Development of a medium-sized photon counting UFXC-demonstrator at SOLEIL synchrotron

Marie Andrä[1], El-Houssain Ait-Mansour[1], Jérôme Bisou[1], Arkadiusz Dawiec[1], Pawel Grybos[2], Brahim Kanoute[1], Claude Menneglier[1], Fabienne Orsini[1]

1. SOLEIL Synchrotron, Saint-Aubin, 91192 Gif-sur-Yvette, France
2. Department of Measurement and Electronics, AGH University of Science and Technology, Krakow 30-059, Poland

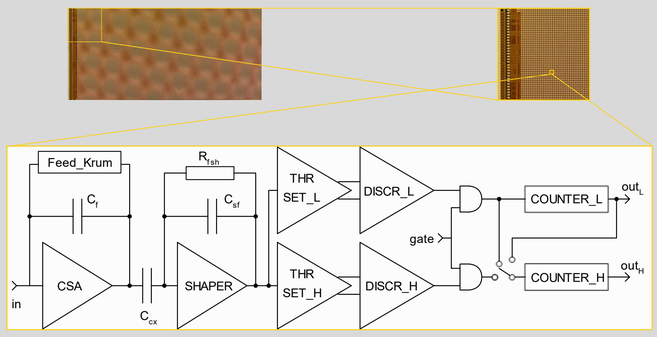
marie.andrae@synchrotron-soleil.fr

ULTRA FAST X-RAY CAMERA DEMONSTRATOR with 8 CHIPS

A **hybrid photon-counting pixel detector** of **medium size** with **very high frame rate**, **high count rate capability** and **short gating time** for **time-resolved pump-probe experiments** and other **new** or **existing applications**

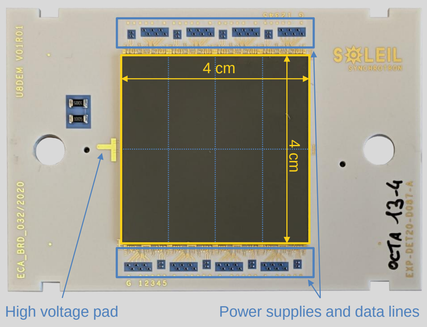
UFXC32k readout chip designed at AGH-UST, Krakow

- 128 × 256 pixels with 75 µm pitch
- Two discriminators with 7 trimbits each and two 14-bit counters per pixel
- Adjustable gain and frontend speed
- Selectable readout counter depth (2, 4, 8, 14 or 28-bit)
- Minimum exposure time < 100 ns
- High count rate linearity > 10^6 ph/pix/s (at 90 % counting efficiency)



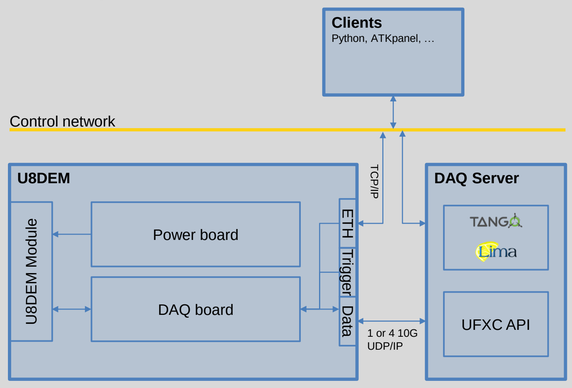
U8DEM module

- Evolution of the existing 2-chip system tested at SOLEIL
- Single Si-sensor (320 µm or 450 µm thickness), bump bonded to eight UFXC32k readout chips
- Detection area: 4 × 4 cm² (250k pixels with 75 µm pitch, including single pixel inter-chip spacing)
- Ceramic PCB (LTCC, 88 × 60 mm²)
- Single high density connector on the backside



Detector

- Compact (16 × 28 × 11 cm³) and light (~3 kg) mechanics
- Efficient water cooling (up to 50 W)
- Power board
- Acquisition board with FPGA
- 1 or 4 x 10G QSFP connections for data transfer
- Power consumption of the detector head < 25 W



