Facility Update

SACLA

Toshinori Yabuuchi
on behalf of SACLA

SACLA Users' Meeting 2023
March 2-3, 2023 (online)

Outline

- **Research activities and highlights in 2022, 10th anniversary year**
  - Current impact of COVID-19 pandemic
  - Operation hours and user experiments
  - Research highlights
- **Overall introduction of facility upgrade**
  - Accelerator, beamlines, and experimental instruments
  - “Stability improvements” and “capability expansion”
- **Future perspectives of our facility for the next phase**
  - Optimization of beamtime allocation in HX FEL beamlines
  - Improvements in XFEL beam parameters

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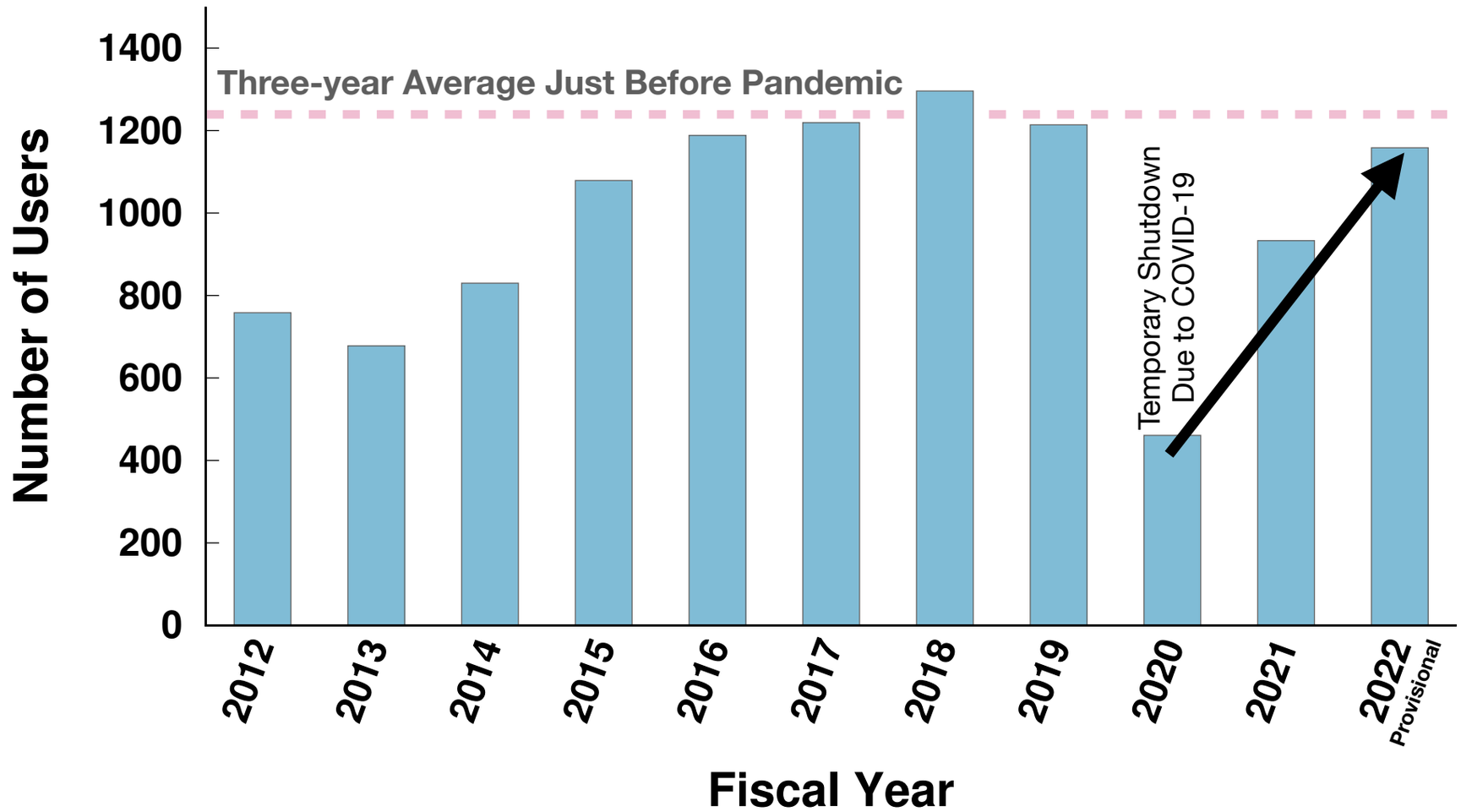
User operation is now fully recovered from COVID-19 pandemic with some advanced capabilities

- Since the COVID-19 pandemic started in 2020, it has been very hard to perform experiments on-site, particularly for international users.
- In October 2022, the government finally mitigated the regulation and resumed the visa exemption program.



