Characterization of a BSI sCMOS as a soft X-ray detector

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Einstein Probe (EP) satellite

A mission for all-sky monitoring to discover and study high energy transients and variability in the soft X-ray band

Monitoring： 0.5-4 keV soft X-ray

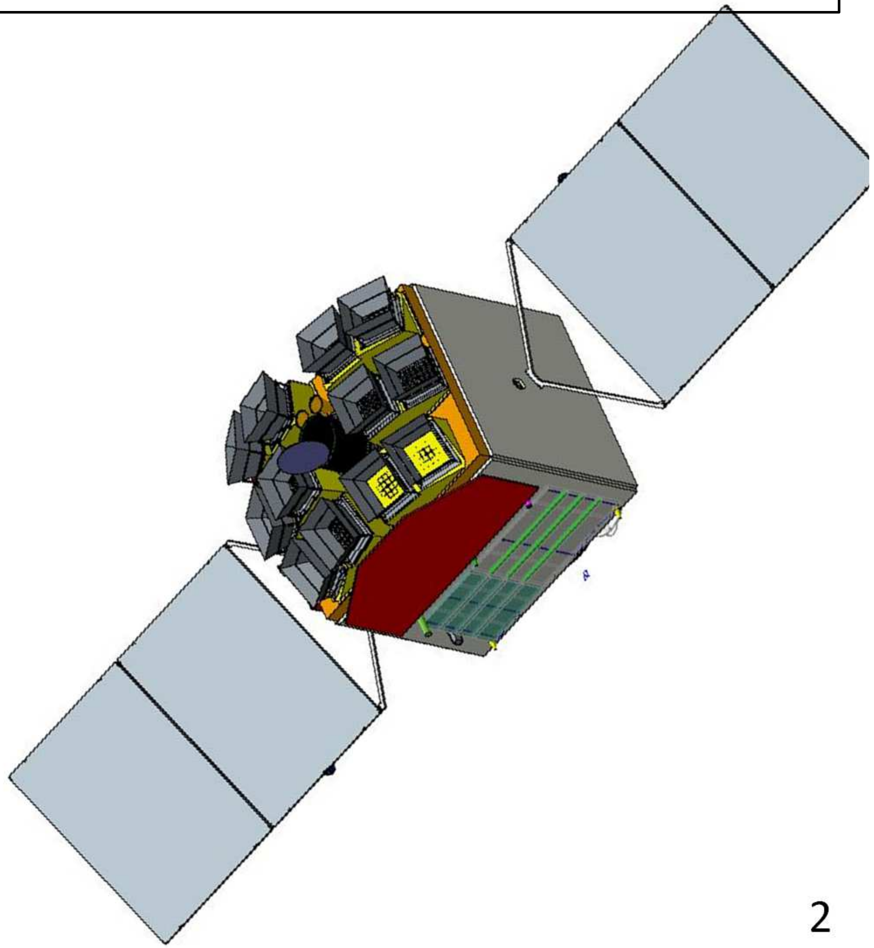
Large Field of View: 3600 sq. deg.

Orbit: 600km

Instruments:

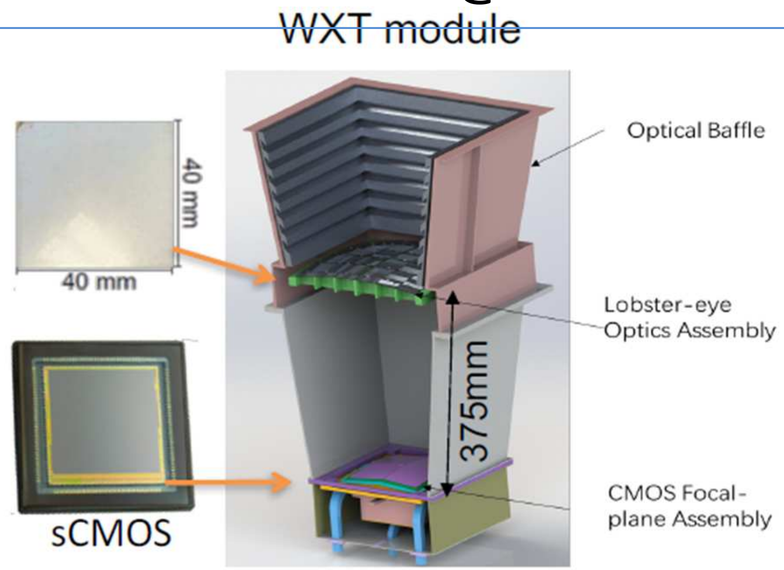
- Wide-field X-ray telescope (WXT)
- Follow-up X-ray telescope (FXT)

