# High Speed X-ray Imaging and Spectroscopy with novel direct detection CMOS based Active Pixel Sensors

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## Introduction and Objectives

High speed counting, imaging and spectroscopic measurements of X-rays at energies between 100 eV and 30 keV require detectors with challenging properties. A back-illuminated 450 µm thick active pixel sensor (APS) was developed and qualified for planetary science applications. Matched to the resolution of the X-ray optics aboard it has 300 µm x 300 µm large pixels in a format of 64 x 64, resulting in a sensitive area of 2 × 2 $cm^2$. It is operated at a frame rate of 7.000 Hz, still delivering Fano limited imaging X-ray spectroscopy. Because the readout is so fast (30 Megapixel per second), the cooling requirements are relaxed and operation can be performed with a thermoelectric cooler. The new device is based on the DePFET principle built on fully depleted back-illuminated 450 µm high resistivity silicon.

## Results and Discussion

To speed up the readout, the sensor is subdivided in two hemispheres, which are read out in parallel. As the regions to be read out can be programmed, areas with higher X-ray flux can be read out more frequently than areas with lower intensity. We have tested the detector system operated at full speed at the calibrated X-ray end stations SX700 and KMC of the PTB (Physikalisch-Technische Bundesanstalt, the German institute of standards) at the synchrotron BESSY in Berlin. Fig. 1 shows a summary of three different detectors systems. The X-ray energies were ranging from 250 eV up to 10 keV. The intrinsic physical limit in energy resolution given by the ionization statistics described by the Fano factor is shown as well. At 200 eV the energy resolution is 61 eV (FWHM) and it is 161 eV (FWHM) at 10 keV. Three different detector systems were tested, they are behaving quite similarly. This concept allows shrinking the pixel size down to 20 µm. Beside X-ray imaging and spectroscopy the detector is equally suited for electron detection from 1 keV up to 400 keV. As in this case a higher readout noise can be tolerated the frame rate can be increased to more than 20.000 frames per second.

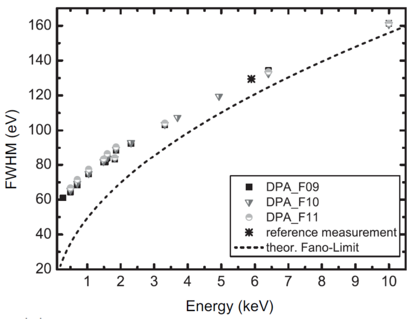


**Fig. 1:** Measured energy resolution from 200 eV up to 10 keV for three sensor systems. The dashed line is the theoretical resolution limit given by the ionization statistics. The symbols above are the measured data from the DePFET camera. The X-ray spectra were taken in a single photon counting mode at the PTB end stations SX700 and KMC at the BESSY synchrotron in Berlin with 7 000 frames per second. $30\times10^6$ pixels are read out in the high energy resolution mode.

## Conclusions

A new high resolution high speed imaging spectrometer is shown, operating close to the theoretical Fano limit, having a monolithic size of 4 $cm^2$. The quantum efficiency is above 90 % from 500 eV up to 12 keV. About 30 million pixel are read out per second with a read noise below 3.5 electrons (rms). More operational options and further improvements of the new concept will be shown.