Development of 20.2 Mpixel CITIUS detector for SACLA

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Abstract
A new X-ray imaging detector, CITIUS-20.2M, has been developed for Serial Femtosecond Crystallography (SFX) at SACLA. CITIUS-20.2M has a seven times higher peak signal, seven times smaller noise, and five times more pixels than the currently used detector MPCCD (Phase III). The total number of pixels will be the world‘s largest as a direct detector for XFEL. Our objective is to improve the spatial resolution of SFX with higher-Q measurements. The detector will be deployed in FY2024. Status of the development and the preparation for the deployment are presented in this poster.

CITIUS-20.2M detector

A new charge-integrating X-ray imaging detector, CITIUS, has been developed for high photon fluxes onto samples with upgraded synchrotron radiation facilities. The integration of CITIUS detectors into synchrotron radiation experiments are in progress at SPring-8.
In parallel, we are also developing another larger version, CITIUS-20.2M, with high spatial resolution for Serial Femtosecond Crystallography (SFX) at SACLA. CITIUS-20.2M will have the world's largest number of pixels as a direct X-ray detector for XFEL. In comparison with the current detector MPCCD (Phase-III) in operation, CITIUS-20.2M has a seven times higher peak signal, seven times smaller noise, and five times more pixels.

Architecture [1-3]
Integrating Pixel & High Frame Rate

Features				
High Dynamic Range	Ultralow Systematic Error	Single Photon Sensitivity	Spectro-Imaging	High Spatial Resolution

[1] SPring-8 II CDR (2014) with updated values.
[2] T. Hatsui, presented at iWorid (June. 2014).
[3] T. Hatsui, AOSFRR (Nov. 2015)

Specifications of CITIUS-20.2M and MPCCD (Phase-III) for SACLA

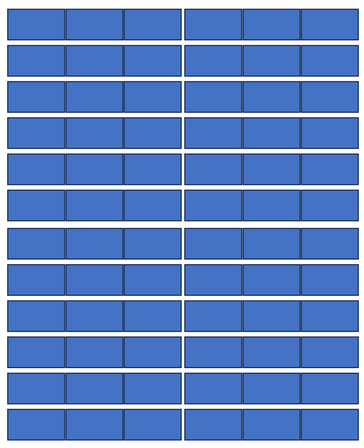
Parameters		Value: CITIUS for XFEL (SACLA)		Value: MPCCD (Phase III)	unit
Sensor	Sensor Material	Silicon			N/A
	Thickness	650	x 2.1	300	μm
	Pixel Size	72.6	x 1.5	50	μm
	Pixel Number	0.28	x 0.6	0.5	Mpixels/sensor module
	Peak Signal	17,000	x 7	2,400	phs/pixel@6 keV
	Typical noise	25	x < 1/7	250	e-rms
	Frame Rate	60*		60	Hz
	Data Rate	1.6**		0.06	GB/s @ digital out
System	Imaging area	321 × 393		100 × 100	mm^2
	Pixel Number	20.2	x 5	4	Mpixels
	Data Rate	107*	x 242	0.48	GB/s @digital out

* The frame rate of CITIUS is 17.4 kHz (SR variant) and 5 kHz (XFEL variant).
** The data rate of CITIUS is the total raw data rate from the sensor. Each frame data has 16 multi- AD sampled data.

CITIUS-20.2M imaging area geometry

The CITIUS sensor module has 0.28 Mpixels (384 x 728 pixels) and an imaging area of 28 x 52 mm^2. CITIUS-20.2M was built by tiling 72 sensor modules, as illustrated in the figures at the bottom and right.