*The total number of users is counted based on the number of participants in all experiments including the involvements remotely, but not including the participants in the feasibility study program and the internal beamtime.

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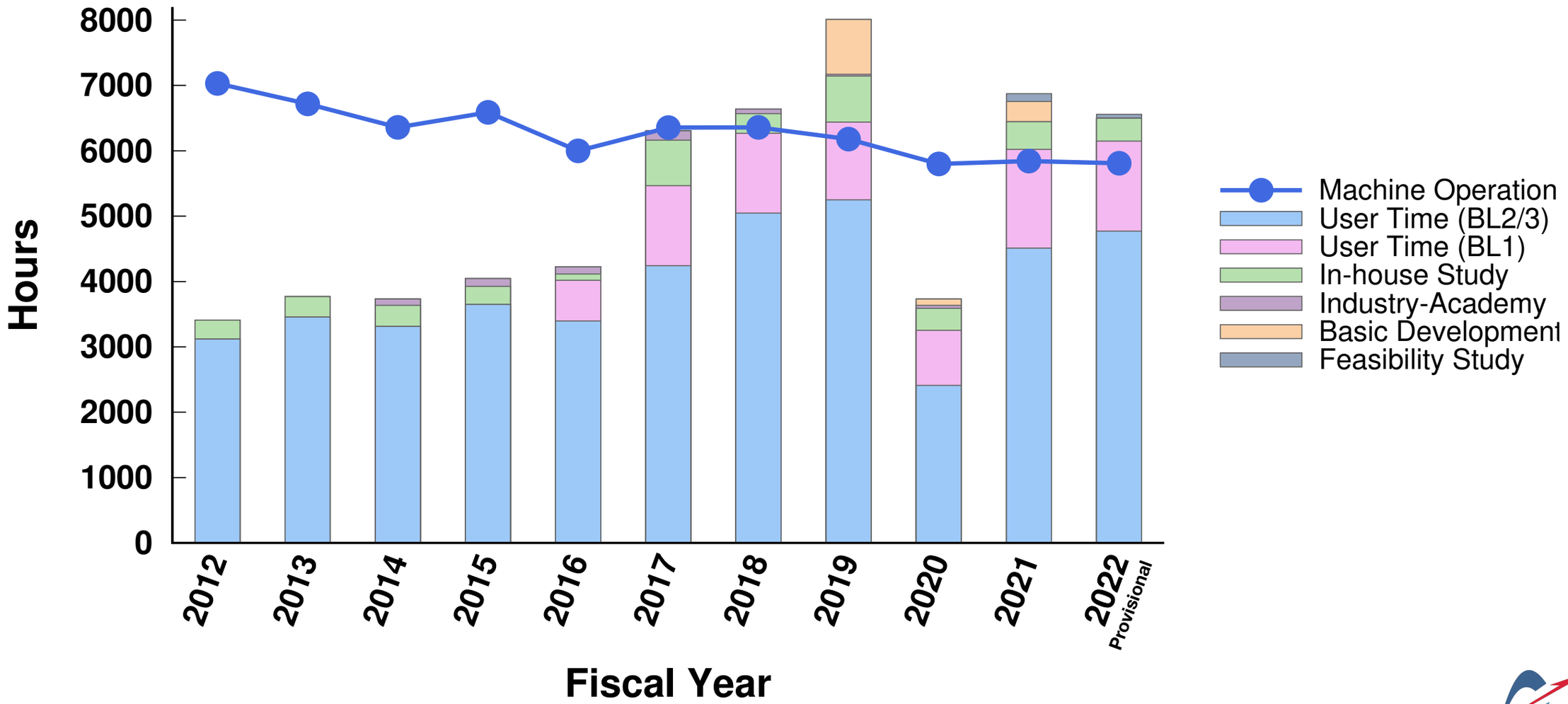
User operation is now fully recovered from COVID-19 pandemic with some advanced capabilities