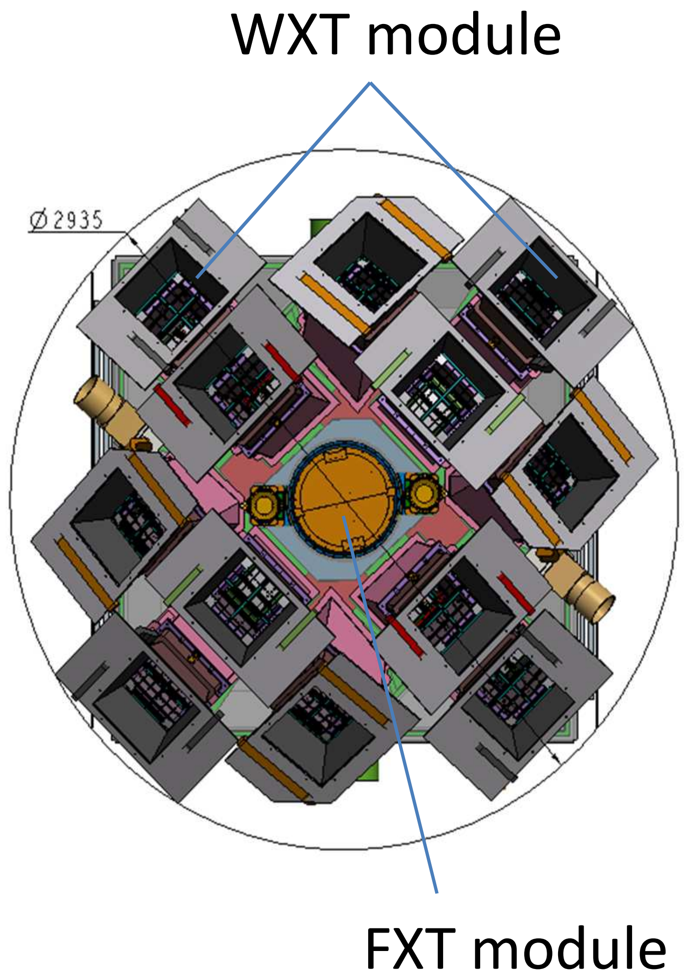
Nominal lifetime: 3 +2 years (2022-)



Wide-field X-ray Telescope (WXT)

Wide-field X-ray telescope (WXT)
12 identical modules
MPO Lobster-eye optics
CMOS detector ~1700 cm^2.
Field-of-view: 3600 sqr.deg.
Spatial resolution: FWHM ~ 5'
Band pass: 0.5-4keV
Effective area: $3cm^2$ @1keV





WXT Focal plane detector

WXT Focal plane detector:

12modules * 12cm * 12cm

Band pass : 0.5~ 4keV

	Gas detector	MCP	CCD	micro calorimeter
	ROSAT RXTE	Einstein Chandra	Chandra XMM-Newton	Suzaku Astro-H
Energy resolution	20%	No	4% (200eV@5keV)	~eV
Time resolution	us	us	s	ms
Temperature			-100°C	~ mK
Advantage & Disadvantage	Low cost, Large area, Ultrathin incident window	High spatial res., Low QE, Good time res.	Good energy res., High QE	Best energy res., Very high cost

