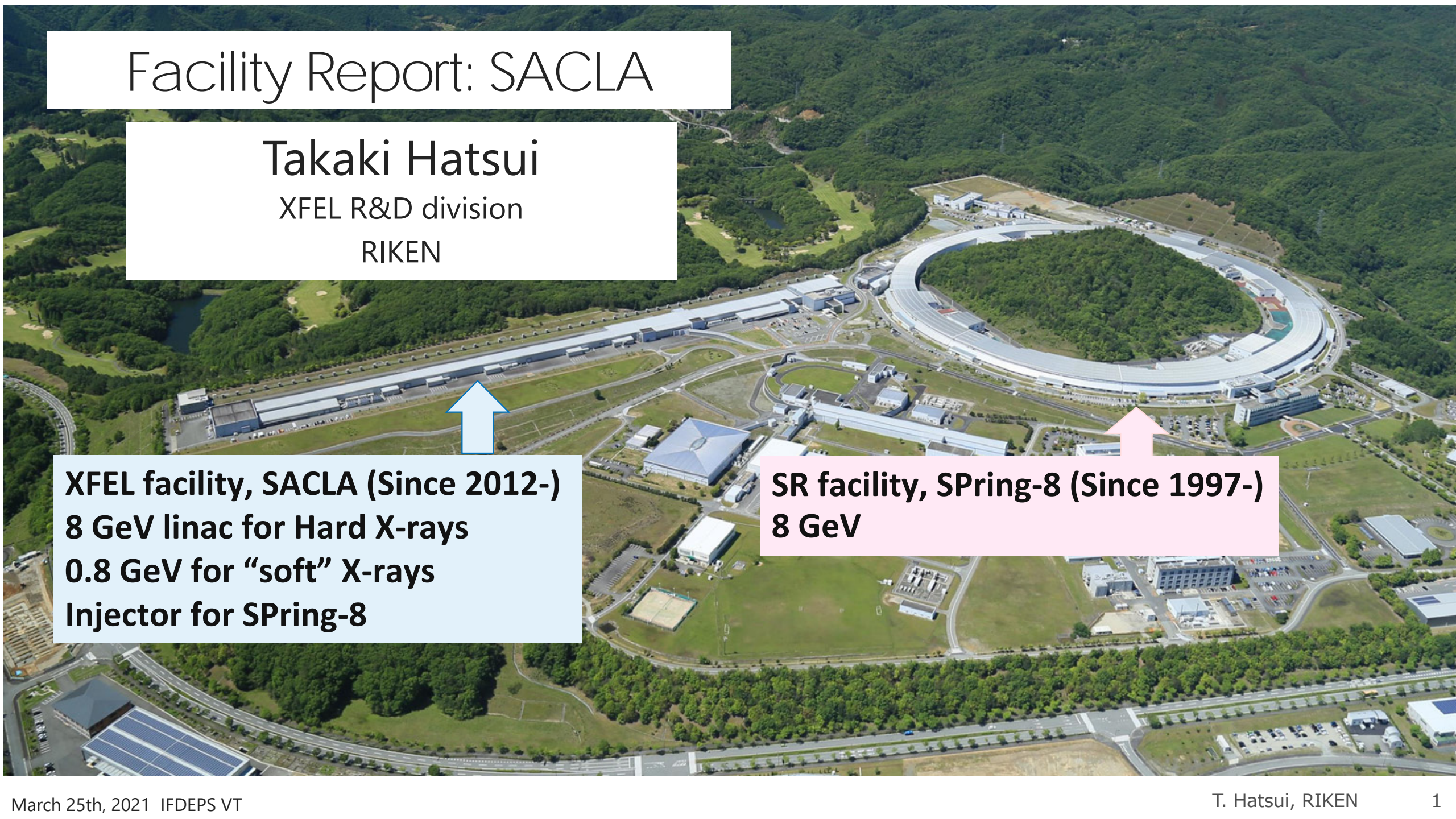


Facility Report: SACLA

Takaki Hatsui

XFEL R&D division

RIKEN

An aerial photograph of the SACLA facility, showing a long, straight building on the left and a large, circular building on the right. A blue arrow points from the text box on the left to the long building, and a pink arrow points from the text box on the right to the circular building. The facility is surrounded by greenery and parking areas.