- Since the COVID-19 pandemic started in 2020, it has been very hard to perform experiments on-site, particularly for international users.
- In October 2022, the government finally mitigated the regulation and resumed the visa exemption program.
- Users still benefitted from various services implemented during the pandemic.
  - Convenient data sharing serves on HPC and NextCloud
  - Improved environment to use GUIs for data analysis on the FastX server
  - Remote-experiment capabilities at some selected platforms

User beamtime in FY22 was maintained at the same level with FY21 even after significant cost increase

- A significant cost increase in electricity was about to impact the facility operation time severely in FY2022.
- The original operation schedule was fulfilled eventually by the supplementary budget.



*The statistical data includes the additional beamtime allocation in 2022B from the runner-ups.

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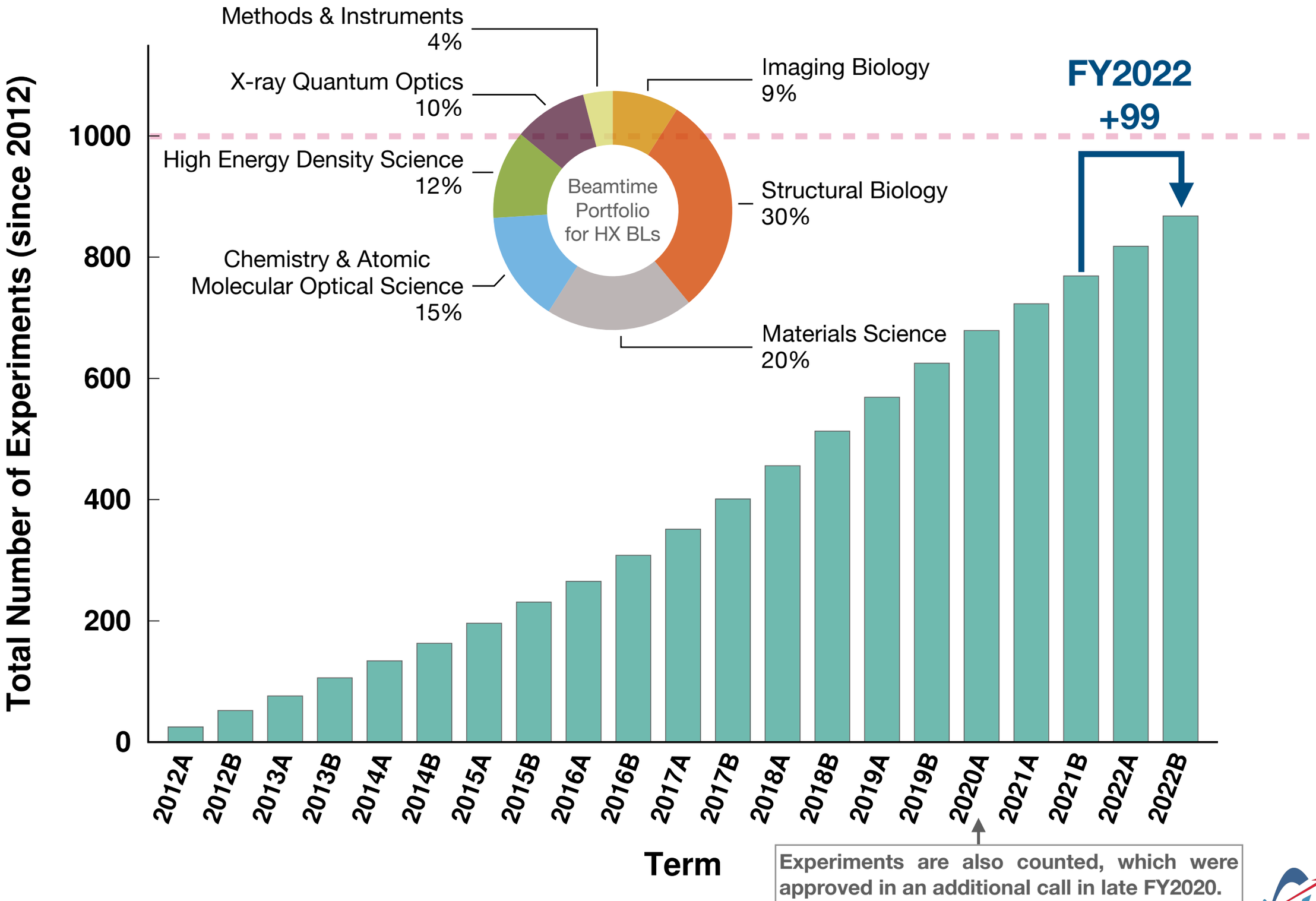
99 experiments were successfully performed in FY22