CMOS detector

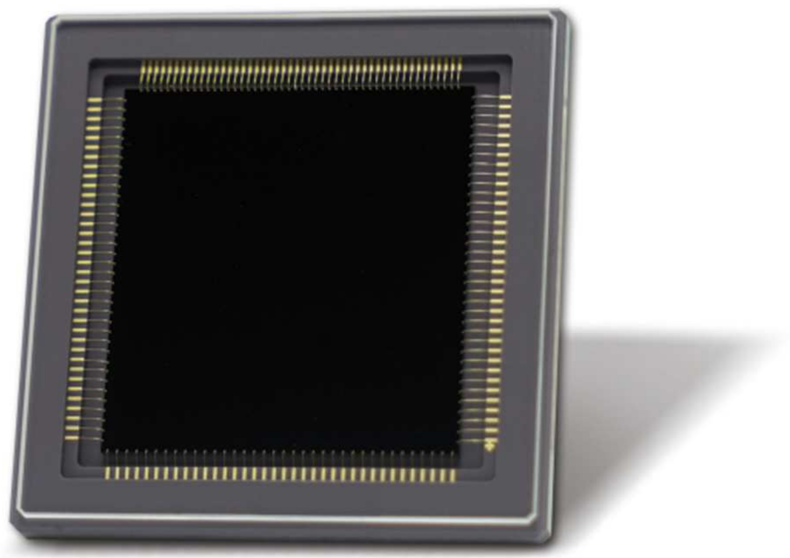
2015: BSI sCMOS (GSENSE400BSI) in China

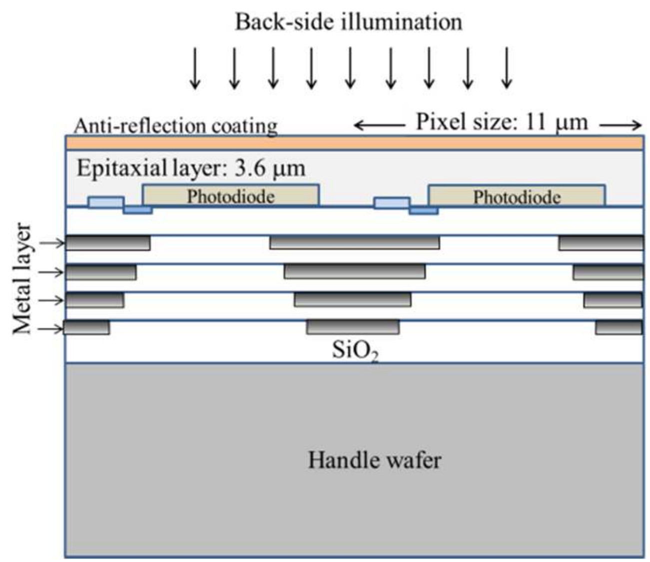
Number of pixels： 2048×2048

Pixel size： 11μm×11μm

Epitaxial layer thickness： 3.6μm

Frame rate： 48fps@STD



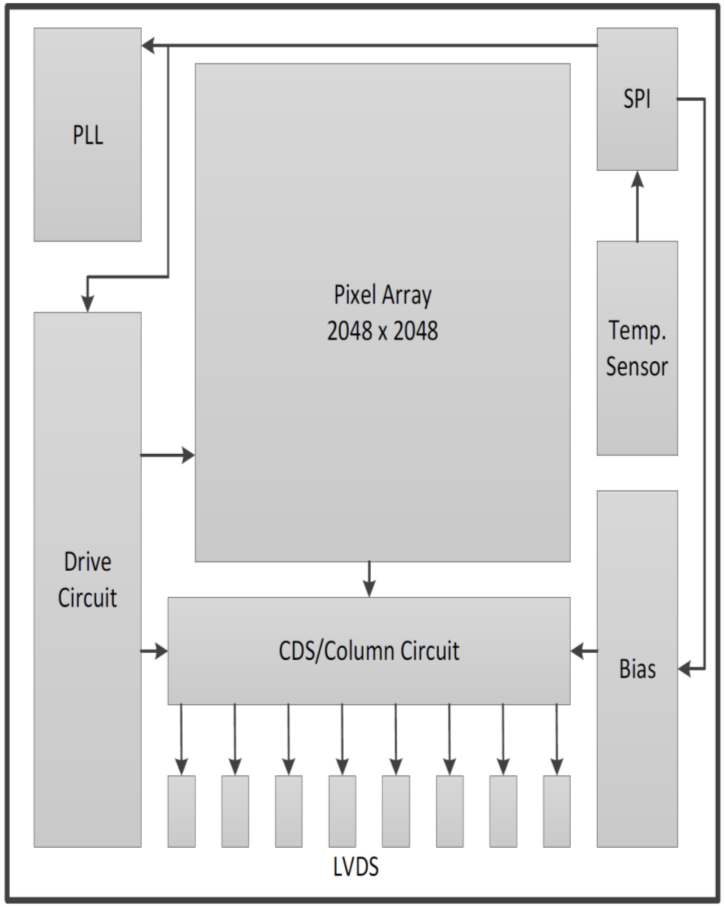


Photograph and physical structure of the GSENSE400BSI.