XFEL facility, SACLA (Since 2012-)
8 GeV linac for Hard X-rays
0.8 GeV for “soft” X-rays
Injector for SPring-8

SR facility, SPring-8 (Since 1997-)
8 GeV

Multi-Port CCD (MPCCD) Detector Family deployed since 2011

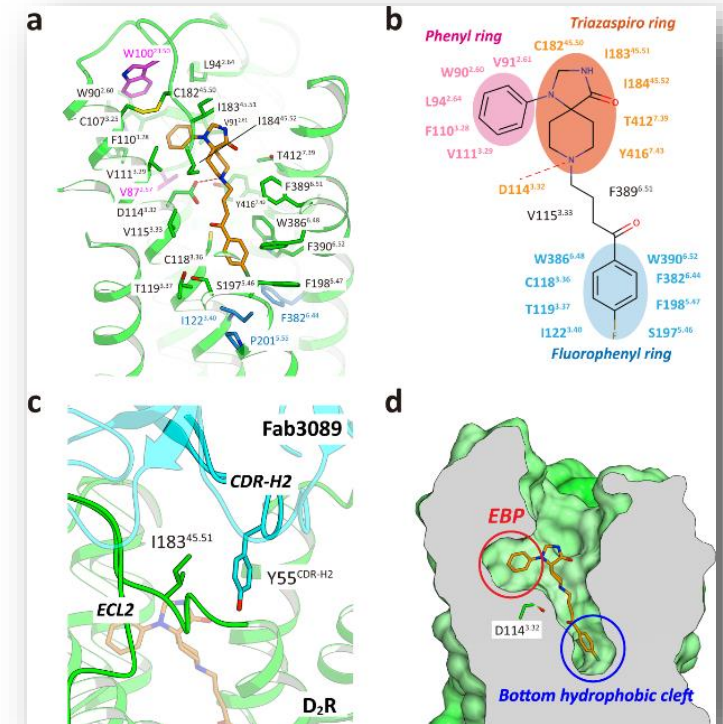
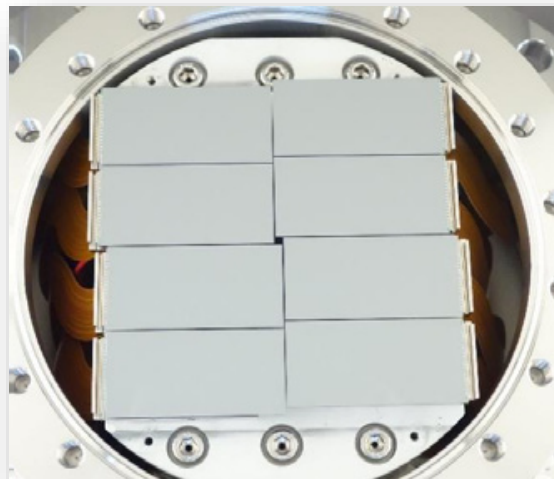
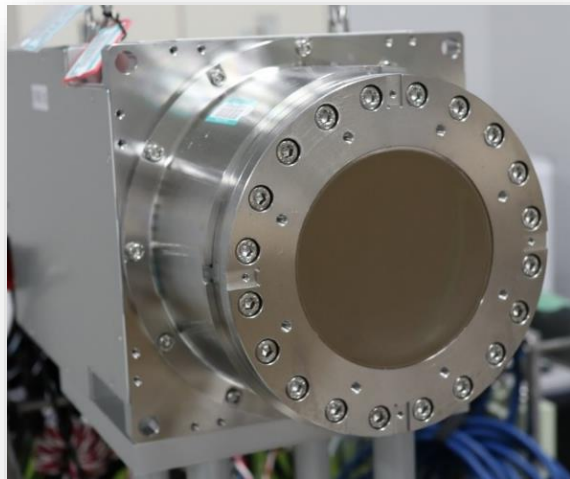
Kameshima et al., Rev. Sci. Instrum. 85, 033110 (2014).

Features

- 50 μm square pixel with max. 4 Mpixels /60 Hz
- 20 bit Effective Dynamic Range
- Dead area between sensor tiles can be 150 or 300 μm

Deployment Status

- Total 14 variants
- 38 systems operational (in total 59 Mpixels)
- More than 60 % experiments uses MPCCD detectors as primary data collection apparatus.



SFX Experiments

Structure of the dopamine D2 receptor in complex with the antipsychotic drug spiperone.

