7.2. Frame Store pnCCD for eROSITA

A frame store pnCCD was developed for the X-ray astronomy mission eROSITA (extended Roentgen survey with an imaging telescope array). The instrument will be launched into orbit in 2011 on a Russian satellite called Spectrum-Roentgen-Gamma (SRG) satellite. The main scientific goals of eROSITA are a systematic detection and analysis of all obscured accreting Black Holes in nearby galaxies and of ten thousand galaxy clusters. Furthermore the nature of dark energy and dark matter will be investigated. The eROSITA instrument will perform the first imaging all-sky survey in the medium X-ray energy range up to 10 keV with unprecedented spectral and angular resolution.

The eROSITA instrument's main components are seven X-ray telescopes of Wolter-I type with seven dedicated focal plane pnCCD detectors (*Figure 1*). The pnCCD detector permits accurate spectroscopy of X-rays as well as imaging with high time resolution. It is based on the successful XMM-Newton pnCCD detector concept but was further improved in terms of design and technology. In particular a frame store section is added to the image area for the purpose of simultaneous imaging and readout in separate CCD areas. The thickness of the whole pnCCD chip of 450 µm is uniformly sensitive to X-rays from very low up to very high energies. The X-ray photon detection efficiency is at least 90 % in the energy band from 0.3 keV to 10 keV. Frame store operation allows very high frame rates up to 200 hundred X-ray images per second without smearing of the image (*Figure 2*).
The pnCCD is tailored to the requirements of the eROSITA mission. These are in particular a 3 cm by 3 cm large image area (corresponding to a field of view of one degree in diameter on the satellite) with a pixel size of 75 µm by 75 µm (*Figure 4*).

The power consumption in the focal plane is about four Watt for the seven pnCCD cameras in total. Interfering electron-hole pair generation due to optical and UV light has to be prevented in space to achieve best X-ray spectroscopy. Instead of a development of an external fragile filter, we deposit directly an on-chip light filter on the photon entrance window of the detector which is feasible with our device production technology. Another important requirement to the seven pnCCD detectors on the SRG satellite is operation during at least five years without any failure. This includes long-term stability of detector performance.

With the existing prototype of our analog signal processor CAMEX for the readout of the CCD signals, we already obtain an excellent detector system readout noise of two electrons rms. The optimized photon entrance window allows straightforward spectroscopy of X-ray lines even at energies below 0.3 keV (Figures 3 and 5). For the best prototype devices we observed no pixel defects (neither noisy nor bright nor dark) at all on the entire detector area.

The pnCCD shows best energy resolution at temperatures below -60 °C. For the satellite mission a lower temperature is required due to the proton environment which causes radiation

Figure 1.

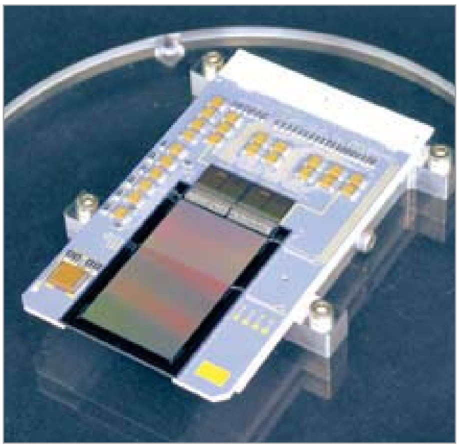

Figure 2.

Figure 1.
Prototype of X-ray telescope array for eROSITA.

Figure 2.
Prototype of the eROSITA pnCCD detector module with 2 cm by 2 cm large pnCCD. The prototype is read out by two 128-channel CAMEX analog signal processors. The chips are mounted and connected on a ceramic multi-layer printed circuit board.

Figure 3.
Low energy response of frame store pnCCD demonstrated with a Mn-K$_\alpha$ spectrum (5.9 keV).

damage by creating defects in the silicon lattice. If an application on ground allows only a relatively warm temperature, spectroscopy and imaging is still possible with acceptable energy resolution.
At a temperature of -10 °C which is easily achievable with a thermoelectric cooler (TEC), the FWHM of the Mn-K$_\alpha$ line at 5.9 keV amounts to 213 eV; the Gaussian shape of the peak is not distorted (*Figure 5*). The eROSITA pnCCD detector offers in addition the possibility to select the optimum gain out of a choice of 16 discrete levels. This option allows spectroscopy and imaging of higher energetic particles, e.g. electrons or protons, on ground as well as in space.