Compare CMOS and CCD

Parameter	G400 BI sCMOS	E2v CCD4240
Resolution	2k * 2k	2k * 2k
Pixel size	11 μm	13.5 μm
Fill factor	100%	100%
Response spectrum	200 – 1100 nm	270-1100 nm
Full well	> 120 ke- (~2k HG)	100 ke-
Noise	1.2 e-	3 e-
Dynamic range	96 dB	90 dB
Dark current	400 e-/pixel/s @20° 0.03 e-/pixel/s @-50° (@LDC)	250 e-/pixel/s@20°
Frame rate	48 fps @STD	~ 5 fps
PRNU	< 1%	
Power	<500 mW	~ 5 W

CMOS detector

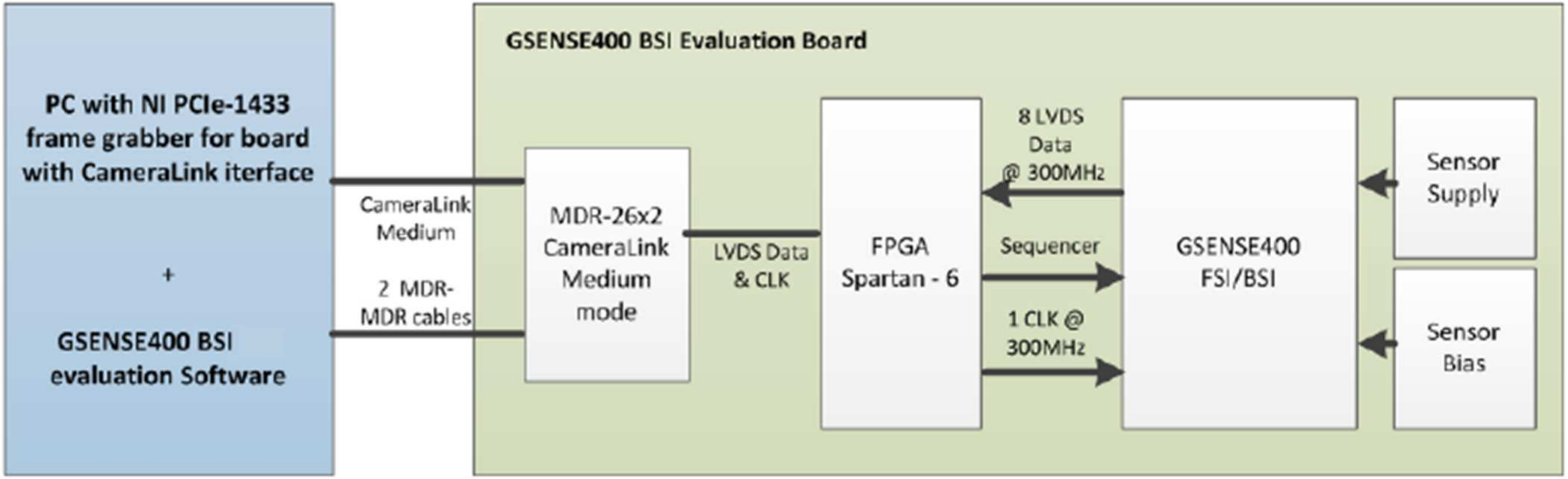


The sCMOS sensor architecture.

The image signals from the pixel array are digitized by a low-power ADC array. The digitized image signals are then read out through 8 low-voltage differential signaling (LVDS) channels.

- Integrates all necessary controls, preamplifiers and digitization
- No charge transfer
- high-speed readout ->Virtual cooling
- No deep cooling required