D. Im, S. Iwata, T. Shimamura, et al., Nat. Commun. 11, 6442 (2020).

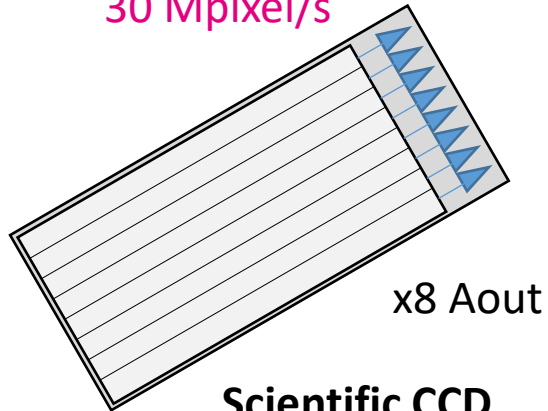
Our Detector Developments: Silicon Integrating-pixel detectors



MPCCD

2009-2011

0.5 Mpixel 60 Hz
30 Mpixel/s



x8 Aout

**Scientific CCD
with Teledyne e2v**

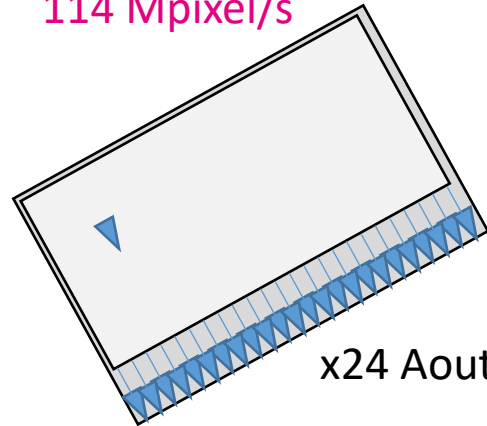
T. Kameshima et al., Rev. Sci. Instrum. 85, 033110 (2014).



