Experimental characterization of the X-ray photon counting detectors

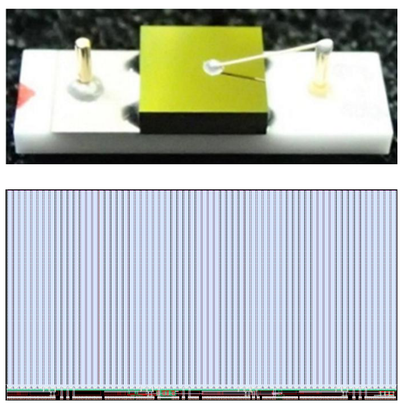
Xuezhi Wang[1,2], Tong Wei[1,2],Zhi Deng[1,2],

[1] Department of Engineering Physics, Tsinghua University, Beijing, China
[2]Key Laboratory of Particle & Radiation Imaging, Ministry of Education, Beijing, China

Tsinghua University

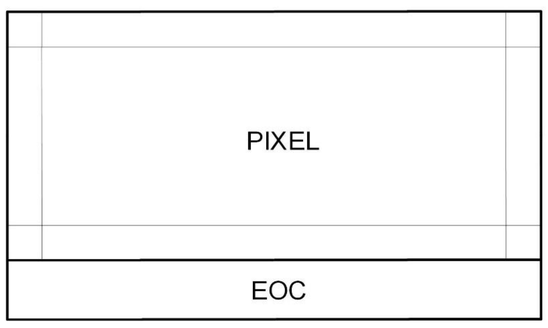
Introduction

- Spectral X-ray Photon-counting imaging
  - Noise suppression
  - Image quality
  - Material discrimination
- Cadmium Telluride(CdTe)
  - High atomic number
  - Proper band-gap energy
  - Operational at room temperature
  - Ideal for hard X-ray and gamma-ray detection
- Pixelated readout ASIC



Architecture and Specification

- Overall architecture



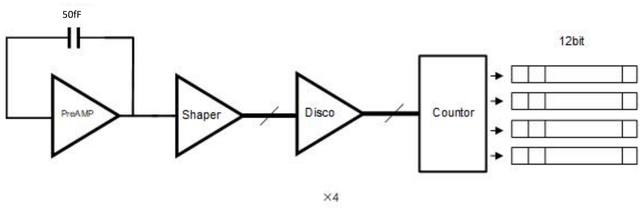
- Main design specifications

design specification	value
pixel size	150 μm× 150 μm
array	64 ×128
power consumption	100 μW/pixel
gain	70 mV/fC
dynamic range	10 fC
ENC	$<100e^-$ @C_{in}=100 fF
pulse width	200 ns
energy window	2/4
counter	24 bit/12 bit
readout frame rate	1 kHz

- the pixel array makes the majority of the ASIC;
- End-Of-Column(EOC) circuit is placed on the bottom so the chip is three-side buttable;

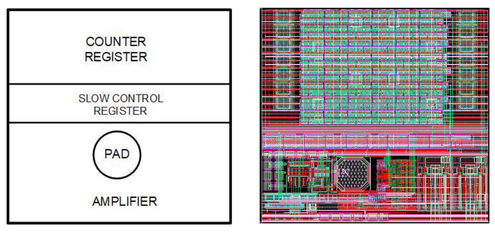
ASIC Design

- Pixel circuit
  - Block diagram



- One low-noise charge sensitive preamplifier
- One CR-RC shaper
- Four discriminators
- Four 12-bit counters
- Two operation modes

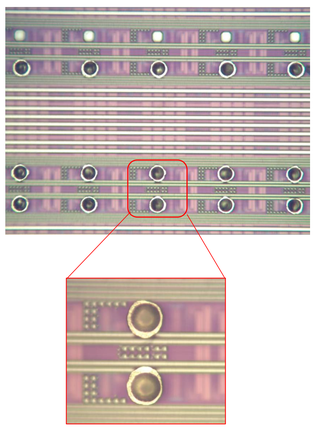
  - Layout

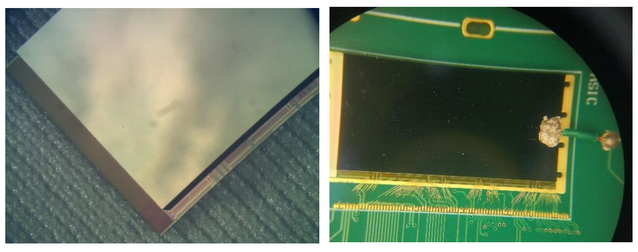


- The analog part and the digital part are divided by slow control registers to prevent digital interference inside the pixel
- Two adjacent columns of pixels are placed on symmetric arrangement to prevent digital interference outside the pixel

- EOC circuit
  - The EOC circuit contains bias generation, slow control and data readout control cirtuit.