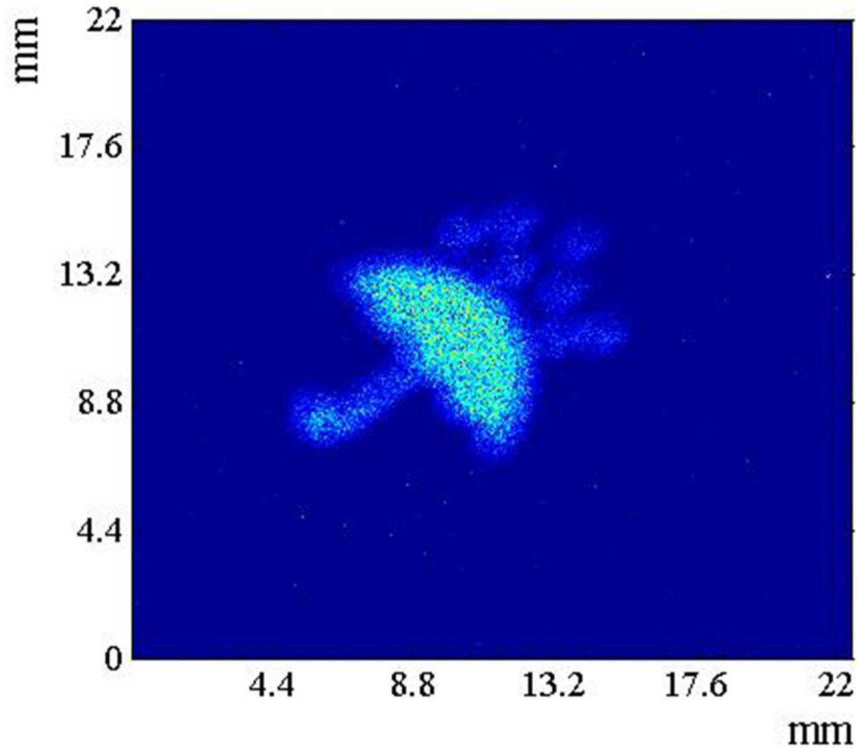
CMOS detector



Block diagram of the GSENSE400BSI evaluation system.

X-ray imaging test

A stainless steel diaphragm
with an umbrella pattern.



X-ray image captured by
the GSENSE400BSI.

CMOS detector

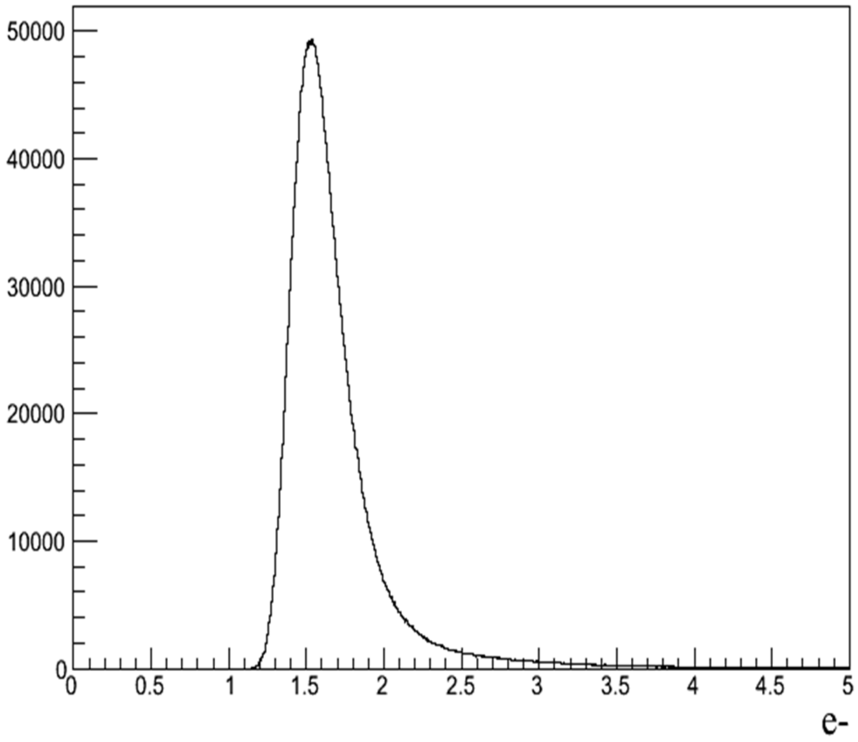
A climate chamber.

Temperature:

