Characterization of a back-illuminated sCMOS camera for soft X-ray beamlines at Synchrotron SOLEIL

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sCMOS-BSI camera adapted in-vacuum for new experiment at SOLEIL

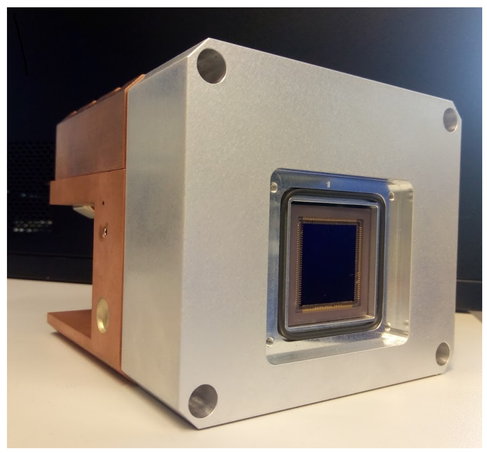
Scientific motivations

Soft X-ray applications using last generation of synchrotron facilities, such as coherent x-ray scattering experiments, require **large 2D direct sensor with small pixels**, **low noise** and **high frame rate**. Last generation of CMOS sensor used under visible light illumination made interesting progress in this direction. Recently, a new type of scientific CMOS Back Side Illuminated (sCMOS-BSI) has been proposed. We report on the characterization of this sCMOS-BSI using synchrotron beams between 40 and 2000 eV on the soft X-ray beamlines METROLOGIE (Bending Magnet) and SEXTANTS (Undulator) at SOLEIL synchrotron in France.

GSENSE400 sCMOS BSI sensor

Developed by Gpixel and integrated into the TUCSEN Dhyana95 camera
Acquisition mode:
- High gain
- Low gain
- HDR (High Dynamic Range): combination: combination of Low and High gain images

Adaptation for in-vacuum experiment designed and integrated by SOLEIL



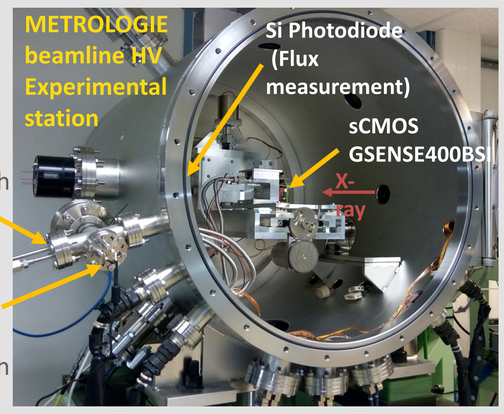
GSENSE400-BSI Specification	
Resolution	2048 x 2048
Pixel size	11 µm x 11 µm
Sensitive area	22.5 mm x 22.5 mm
Shutter type	Rolling shutter
Dark noise	1.2 e-
Dynamic range	> 97 dB
Full well charge	91 ke-
Frame rate	48 fps @ STD, 24 fps @ HDR
Dark current	0.2 e-/s/pix @ -50°C

METROLOGIE beamline – UV Branch

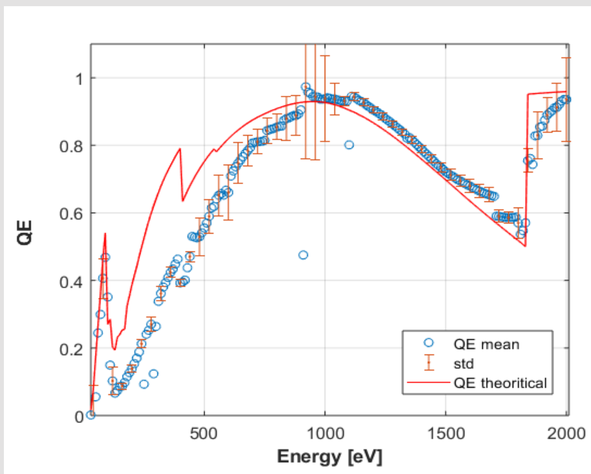
- Energy: 30 to 1900 eV
- Flux: few 10^9 photons/s
- Beamsize: 200 (H) x 150 (V) µm² FWHM
- End-station:Two-axis high vacuum goniometer