Module Assembly





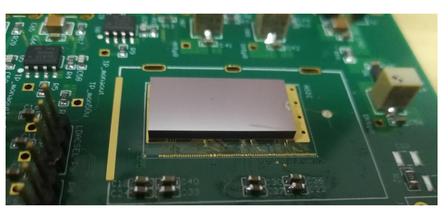
Detector Parameter	Value
Area	19.515 mm x9.915 mm
Thickness	1 mm
Electrode	Pt Ohmic/ Schottky

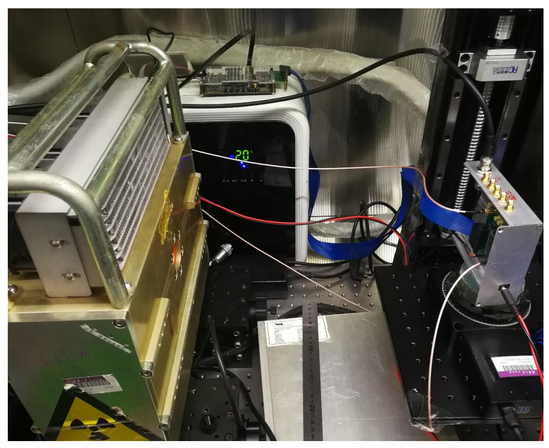
- CdTe semiconductor detectors are provided by Arcorad Corporation;
- Flip chip assembly service is provided by Polymer Assembly Technology;

Contact Information

Xuezhi Wang, PhD candidate, wang-xz18@mails.tsinghua.edu.cn
Zhi Deng , Associate Professor, dengz@mail.tsinghua.edu.cn

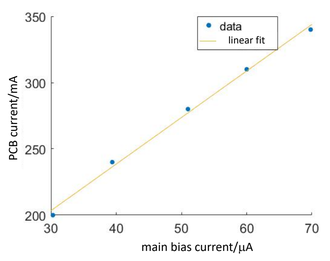
Test Systems



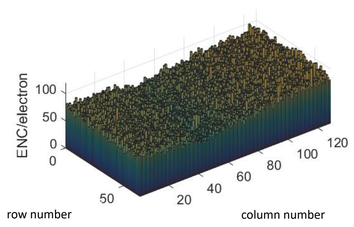


Test Results

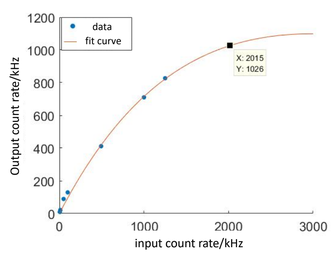
- Electrical test results



- The power consumption is measured to be 60 μW per pixel.

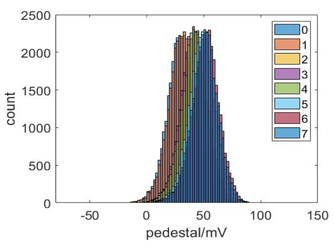


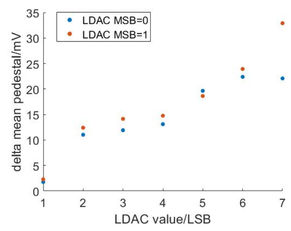
- The ENC in the worst case is measured to be less than 100 electrons.



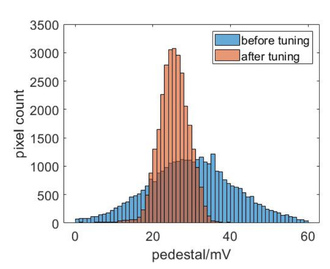
- 2MHz input count rate (poisson distribution) is compatible.

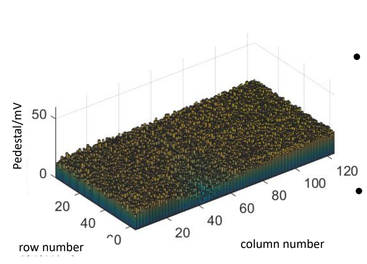
- Threshold tuning





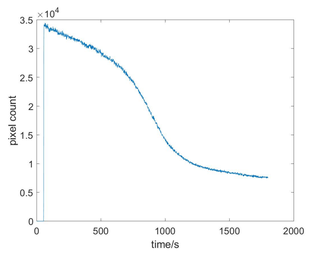
- The threshold distribution of the pixel comparators can be measured by scanning global DAC values and the injected charge .
- The local DAC tuning step of each pixel can be obtained by scanning the local tuning DAC values and repeating the measurement of the corresponding threshold distribution.

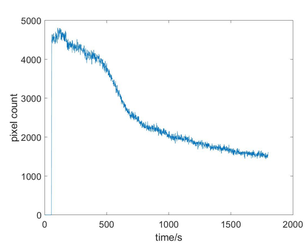




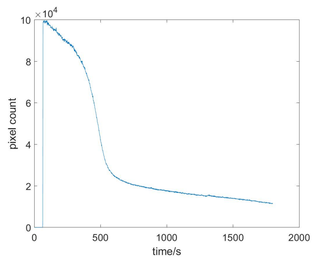
- Proper local DAC tuning values of all the pixels can then be calculated according the tuning step-tuning DAC value table.
- The threshold distribution standard variation of all four comparators can be reduced from 10 mV to 3.5 mV.

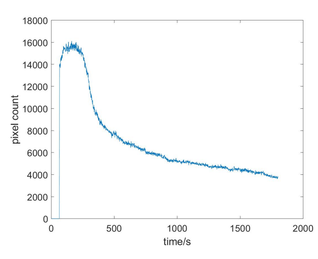
- Detector module test results
  - Polarization effect





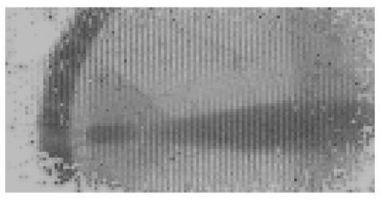
- The polarization effect can be observed.





- The detector tended to stabilize faster under higher count rate.

  - First imaging test



- The spatial uniformity of the detectors was analyzed.
- the flat field correction was conducted to improve image quality.

Summary

- A pixelated photon-counting ASIC was developed. The prototype chip was evaluated.
- The detector module consisting of our prototype ASIC and the CdTe detector was tested and the imaging function was preliminarily verified.