Breakout Session A3: Detectors

Organizers: Takaki Hatsui (SACLA) & Taito Osaka (SACLA)

Goal: Enhance scientific activities of users at SACLA by sharing the current status & prospects of detectors at SACLA, and various advanced analysis methods. Also, collect real needs on detectors for various measurement techniques from user community to feedback to plans for deployments of new detectors (in particular, CITIUS).

- Takaki Hatsui (SACLA, Japan)
  "Overview of detectors at SACLA and introduction of new detectors under development"

  New Variant of KamCam: 200 nm L&S resolution, 2.6 x 1.9 mm^2 field of view, 150 Mpixel
  CITIUS: new detector that may replace MPCCDs

- Mariano Trigo (SLAC National Accelerator Laboratory, USA)
  "Detectors for studies of ultrafast structural dynamics of materials"

- Yuya Shinohara (Oak Ridge National Laboratory, USA)
  "X-ray photon correlation spectroscopy / X-ray speckle visibility spectroscopy"

- Takashi Kimura (The University of Tokyo, Japan)
  "Single-shot coherent diffraction imaging of samples in mixed solution"

- Kunio Hirata (RIKEN SPring-8 Center, Japan)
  "Desired specifications of a detector for Protein crystallography (MX)"

Breakout Session A3: Detectors
Discussion summary

Parameters	CITIUS XFEL for SACLA	MPCCD Phase III/III-L
Thickness	650 μm	300 μm
Noise	<60 e-	300/60
Peak Signal	17,000	2,400
Pixel Size	72.6 μm	50 μm
Image Format	384 x 728	512 x 1024
Inter-module gap	∼3 mm	< 1 mm

Better

Worse

- CITIUS-XFEL will meet the requirements for many of the experimental techniques at SACLA.
- Spectro-imaging with ΔE ∼700 eV FWHM will be possible
- , but larger pixel size (50 μm → 72.6 μm) and wider inter-module gaps (<1 mm → ~3 mm) could be problematic for some techniques.
- Since some artifacts could be seen in the initial deployment phase (like MPCCD), need to have good communications between facility and users.

<u>**Items need to be discussed:**</u>

- Movable central aperture as of MPCCD Octal (for CDI etc.)
- Asymmetric inter-module gaps to prevent from loosing signals at specific Q
- Support on data analysis from facility (photon counting via droplet analysis, rejection of cosmic rays etc.)
- Intrinsic ΔE of Si ∼ 120 eV @ 6 keV and is better to have.
  - Technically feasible, but budget hungry. SACLA will look into it as a long-term plan.

<u>**Strategic replacement plan should be established:**</u>

- SACLA is finalizing deployment plan for FY2022-2023 by the end of April 2021.

Discussion

- Nishino-san
  - Movable Central aperture of MPCCD octal detector is useful.
  - Small gap between sensor module of MPCCD is beneficial for coherent study

  - A) we would like to hear more on the needs, and keep the detector sets available for coming years.
  - In the long term, we need to replace MPCCD to CITIUS. Please let us discuss some feasibility study on CIITUS for coherent study.

- Yamamoto-san
  - Can the gap lines be asymmetric?

  - A) we are aware of the needs. We planned to solve this issue by putting the x-ray off the center of the CITIUS 20Mpixel detector. If it does not meet the needs, we will consider asymmetric camera head.

- Prof. Trigo of SLAC
  - Higher dynamic range than MPCCD is mandatory for local k study.
  - Fluorescence rejection is required for low intensity signal detection.

  - A) For CITIUS
    - Peak signal and noise will be similar or better than Jungfrau.
    - Q.E. will be better as silicon is thicker for CITIUS.
    - Fluorescence detection will be given in the next slides.

Prof. Trigo of SLAC

Detector wish-list for hard-x-ray scattering from materials

- high dynamic range (> 10^4 photons): diffuse regions contain bright spots (near Bragg) as well as weak, broad features
- ability to discriminate and filter fluorescence from elastic: diffuse intensity can be weaker than fluorescence
- large area (diffuse) and flat pixel gain variation: diffuse intensity can extend over all reciprocal space
- small pixels (high-resolution diffraction): in many situations, the important science is in the small details of how peaks shift and distort

must be compatible with complex sample environments

- A) For CITIUS
  - Peak signal and noise will be similar or better than Jungfrau.
  - Q.E. will be better as silicon is thicker for CITIUS.
  - Fluorescence detection will be given in the next slides.
  - We would like to discuss on the sample environment compatibility with SACLA BL scientists

Spectro-imaging of CITIUS: linear scale, droplet

~700 eV FWHM

Intentionally blank because it is not yet published.
If you need data, please get in touch with hatsui@spring8.or.jp

Very preliminary results with prototype. Please not that this performance may not be achieved at the final system.

Spectro-imaging of CITIUS: logarithmic scale, droplet

～700 eV FWHM

Intentionally blank because it is not yet published.
If you need data, please get in touch with hatsui@spring8.or.jp

Very preliminary results with prototype. Please not that this performance may not be achieved at the final system.

Spectro-imaging of CITIUS: linear scale, single event

400～450 eV FWHM

Intentionally blank because it is not yet published.
If you need data, please get in touch with hatsui@spring8.or.jp

Very preliminary results with prototype. Please not that this performance may not be achieved at the final system.