While still various tests with the prototype detectors are carried out, the production of the flight pnCCD wafers and CAMEX readout chips has meanwhile been started. The entire eROSITA camera including control and readout electronics is developed in a close cooperation by MPE and MPI HLL.

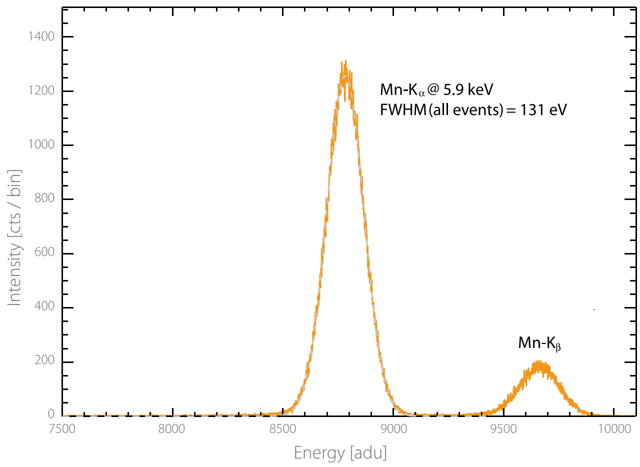

Figure 3.

Figure 4.
Schematic drawing and geometry of the eROSITA flight detector. The pnCCD comprises image area and frame store area pixels as well as on-chip amplifying transistors. The CCD is read out by three CAMEX ASICs with 128 signal processing channels each. One ADC is used per CAMEX.

Figure 5.
Low energy response of frame store pnCCD demonstrated with a C-K$_\alpha$ spectrum (277 eV).

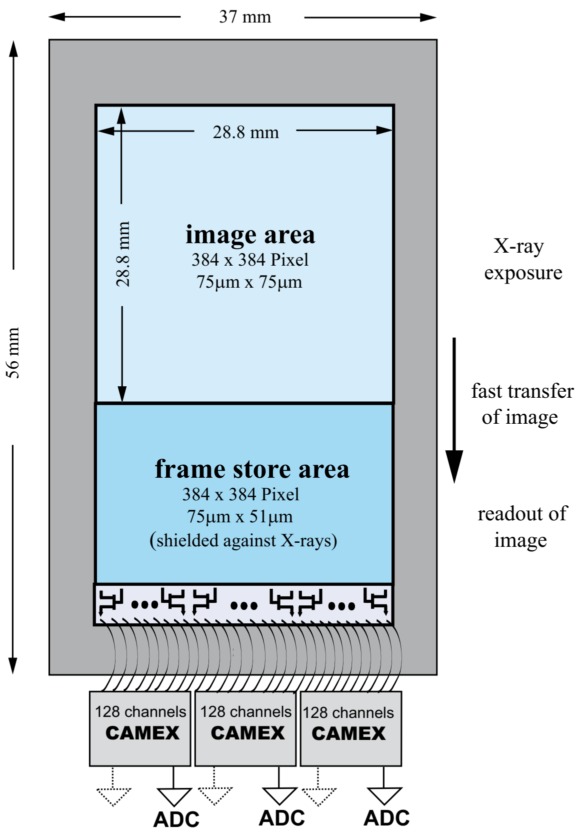

Figure 4.

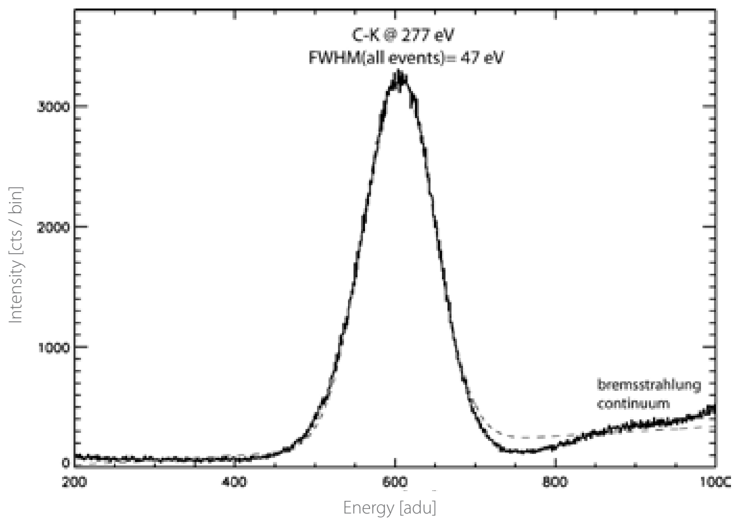

Figure 5.