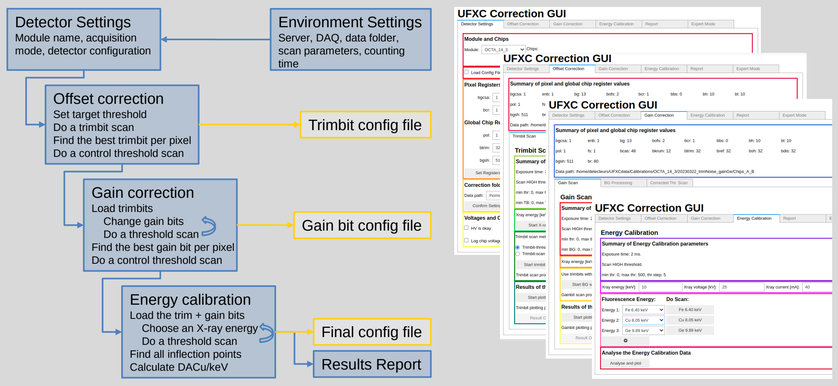
FIRMWARE AND SOFWARE STATUS

Firmware + Library developed for U8DEM

- Based on firmware + decoding library made for the 2-chip system
- Interface to TANGO and LIMA to ease integration into the SOLEIL beamline control system
- Controls 8 chips simultaneously
- Frame rate between 3.4 kHz and 23 kHz (depending on the acquisition mode)
- Based on FEM-II acquisition board (Virtex 6 FGPA + Zynq SoC)
- Under finalization

Correction + Calibration Software

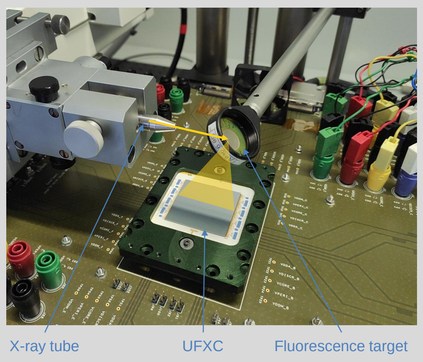
- Semi-automatised offset and gain correction and energy calibration
- Control of the detector and X-ray generator (via TANGO devices)
- Generates the configuration files and pixel mask
- Displays and saves all resulting plots and data
- GUI based on Jupyter-Notebook widgets
- Under finalization



FIRST CHARACTERISATION MEASUREMENTS

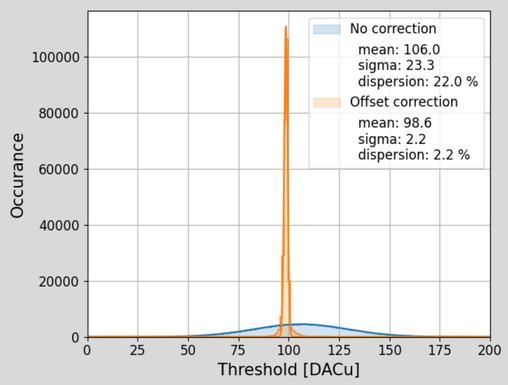
All presented measurements have been acquired with the existing 2-chip readout system and in the laboratory X-ray setup using fluorescence photons. The data of all 8 chips are presented.

Laboratory X-ray setup



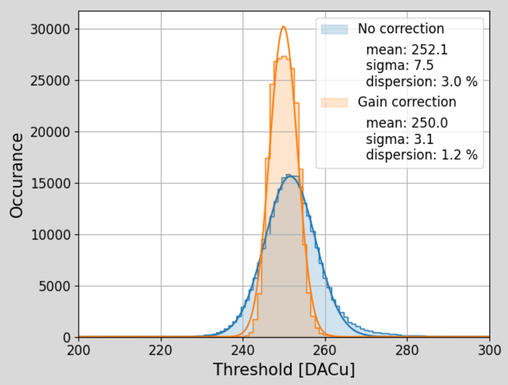
Fluorescence setup with temporary readout system

Offset spread



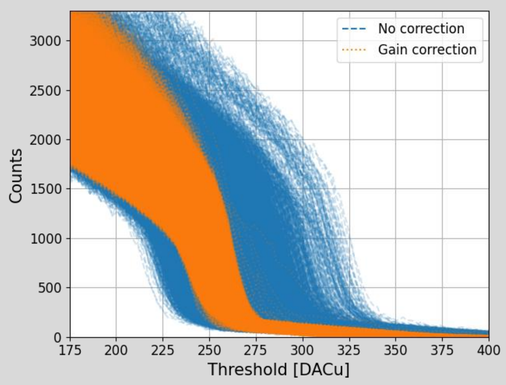
Very low offset spread after the correction