Dr. Shinohara
Q.E. of CITIUS and trade-offs (1/2)

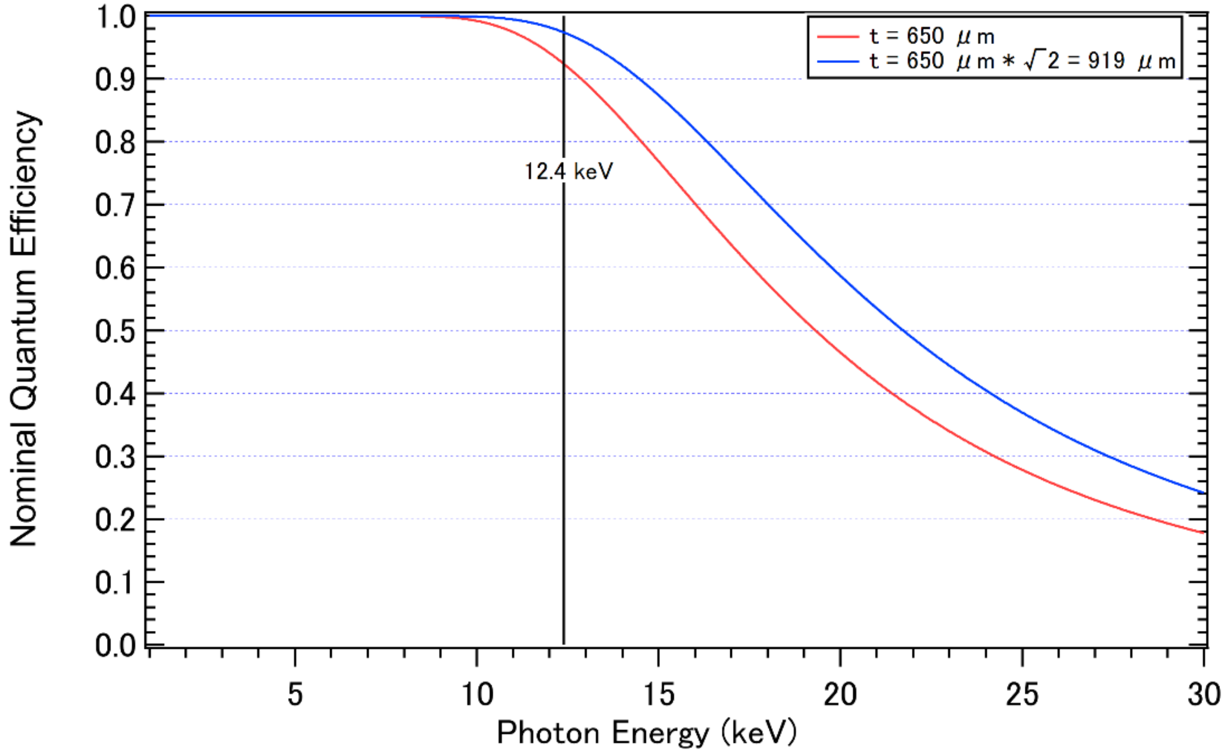

Figure 1-1 (red line) Nominal Quantum Efficiency of the CITIUS detector at normal incidence. At photon energies higher than 15 keV, Compton scattering cross section becomes non-negligible. The quantum efficiencies depend how Compton-scattered signals are analyzed. When Compton-scattered signals are rejected in the analysis procedure, the quantum efficiency becomes smaller than this plot especially > 15 keV by 10-20 %(TBC). (blue line) Nominal Quantum Efficiency of the CITIUS detector at $2\theta = 45°$. At the photon energy higher than 15 keV, parallax effect will be prominent. For details, see Figure 1-4 and text.

For CITIUS and MPCCD Phase III and III-L, Q.E. beyond 1 keV is well approximated by the thickness of silicon, where all the photons interacting Si through photo-electric effect are detected without loss.

Dr. Shinohara
Q.E. of CITIUS and trade-offs (2/2)

- Pre-sampled Point-spread function (PSF)
  - which is defined as standard deviation of the signal charge generated at the entrance region of the sensor.
  - Ratio of single event/charge shared event depends on PSF/[pixel size].

- MPCCD Phase III, III-L and CITIUS will have similar PSF/[pixel size].
  - Analysis experience of MPCCD phase III,III-L will be useful for CITIUS.

- CITIUS has larger pixel size, and fewer pixels/sensor module. We would like to know whether this will make any trouble in your experiments.
  - CITIUS sensor module has 384 x 728 pixels.
  - If you need 500 x 500 pixels with CITIUS, you need multiple sensor tiles, and we will have a gap in your region of interest.

Dr. Shinohara
XPCS at SPring-8

- CITIUS SR is under discussion for future XPCS at SPring-8.
- It will support upto 10 MHz in a dedicated double exposure scheme, and ～50 kHz in quasi continuous recording mode.
- Please give us your inputs to this area as well
  - hatsui@spring8.or.jp would be ok.

Dr. Hirata

Required specifications

Items	Requirements
Pixel size	50-80 µm (also relevant to 'area')
point-spread function	~ 1 pixel
Field of view	>= 200 mm x 200 mm with 50 µm pixel
Peak signal	**> 5 x 10^8 photons/s/mm^2**
Single photon detection	Important 10 ~ 15 keV
Quantum efficiency	As high as possible at < 15 keV
Spectral imaging	We'd like to set two 'energy threshold's.
Working circumstances	In both air / in-vacuum
Frame rate	60 Hz for SACLA/200 Hz for SPring-8

Similar requirements for both at SPring-8/SACLA

- It seems all the specifications are met with CIITUS XFEL and CITIUS SR.
- CITIUS SR has 6 x 10^8 photons/s/pixel in HDR variants

We are here for science
Please let us know your issue!