Tests at METROLOGIE beamline

Quantum efficiency measurement

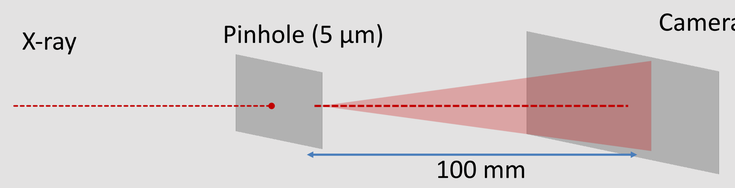


Quantum efficiency (Q.E.) measurement compared to simulated Q.E. with a sensor made of 7.5 nm of SiO, 63 nm of SiN and Si-Epi of 10 µm

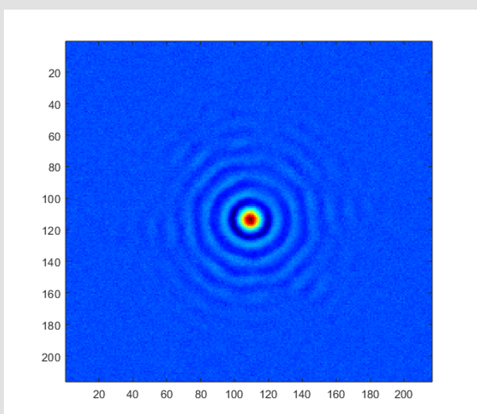


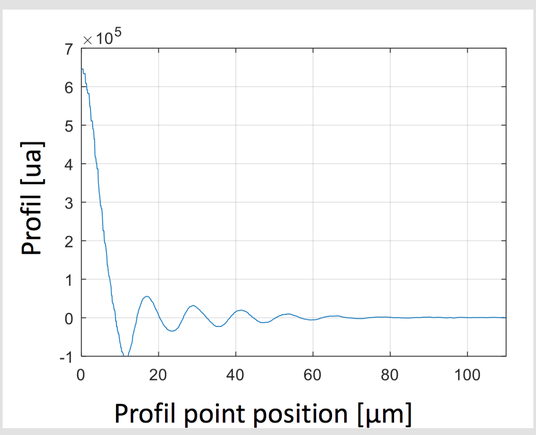
- @ 90 eV: transient rise efficiency coming from X-ray beam transmission through coated thin layer (SiO and SiN)
- @ 410 eV: absorption from Nitrogen
- 550 eV: absorption from Oxygen
- 1830 eV: absorption from Silicon

Diffraction pattern of a pinhole with 186 eV beam



Sum of 100 dark corrected images (100 ms exposure time)