Threshold dispersion @ 10 keV



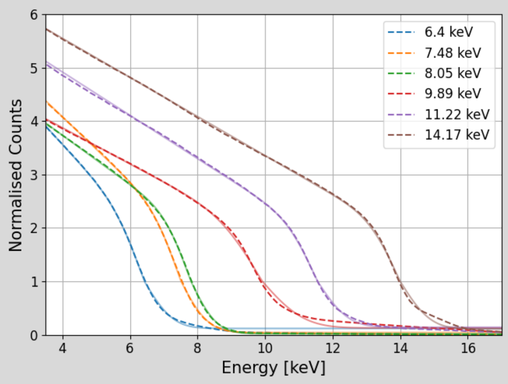
Reduced threshold dispersion < 2% after gain correction

Corrected threshold scans @ 10 keV



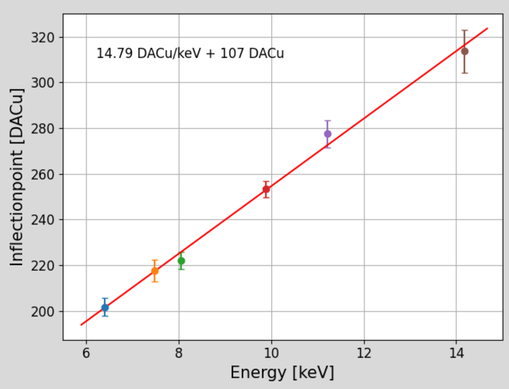
Threshold scans before and after gain correction

Threshold scans at different energies



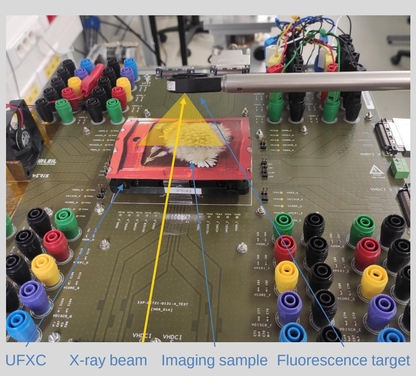
Median threshold scans after corrections at low gain

Energy Calibration



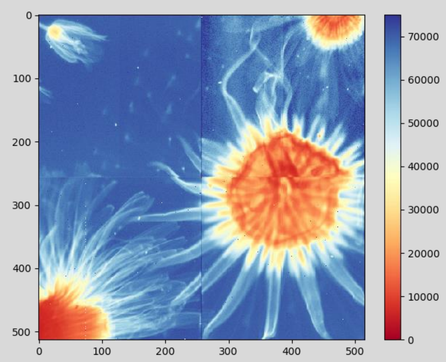
Median energy calibration at low gain

Imaging setup at the beamline



UFCX with imaging sample using fluorescence photons

First imaging @ 10 keV



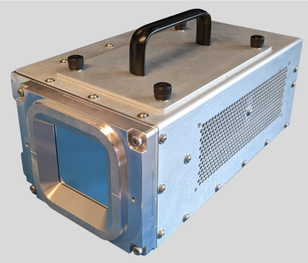
Flatfield and inter-chip gap correction

Shifts in the image are due to the composition of four 2-chip images taken one after the other

SUMMARY AND OUTLOOK

- ✓ An 8-chip demonstrator has been developed
- ✓ Offset, gain correction and energy calibration work as expected
- ✓ Validated good quality of several hybrid modules
- ⏳ Firmware and software are in the final development stage

Goal: Have the first fully assembled and operational U8DEM detector by end 2023 / beginning 2024



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[1] A. Dawiec et al., AIP Conf. Proc. 2054, 060067, (2019)
[2] P. Grybos et al., IEEE Trans. Nucl. Sci. 63 1155, (2016)
[3] D. Bachiller-Perea et al., J. Synchrotron Rad. 27, (2020)

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