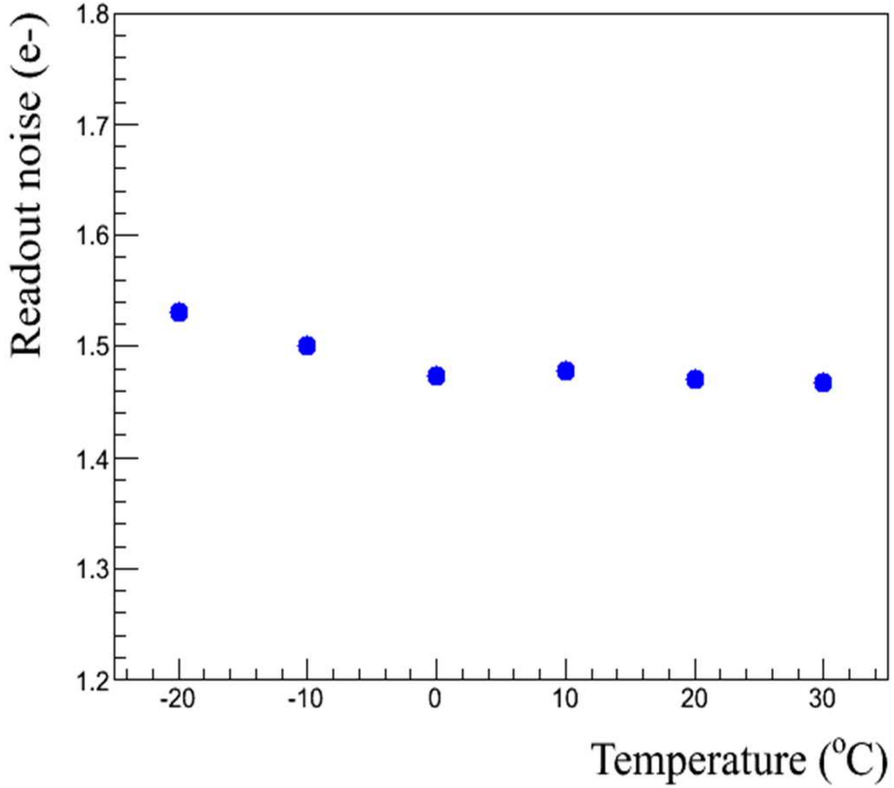
-20°C ～ 30°C

- Readout noise
- Dark current
- Energy resolution

Readout noise

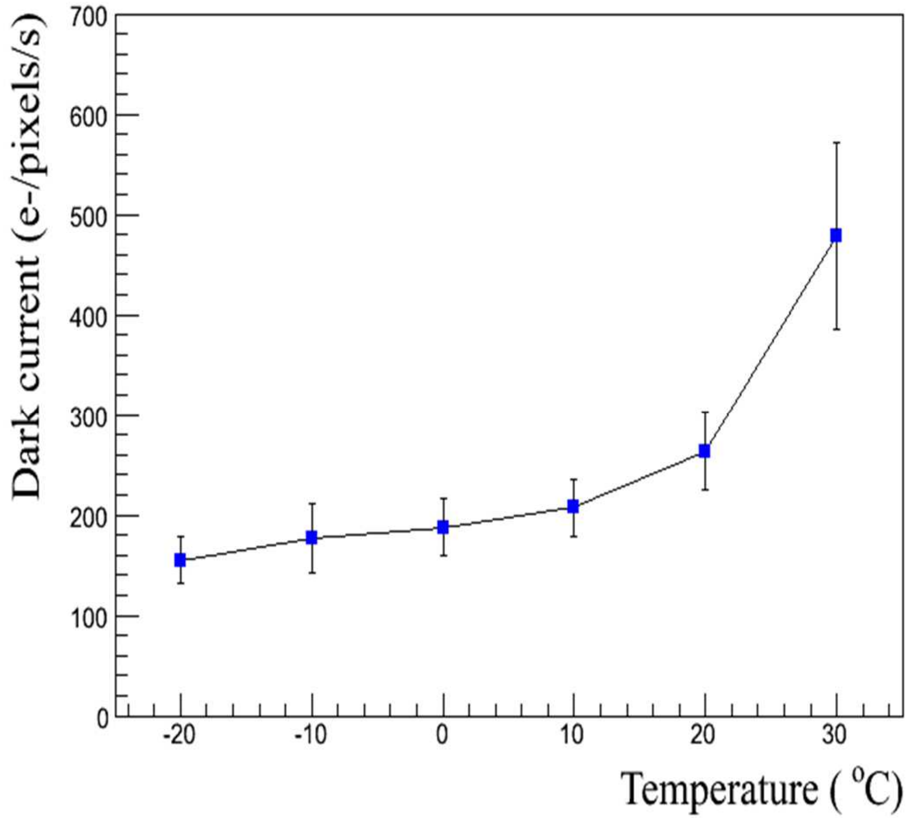


Readout noise at -20°C.



Readout noise as a function of temperature.

