High Frame Rate Readout Modes for CMOS Based Direct Electron Detectors

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A number of different electron microscopy techniques, such as in situ TEM[1] and 4D STEM[2] require high frame rates and camera readout speeds. Here, we describe two readout modes that are designed to help users perform high frame rate experiments.

Most CMOS based sensors operate only in rolling shutter readout mode, in which each row of pixels is read out sequentially, at a slightly different point in time. Images acquired in rolling shutter mode can contain distortion artefacts resulting from the fast motion of specimen particles in the case of in situ TEM, or the motion of the STEM probe in 4D STEM[3]. Distortion artefacts can be prevented by operating the detector in global shutter readout mode, in which the read out of rows of pixels is properly synchronized, so that each frame of the camera represents a single snapshot in time[3].

Another feature of CMOS based detectors is that readout speed increases as the number of rows read out decreases. To boost the readout speed of the camera, whilst preserving field of view, we have developed a readout mode called arbitrary kernel row addressing (AKRA)[4], which allows the readout of rows on the sensor to be selectively skipped, as illustrated in Figure 1. AKRA may be helpful for applications where readout speed is critical, for example, tracking fast dynamics in in situ TEM, or imaging radiation sensitive specimens that normally degrade quickly under the electron beam. AKRA may also be of interest to users who wish to experiment with image reconstruction and "compressed sensing" techniques.

References:
1. Chee, S.W. et al. *Nano Letters,* **19**, (5), 2871–2878 (2019).
2. Levin, B.D.A. et. al. *Microscopy and Analysis,* (46), 20–23 (2020)
3. Bammes, B. et. al. *Microsc. Microanal.* **25**, (S2), 68-69 (2019).
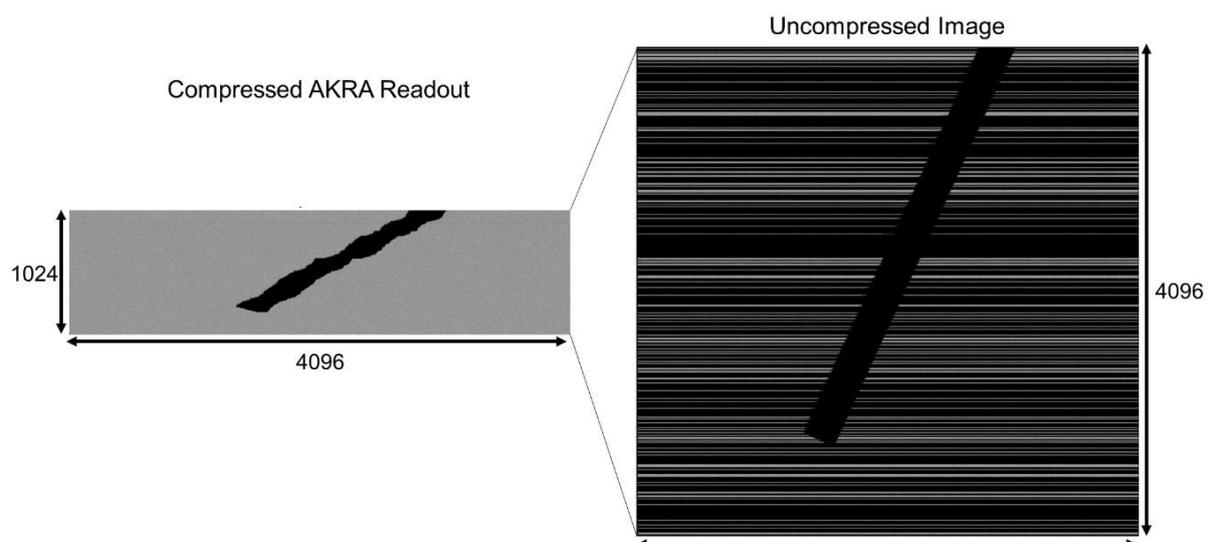4. Bammes, B. et. al. *Microsc. Microanal.* **25**, (S2), 1466-1467 (2019).

Figure 1. Example of AKRA readout with subsampling of 4, yielding a 4-fold increase in readout speed. In the uncompressed 4096 x 4096 pixel image, the position, shape and orientation of the test object all remain clear despite the use of subsampling.