reduce Data Size for In Situ TEM

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In situ TEM is a powerful technique for studying dynamics of materials at medium or atomic resolution [1,2]. For example, structural changes in materials can be studied during compression, heating, crystal growth, electrical stimulation, etc. This technique has been bolstered by the introduction of fast CMOS-based detectors, which can acquire "movies" much faster than older CCD-based cameras. However, observation of very high-speed processes remains challenging due to insufficient camera framerate, deleterious rolling shutter artifacts, and inadequate signal-to-noise ratio (SNR) at the low electron exposure in each high-speed movie frame. Many of these challenges are addressed through the use of direct detection cameras [3], which deliver higher speed acquisition together with significantly improved sensitivity to maintain sufficient contrast when the exposure per frame is low.

In situ experiments of systems with fast dynamics require commensurate speed from the camera. In many CMOS detectors (whether scintillator-coupled or direct detection), the frame rate of the camera may be increased by reducing the field-of-view on the camera in the Y dimension. Since row readout is sequential, reducing the number of rows being readout reduces the amount of time required for readout of each frame and thus increases the maximum frame rate of the camera. Unfortunately, since these detectors generally require readout of contiguous rows, reducing the number of rows readout from the camera also reduces the field-of-view of the camera. Particularly for liquid or gas cell in situ TEM experiments, use of such a small field-of-view is challenging, since the specimen of interest may move out of the camera's field-of-view.

To address these challenges, we have implemented a new undersampled and compressed readout mode—called Arbitrary Kernel Row Addressing (AKRA)—on the DE-16 direct detection camera (Fig. 1). In AKRA readout mode, the user can specify any arbitrary combination of kernel rows (which are eight unbinned pixels in height) from the detector to read, while all other kernel rows are skipped. By reading out fewer pixels, the detector framerate can be significantly increased, yet since the kernel rows are distributed across the entire sensor, the field-of-view on the specimen is not reduced. Depending on the application, "missing" pixels from AKRA images can be reconstructed using in-painting algorithms [4], or measurements can be made directly from the actual rows that are readout as long as the coordinates of each image are properly accounted for.

For example, in situ experiments to study nanoparticle interactions [5] may not require detailed analysis of the shape of each nanoparticle, but rather would track the location of each nanoparticle within the field-of-view of the camera throughout the experiment. In such an experiment, recording every pixel on the detector is oversampling, since only a small number of pixels in any neighborhood are necessary to determine the presence and location of a nanoparticle. AKRA readout is idea for such an experiment, since it would enable high-speed in situ movie acquisition without sacrificing any field-of-view on the specimen.

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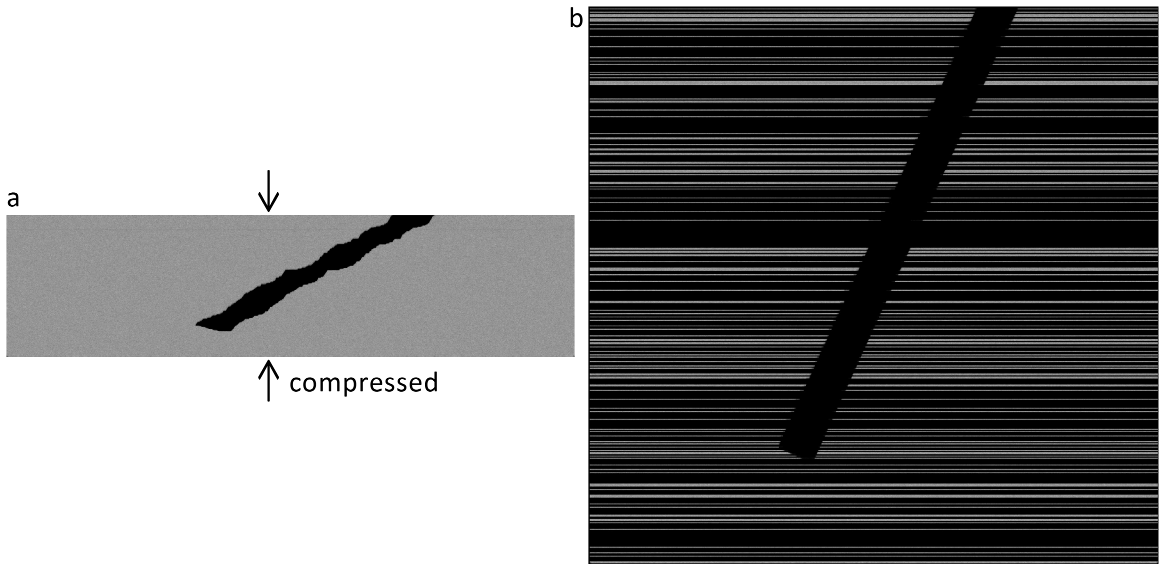

Figure 1. An image of a TEM beamstop acquired in AKRA mode with 25% subsampling. (A) Readout from the camera was a compressed 4096 × 1024 image. (B) Expansion of the compressed image shows the missing rows (black) and the full 4096 × 4096 field of view.

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