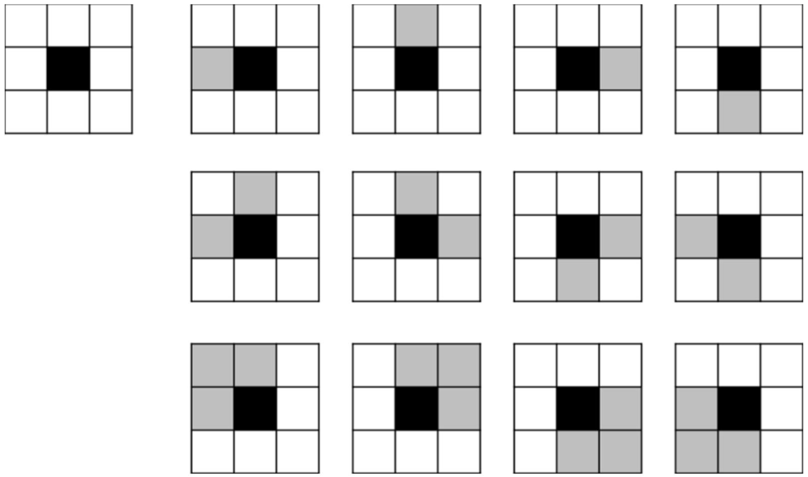
Dark current

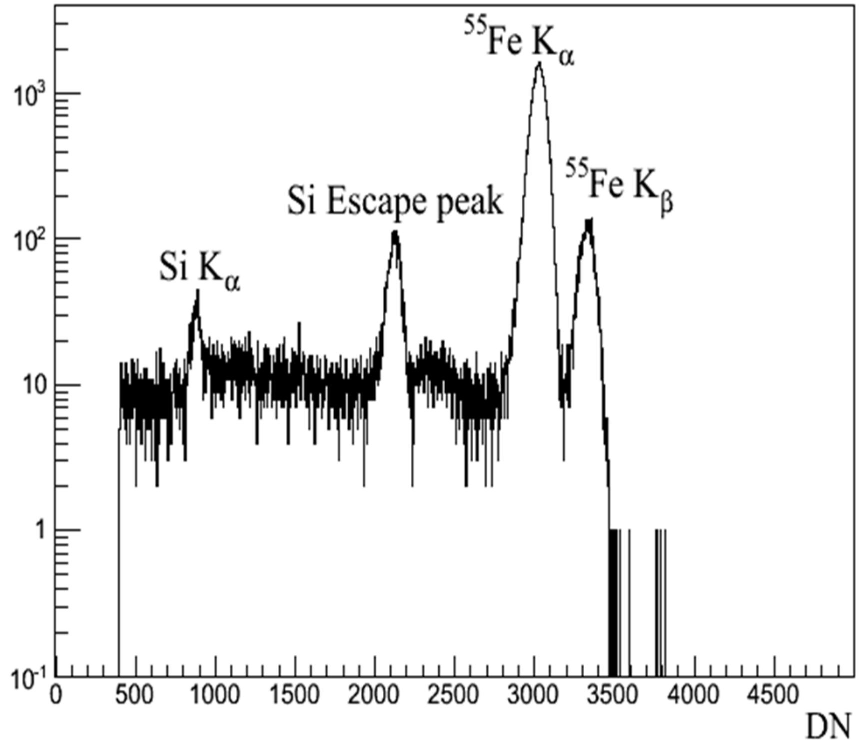


Dark current as a function of temperature.

X-ray spectrum

X-ray grade

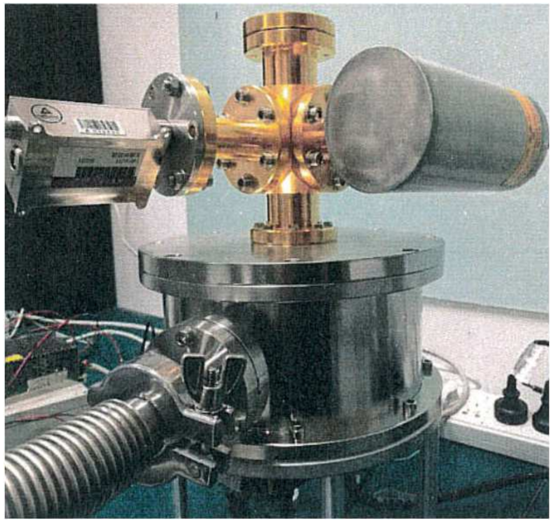




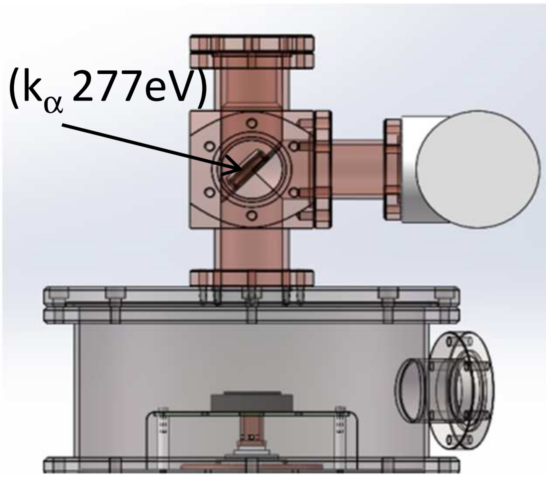
X-ray spectrum from the ^{55}Fe source at 20°C (Only single-pixel events).

