

## 4D STEM and EELS Acquired Simultaneously with a Fast Pixelated Direct Detector with Center Hole

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In four-dimensional scanning transmission electron microscopy (4D STEM) imaging, a focused beam of electrons scans the sample in a two-dimensional (2D) raster pattern, while a two-dimensional (2D) image is recorded at each scan position. This technique is meanwhile commonly used and is applied to a wide range of materials. We present an ultrafast and direct electron detection system, the pnCCD (S)TEM camera which is equipped with a novel chip with a center hole in the middle of the detector. The annular pnCCD sensor with a central hole (264x264, 48 $\mu$ m<sup>2</sup>, physical hole 2.5mm diameter) allows the central beam component to pass through the detector, thus becoming available to the EELS instrumentation, without losing the possibility to reconstruct 4D data. The pnCCD (S)TEM camera is compatible with electron energies ranging from 10 keV to 300 keV and can be operated with up to 7500 frames per second. If long dwell times are used for the EELS measurement, online averaging over any number of frames is possible to reduce data while extending the dynamic range by reading out multiple times per scan pixel.

The simultaneous acquisition of electron energy loss spectroscopy (EELS) data and diffraction signal using two hardware synchronized instruments adds attractive information about the sample like elemental composition, phonon or plasmon excitation or core loss phenomena. With formerly available detector systems, a decision needed to be made if either a 4D STEM or an EELS measurement is taken.

In this contribution, we show details of the new sensor and first measurement results recorded at 200keV on a JEM-F200 (JEOL Ltd.) with a cold field emission gun using a prototype camera. The data show that the experimental conditions for EELS and 4DSTEM can be matched and, most importantly, no disturbance in the EELS data is found due to that fact that the electron beam passes through the pnCCD detector.

### Keywords:

4D-STEM STEM EELS Phase