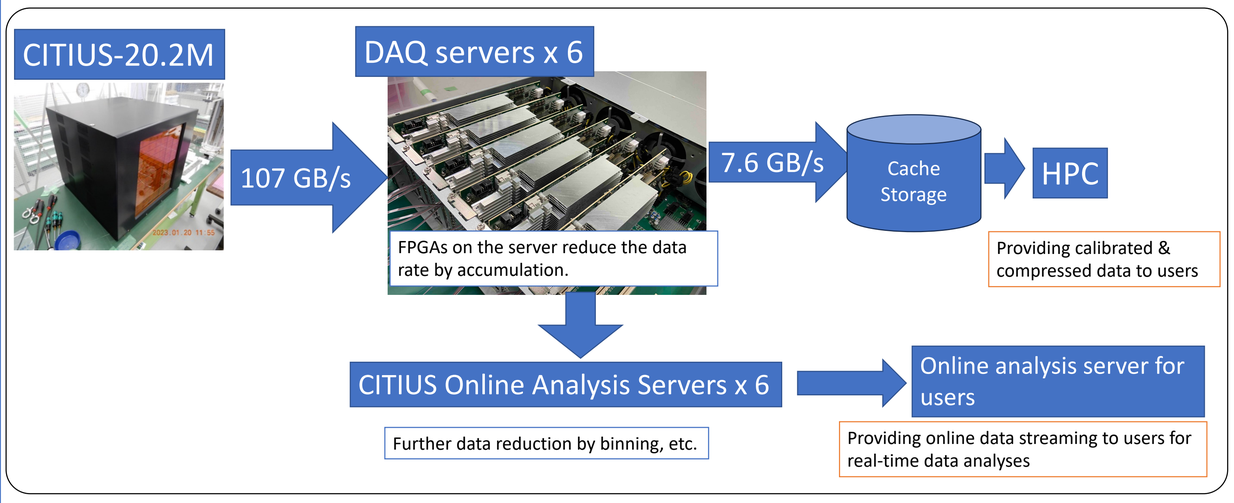
Side view of the imaging area from above



Front view of the imaging area

Preparation of data acquisition system

CITIUS-20.2M generates orders of magnitude more data than the data rate of MPCCD.
This amount requires dedicated computers for data acquisition and data processing. The new computing system will have an analysis environment similar to the one currently used for SFX experiments with MPCCD environments for SACLA users, by reducing the huge amounts of data



Outline of CITIUS-20.2M data flow

Data acquisition computers for CITIUS-20.2M installed in the server room of SACLA

Preparation Status

The data acquisition computers for CITIUS-20.2M have started running in the server room of SACLA since the winter shutdown period.
Data processing testing started by generating dummy data simulating the data rate of CITIUS-20.2M.
We will start integration testing early next FY when CITIUS-20.2M is installed at BL2EH3 of SACLA.

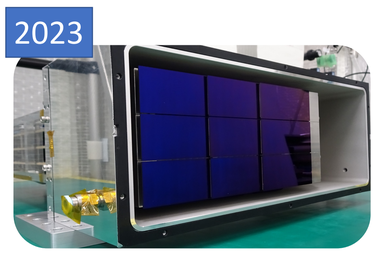
Timeline for deployment

- FY2022: Feasibility study with CITIUS-560k
- FY2023: 20.2M camera assembly and the installation of data acquisition system
- FY2024: Installation of CITIUS-20.2M at SACLA on BL2 EH3

2022

First (XFEL) light on CITIUS using CITIUS-560k

2023



Assembly of Sensor Sub System (SSS) consisting of 9 sensors

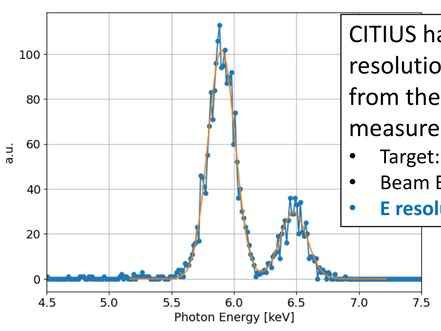
2024

Installation of CITIUS-20.2M

Feasibility Study with CITIUS-560k

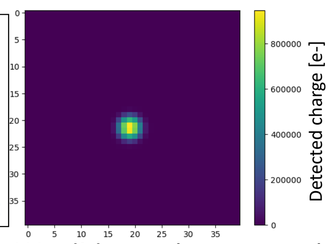
The first beamtime at SACLA, using CITIUS-560k, has been conducted in December 2022 and the response of CITIUS to XFEL beam conditions has been measured.
The successful DAQ integration to RunControl of SACLA, the lower noise, higher dynamic range, and linearity have been confirmed.

Energy resolution



CITIUS has better energy resolution than MPCCD from the fluorescence measurements:
- Target: Mn
- Beam Energy 10 keV
- **E resolution: 253 eV (FWHM)**

Response to a high intensity signal



CITIUS's response to a high intensity signal equivalent to 1.8 x 10^5 photons @ 10 keV, which is 100 times higher than the peak signal of MPCCD

We did not observe any blooming, which was a wide charge spread over surrounding pixels observed with MPCCD.

Summary

- CITIUS-20.2M is the world's largest direct X-ray detector developed with high spatial resolution of SFX at SACLA.
- The sensor of CITIUS detectors has been confirmed to work as expected for XFEL. CITIUS-20.2M is now under assembly and the data acquisition computers are in preparation.
- CITIUS-20.2M will be installed in FY2024. After the verification of CITIUS-20.2M through test experiments, the detector will be provided for users' experiments.

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