Energy resolution: 192 eV (3.3%) at 5.9keV.

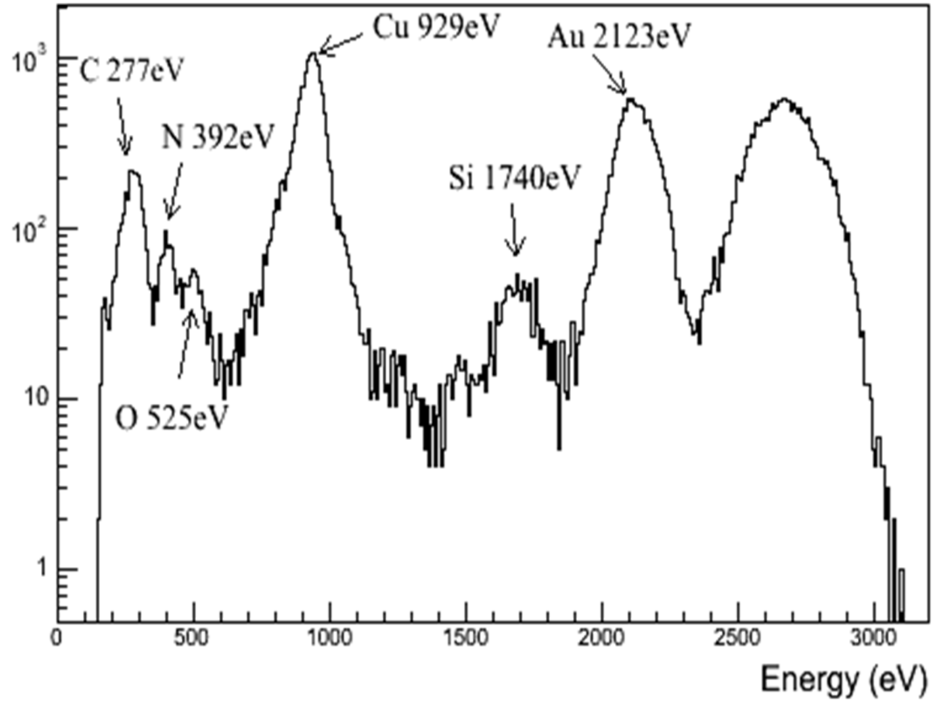
Low-energy X-rays test



Target:
Carbon (k_α 277eV)

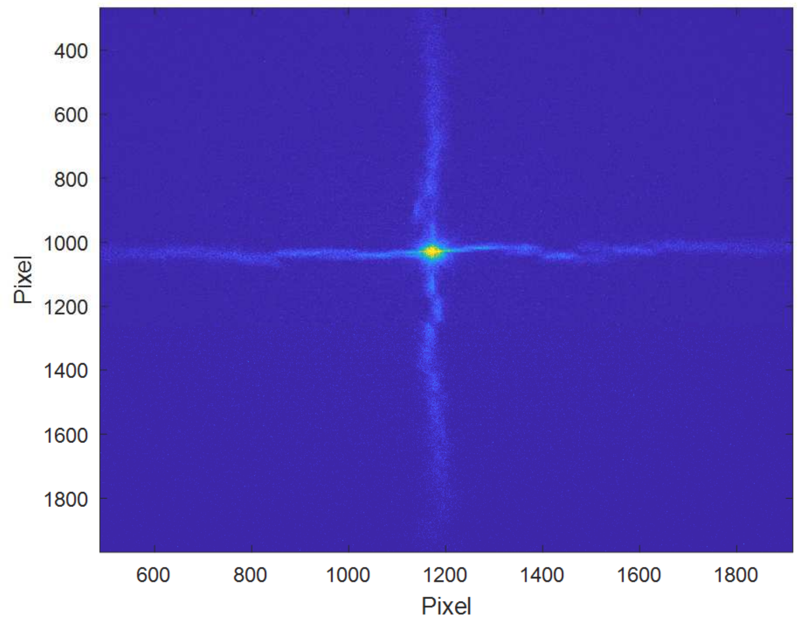


The schematic of the vacuum chamber setup.



The spectrum from the low-energy X-rays test.

Test with MPO



The corresponding focused image of the point spread function (PSF) of the MPO by integrating the response of the GSENSE400BSI.

Thank you!