ePixHR10k: a tender X-ray imager for LCLS-II

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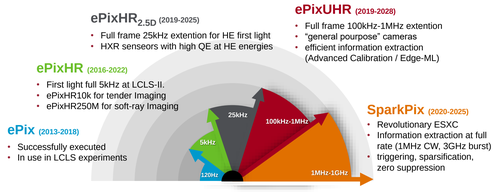
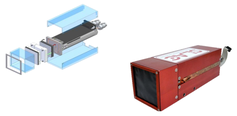
Introduction

ePixHR project aims at developing a high rate camera for tender X-rays scattering/imaging experiments at LCLS-II at 5kHz and at 25kHz for HE.
Following an incremental and risk mitigating approach, ePixHR lays the foundation blocks for the long term path toward full frame cameras at 100kHz.



ePixHR is natively a variant of the successful ePix family, a class of detectors developed at SLAC for LCLS based on a common platform [1]. Modular approach advantages:

- Integration
- Versatility
- Scalability
- Cost reduction
- Time and power efficiency
- Full integration into system



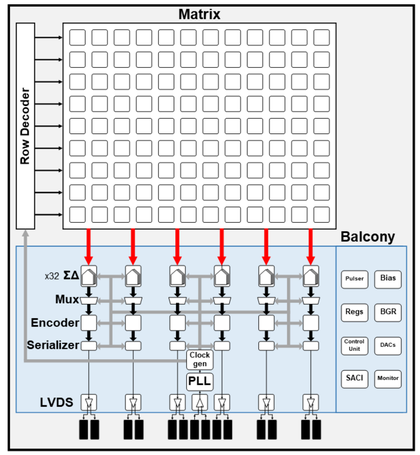
ePixHR10k is the hybrid pixel detector variant optimized for 5 kHz frame rate operation.

Key detector for:
TXI experiments in LCLS-II NEH 1.2 - 2023

Specifications

ePixHR10k	
Mode of Operation	Integrating with: • auto-ranging high-low • auto-ranging medium-low • fixed high gain • fixed medium gain • fixed low gain
Pixel Size	100 µm x 100 µm
Matrix Size	144 x 192
Full Size	Full Reticle
Range	Auto-ranging: 64000 keV Fixed high gain: 880 keV Fixed medium gain: 2640 keV Fixed low gain: 64000 keV
Technology	0.25 µm
ENC	~75e-rms (~ 270eV)
Frame Rate	5 kHz

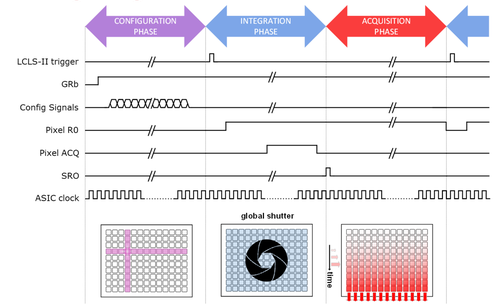
Core components architecture



The figure shows a simplified block diagram of ePixHR10k ASIC architecture. The global shutter analog pixel matrix is arranged in a 144 x 192 shape with pixel pitch 100 µm. The matrix is bump-bonded to a dedicated fully depleted silicon sensor. Each matrix column is connected to a 14-bit ΣΔ ADC present in the balcony section to perform on-chip parallel Analog-to-Digital conversion. The 192 ADCs outputs are multiplexed in groups of 32 and encoded on a 16b/20b protocol. After serialization, data is sent out through 6 high speed LVDS transmitters.