SOPHIAS

2009-2014

1.9 Mpixel 60 Hz
114 Mpixel/s



x24 Aout

SOIPIX with Lapis Semiconductor

Installed to 10 BLs at SPring-8

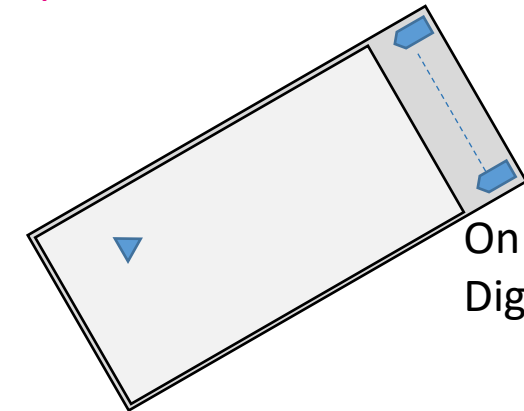
T. Hatsui, et.al., IISW proc. 2013



CITIUS

XFEL variant 2013-
0.28 Mpixel 5,000 Hz
1400 Mpixel/s

SR variant
0.28 Mpixel 17,400 Hz
4872 Mpixel/s



On chip ADCs
Digital Out

Dedicated CMOS Image Sensor with Sony

T. Hatsui, et.al., in preparation

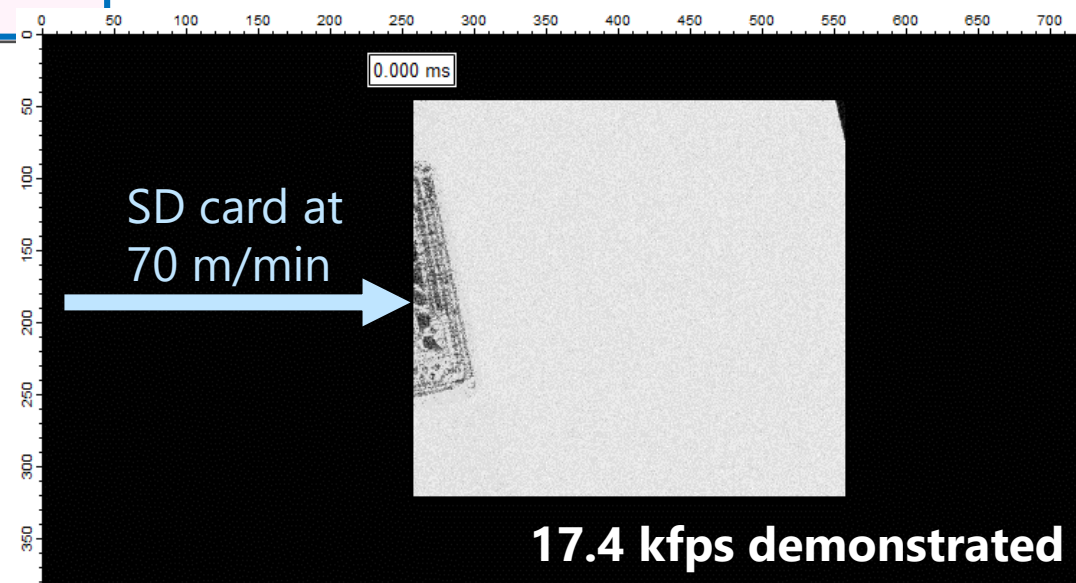
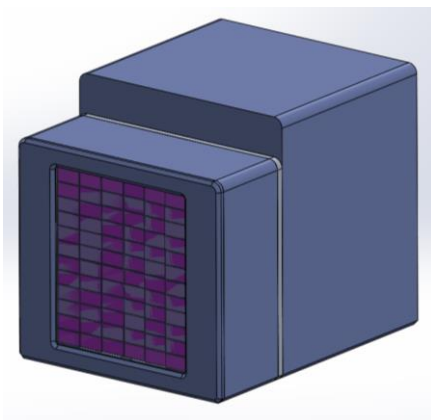
Experimentally verified Performance

Parameters		Value	
Sensor	Thickness	650 μm	
	Pixel Size	72.6 μm	
	Pixel Number	0.28 Mpixel/sensor	
	Noise	0.027 phs.@8 keV (60 e-)	
		SR variants	SR variants
	Peak Signal	> 17,000 phs. @ 6 keV	> 1,800 phs.@12 keV
	Frame Rate	5 kHz	17.4 kHz

System Development

Largest System	Pixel Number	20.2 Mpixel
	Image Area	325 x 363 mm

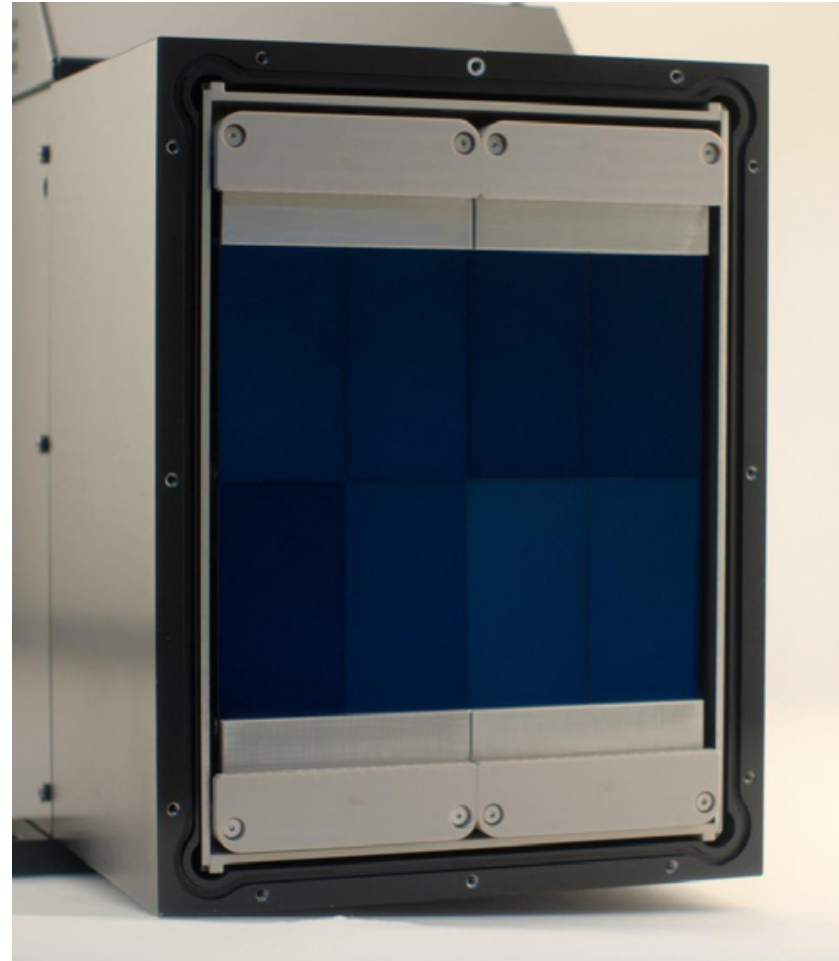
30 Mcps@ 12 keV
600 Mcps@ 12 keV
in extended mode



