Characterization of Hybrid Pixel Detector With CdTe Sensor

L. Rosa[1 2], L. Mendes[1 2], P. Oliveira[1], T. Barbosa[1], A. Tomal[2]

[1] PITEC, Campinas-SP, Brazil
[2] "Gleb Wataghin" Institute of Physics, University of Campinas, UNICAMP, Campinas-SP, Brazil

Abstract

This work presentes the results of the characterization and performance of a PIMEGA CdTe 1 mm thick detector with 55 µm pixel pitch bump-bonded to Medipix3RX chips. Imaging capabilities were evaluated in terms of the spatial resolution and detective quantum efficiency. The studies were carried out using a conventional X-ray tube with the detector operated in single-pixel mode. The results show the high quality imaging capabilities of the detector with outstanding values of MTF and DQE.

Introduction

PIMEGA is a detection system with hybrid photon-counting technology based on semiconductor hybrid-pixel sensors assembled over Medipix3RX ASICs [1], and developed for large-area applications at synchrotron light sources. Due to Silicon's (Si) poor efficiency at energies above 20 keV, sensors made of materials with higher Z numbers are needed. In PIMEGA systems, Cadmium Telluride (CdTe) was chosen to handle high-energy applications. In order to describe these sensors, a thorough characterization for assessing imaging capabilities and detection performance was executed based on the most important detector qualities required: high detective quantum efficiency and high resolution.

Methods

The characterization of the PIMEGA detector with a 1 mm thick CdTe sensor was based on the following quantities:

MTF

The Modulation Transfer Function (MTF) is used to analyze the spatial resolution response of the detector as a function of the frequency of the input signal. The MTF was measured with the standard slanted-edge technique [2] by recording images of a slanted tungsten edge positioned close to the detector surface at approximately 2.5 degrees to a sensor row.

DQE

Detective Quantum Efficiency (DQE) is a measurement that quantifies the detection efficiency as a function of spatial frequency, given by:

$$DQE(\nu) = \frac{MTF^2(\nu)}{SNR_{in}^2 \cdot K \cdot NPS(\nu)} \quad (1)$$

It was measured by recording a stack of flatfield images to calculate the Noise Power Spectrum (NPS), and according to Eq. (1).

Results

MTF was found to be better when increasing the detector's energy threshold, which means a minimization in the charge shared among adjacent pixels occurs due to the reduction in the effective pixel size.

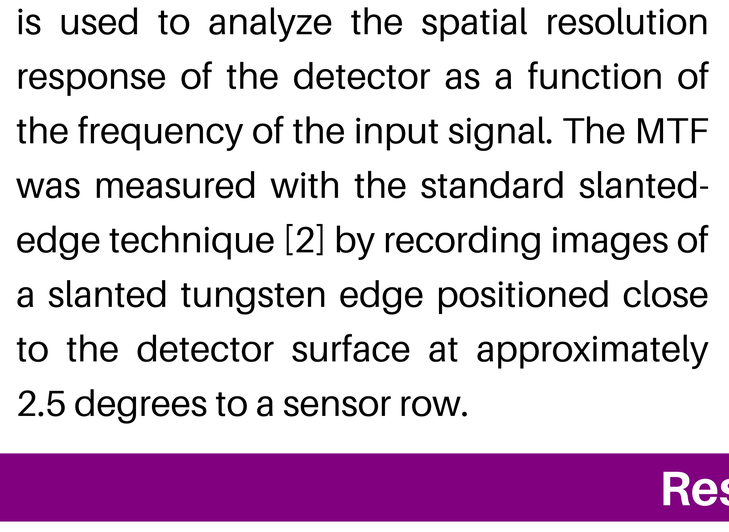


Figure 1: MTF dependence on detector's energy threshold. The Figure shows the MTF curves computed from the experimental image and the theoretical results for a squared-pixel detector, based on the cardinal sinus.

An imaging validation was performed to investigate the ability of the sensor for small animal imaging with high resolution using a scanning detector that provides a larger detection area.

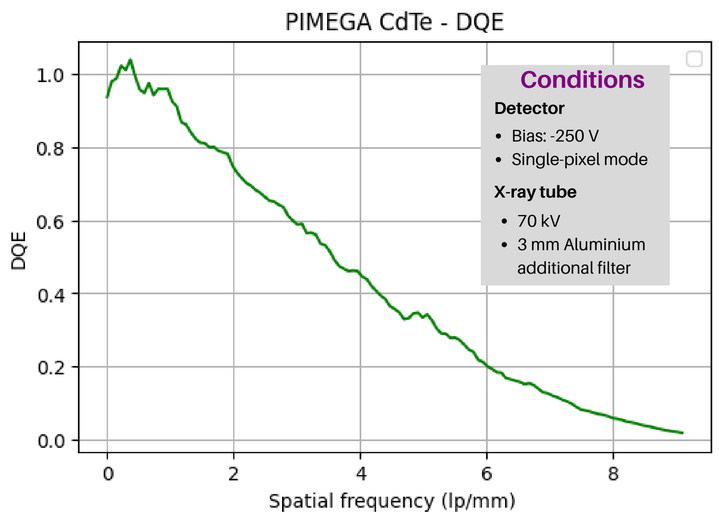


Figure 2: DQE curve obtained for PIMEGA CdTe sensor measured at the same conditions as MTF.