Additional features include:
- LVDS receiver and PLL for ASIC main clock generation
- Configuration, Calibration and monitoring circuits
- Control Unit, SPI interface, registers
- Bias and bandgap reference for the matrix and the ADCs
- Pulser for matrix calibration

Timing Diagram



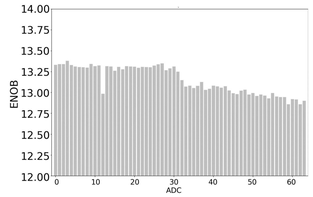
Configuration phase:
- Matrix gain, mask and calibration mode configured on a full array, single row, single column or single pixel basis
- Balcony: ΣΔ ADCs, references and bias, DACs, monitoring, etc.
- Power saving mode

Integration phase:
- global shutter analog matrix processing
- no digital activity with ADC in power saving mode

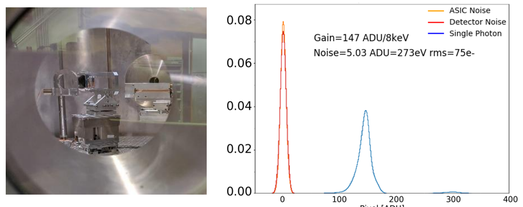
Acquisition phase:
- parallel column readout on a programmable row-by-row basis
- A/D conversion, data encoding, serialization and transmission.

Test results

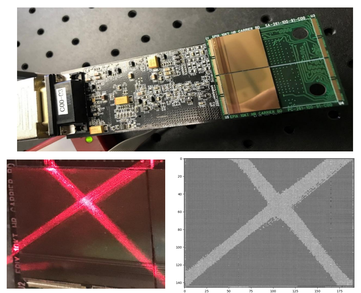
Several tests have been performed on a first prototype.
Measured ΣΔ ENOB 13 (two banks shown):



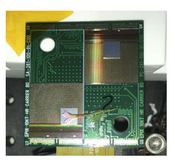
Equivalent noise charge ENC = 75 e⁻.
MEC run at LCLS-II integration time.

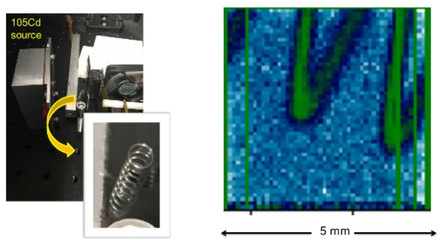


ASIC principle of the operation is shown in the following picture. A red laser cross is projected over the chip and the relative digitized image is shown.



Test with sensor (48 x 48).
Visual light vs ePixHR10k X-ray image.



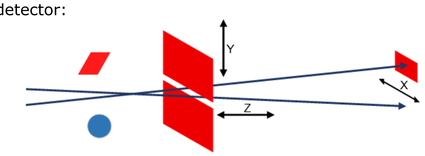


Detector configuration

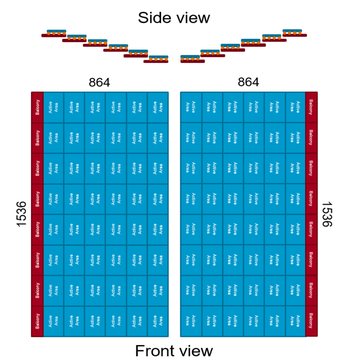
Tiling for a 2Mpix ePixHR10k 5kHz camera.

Parameter	2M ePixHR LCLS-II	2M ePixHR HE
Pixel Pitch [µm]	100	100
Read Noise [e- rms]	75	75
Frame Rate [kHz]	5	25
Array size [pixels]	1536x1720	1536x1536
Well Depth [Number of 4keV photons]	>16000	>20000

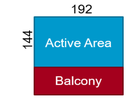
TXI detector:



- Shingled assembly to maximize fill factor
- Overall dimensions compatible with requirements



Core element:



References

[1] A.Dragone et al., "ePix: a class of architectures for second generation LCLS cameras," in Journal of Physics: Conference Series, vol. 493, no. 1. IOP Publishing, 2014, p. 012012.
[2] H. Ali et al., "Single-Ended-to-Differential Sampling Technique for Sigma Delta ADCs in X-Ray Detectors". IEEE 62nd International Midwest Symposium on Circuits and Systems (MWSCAS) - August 2019.
[3] P. Caragiulo, C. Tamma et al., "Design and characterization of a high-rate readout backend for ePix detectors at LCLS II," in 2018 IEEE Nuclear Science Symposium, Medical Imaging Conference and Room-Temperature Semiconductor Detector Workshop (NSS/MIC/RTSD). IEEE, 2018.