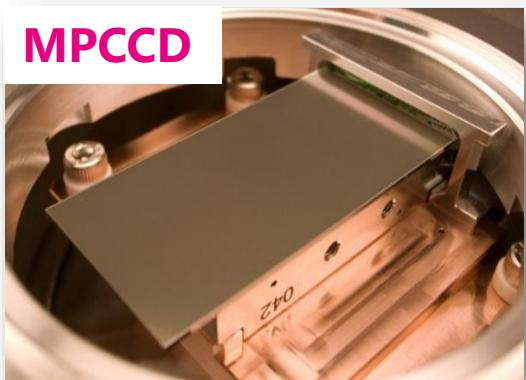
X-ray Generator: Target Element of Mo, 40 kV 140 mA

CITIUS: Recent Progress

2.2M pixel Detector Assembly Completed



Our Detector Developments: New project mxdCMOS



MPCCD

2009-2011



SOPHIAS

2009-2014



CITIUS

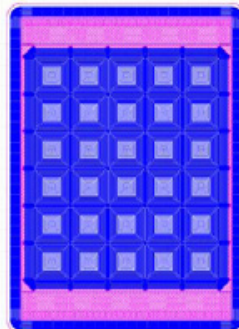
2013-

2019-

2019-2020
Rad. Hard SOI-Transistors
developed. (I. Kurachi et.al.,)



mxdCMOS



Advantage:
small photodiode capacitance
Stacking to achieve thick sensor

Multi-element x-ray energy dispersive detector
Target spec. for phase 1

- 1 Mcps with 140 eV FWHM @ 6 keV
- 1.8 mm square element
- 64 elements/chip
- 64 Mcps/14.4 mm x 14.4 mm

Current Status

Proto type chip (30 elements)
submitted

sxCMOS: soft x-ray imaging detector

U.of Tokyo, Tohoku U., U. Hyogo, and AIST.

Hiroya Shike, **R. Kuroda**, R. Kobayashi, M. Murata, Y. Fujihara, M. Suzuki, S. Harada , T. Shibaguchi, N. Kuriyama, T. Hatsui, J. Miyawaki, T. Harada, Y. Yamasaki, T. Watanabe, Y. Harada, and **S. Sugawa** to appear in IEEE Trans. Elec. Dev.

- Funded by SACL A Basic Development Program
- Main Feature demonstrated by a prototype sensor with 160 x 88 pixels

Pixel Size	22.4 μm square
Full Well Capacity	21.9 Me ⁻ , 160,000 photons @ 500 eV
System Noise	8.1 e-rms @ room temp for 1 ms exposure (S/H cap. Limit is 2.3 e-rms)
Process	Back-illuminated CMOS Image Sensor Process with trench cap.
Shutter	Global Shutter
Frame Rate	450 fps (1k x 1k full chip to be operated at 1000 fps)
Fill Factor	100 %
Radiation Hardness	45 μm thick silicon 3 x 10 ¹⁶ photons/mm ² @ 1 keV did not show any damage

Summary

CITIUS: an integrating-pixel fast-framing detector

- All the sensor features demonstrated. Highlights are

- 17.4 kfps frame rate
- 600 Mcps/pixel count rate

See associated data challenge in Hiraki's flash talk on April 1st.

- We seek collaboration in many area.

- Scintillator coupling option is to be investigated in collab. with ESRF.

mxCMOS: an energy dispersive silicon detector with 64 elements in a chip.

- 30 element prototype submitted.

- We seek collaborations on photodiode design (TCAD), ASIC, Readout, Digital Signal Processing....

sxCMOS: an high dynamic range soft x-ray image sensor (led by U. Tokyo and Tohoku U.)

- 8.1 e-rms noise, 21.9 Me⁻ peak signal for 22.4 μm square pixel demonstrated for a prototype chip.
- Full chip will run at 1000 fps
- Development by CMOS Image sensor experts is progressing rapidly.
- A CMOS Image sensor process with trench cap. enables extremely large peak signal and low noise in a global shutter mode.
- They are also seeking collaboration.

Post-doc position now open.