The higher the DQE, the higher the detective quantum efficiency of the detector, with a low noise added, decreasing up to the Nyquist frequency.

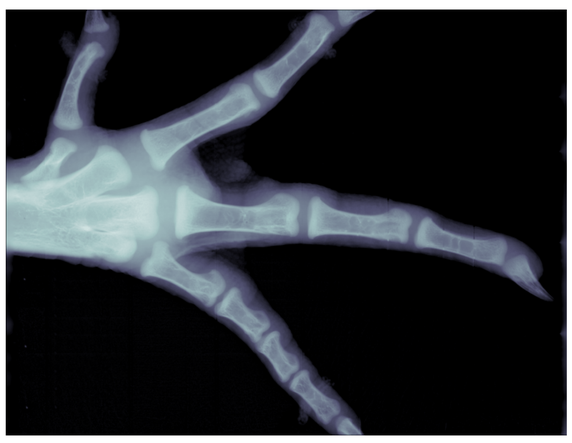
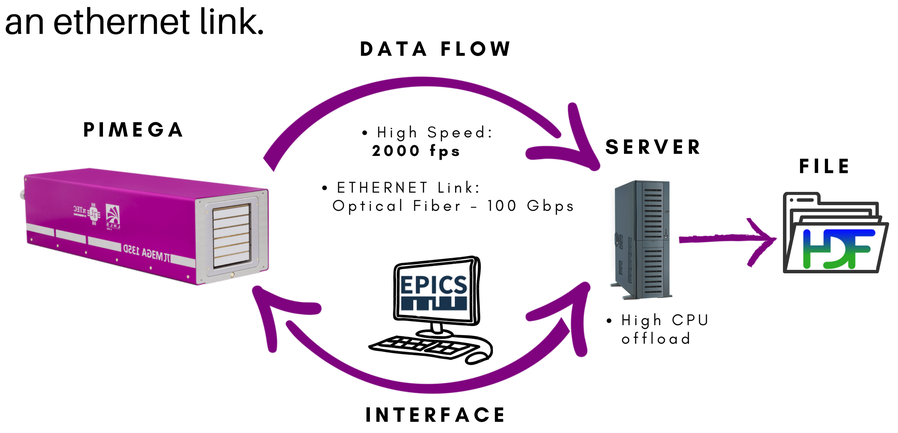


Figure 3: X-ray image of a chicken paw taken in multiple shots (acquired by scanning the sample with 2 sec. exposure time each) in single-pixel mode with the low energy threshold counter set at ~6 keV and the X-ray tube at 30 kV. A stitching reconstruction algorithm was applied along with flat field and correction.

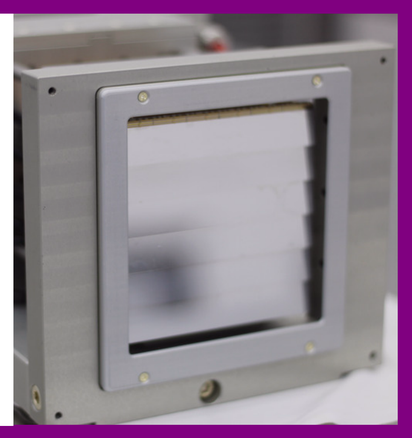
PIMEGA System

PIMEGA is a customizable, modular detector with a highly reconfigurable core. The readout system encapsulates data in packets with RoCE protocol headers for direct writing into a remote memory via an ethernet link.



Key Features

- Noise-free detection
- Two energy thresholds
- High dynamic range (24 bits)
- Low dead area
- Continuous data acquisition
- Short readout time: 500 µs
- Small pixel size: 55 µm



Next Steps

Future work will include a performance study and characterization taking into consideration the influence of different biases and the charge summing mode in comparison with the single-pixel mode. The count rate will also be investigated for CdTe at high fluxes at a synchrotron beamline in single-pixel and charge-summing modes.

Conclusion

The PIMEGA CdTe detector with 55 µm pitch and 1 mm thick demonstrates excellent imaging performance. A good resolution was achieved with MTF's reasonable decay rate as a function of the spatial frequency [4], while the detective quantum efficiency presents a sharp decreasing rate but with high associated efficiency [5]. It was verified that the high dynamic range and the noise-free detection combined with its low energy threshold enable a high contrast quality image.

References

[1] R. Ballabriga et al., The Medipix3RX: A High Resolution, Zero Dead-Time Pixel Detector Readout Chip Allowing Spectroscopic Imaging, J. Inst. 8, C02016 (2013).
[2] E. Samei, M. J. Flynn, and D. A. Reimann, A Method for Measuring the Presampled MTF of Digital Radiographic Systems Using an Edge Test Device, Med. Phys. 25, 102 (1998).
[3] D. Maneuski et al., Imaging and Spectroscopic Performance Studies of Pixellated CdTe Timepix Detector, J. Inst. 7, C01038 (2012).
[4] Thomas Koenig et al 2014 Phys. Med. Biol.59 6195.
[5] D. W. Davidson et al., "Detective quantum efficiency of the Medipix pixel detector," IEEE Transactions on Nuclear Science, 50 (2003).