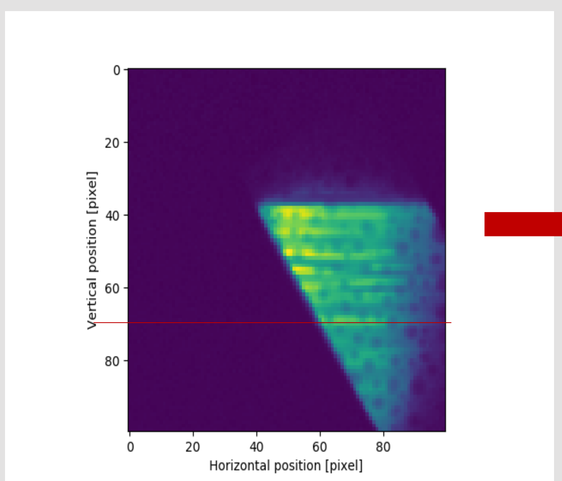


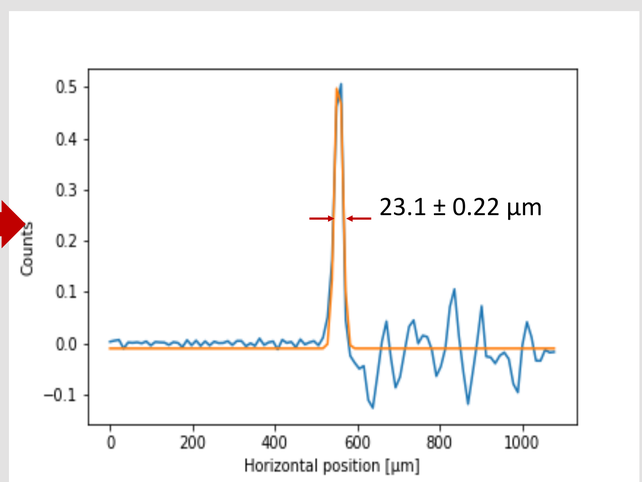


Airy disk presents a nice first result with this non-dedicated setup with the good camera dynamic able to visualize several orders of the diffraction pattern.

Signal spatial dispersion (slanted edge)

A Plexiglas with 3 holes is located as near as possible from the sensor. Two of these holes have a slit of Si3N4 with different orientations and one hole is free for setting the beam energy and size before acquiring data





Acquisition program

For improving analysis, different acquisitions have been done:
- accumulation of 100 images with beam and slit
- 100 dark images with slit
- 100 images with beam and without slit
- 100 dark images without slit

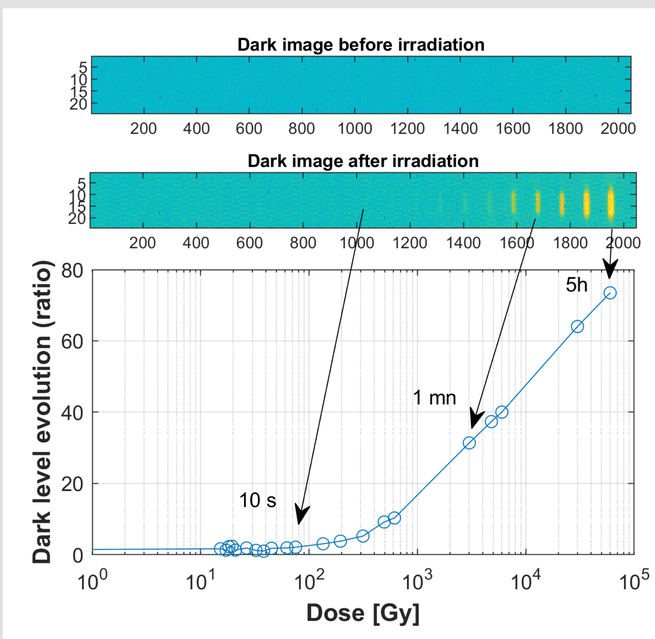
- Mechanics had some lubricant traces => a thin layer of oil has been accidentally deposited on the surface of the sensor while pumping

Results

- Temporal offset reduced and images normalised
- Profile gets for position where the edge does not have a ”oil bubble”
- Calculate derivative of this profile and fit with a gaussian
- FWHM measured:

2.5 pixels ± 0.02 => 23.1 ± 0.22 µm @ 1050 eV

Radiation damage evaluation (E = 1600 eV, ϕ = 9 10^6 ph/s)



Comparison of dark image signal before and after irradiation:

- Different energies and fluxes have been chosen
- After ~ 50 Gy, there is a degradation on the dark level

Then, the incident photon flux should be limited especially for the high energy beam (>1000 eV) which penetrates the sensor deeply.

Summary and perspectives

- GSENSE400-BSI has been evaluated and adapted for in-vacuum tests
- Quantum Efficiency has been measured and fits reasonably to the simulation
- Diffraction images have been recorded and prove capability to use this camera fort soft X-ray application
- Incident photon flux should be limited for energy below 1 keV to avoid damages
- Line Spread Function gives a spatial resolution of few pixels and this measure will be improved
- A camera will be installed in the new experimental station of the SEXTANTS beamline for user operation

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