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"Feasibility Study Program" provides opportunities for users to confirm SACLA capabilities

- The Feasibility Study Program (FSP) provides opportunities to use SACLA on a trial basis to test the feasibility of new experimental designs or samples at platforms for SFX or high-power nanosecond laser.
- FSP is beneficial to learn about the facility, especially for new users.
- Half of the applicants who were selected for FSP had submitted proposals for general beamtime afterward, and >70% of them were approved.

Number of FSP†	2021A	2021B	2022A	2022B	2023A (planned)
SFX	3	3	3	0	0
HP ns Laser	6	2	0	2	2
Total	9	5	3	2	2
General proposal submission after FSP†	5	2	3	1	-
General proposal approval after FSP†	4	1	2	1	-

†Number of proposals are counted based on individual PIs.

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Research highlights from publications in 2022

nature nature chemistry

- E. A. Schriber et al., "*Chemical crystallography by serial femtosecond X-ray diffraction*", Nature, **601**, 360 (2022).
- M. Maestre-Reyna et al., "*Serial crystallography captures dynamic control of sequential electron and proton transfer events in a flavoenzyme*", Nat. Chem., **14**, 677 (2022).
- X. Liu et al, "*Excited-state intermediates in a designer protein encoding a phototrigger caught by an X-ray free-electron laser*", Nat. Chem., **14**, 1054 (2022).

Science Advances

- H. Jang et al., "*Characterization of photoinduced normal state through charge density wave in superconducting $YBa_2Cu_3O_{6.67}$*", Sci. Adv., **8**, eabk0832 (2022).
- Z. He et al., "*Diamond Formation Kinetics in Shock-compressed C-H-O Samples Recorded by Small-angle X-ray Scattering and X-ray Diffraction*", Sci. Adv., **8**, eabo0617 (2022).

PNAS

- T. Hosaka et al., "*Conformational alterations in unidirectional ion transport of a light-driven chloride pump revealed using X-ray free electron lasers*", Proc. Natl. Acad. Sci. USA, **119**, e2117433119 (2022).
- Y. Zhang et al, "*Generation of intense phase-stable femtosecond hard X-ray pulse pairs*", Proc. Natl. Acad. Sci. USA, **119**, e219616119 (2022).

PHYSICAL REVIEW LETTERS

- I. Inoue et al., "*Delayed onset and directionality of X-ray-induced atomic displacements observed on subatomic length scales*", Phys. Rev. Lett., **128**, 223203 (2022).

PHYSICAL REVIEW RESEARCH

- L. Randolph et al., "*Nanoscale subsurface dynamics of solids upon high-intensity femtosecond laser irradiation observed by grazing-incidence X-ray scattering*", Phys. Rev. Research, **4**, 033038 (2022).
- T. Osaka et al., "*Hard X-ray intensity autocorrelation using direct two-photon absorption*", Phys. Rev. Research, **4**, L012035 (2022).

Related topics and research details (blue) will be presented in the scientific talks.

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Research highlights from publications in 2022

Industrial Applications

NANO LETTERS

Femtosecond X-ray Laser Reveals Intact Sea–Island Structures of Metastable Solid-State Electrolytes for Batteries

A. Suzuki, Y. Nishino + Toyota Motor Corp. et al.,
Nano Lett., **22**, 4603 (2022)

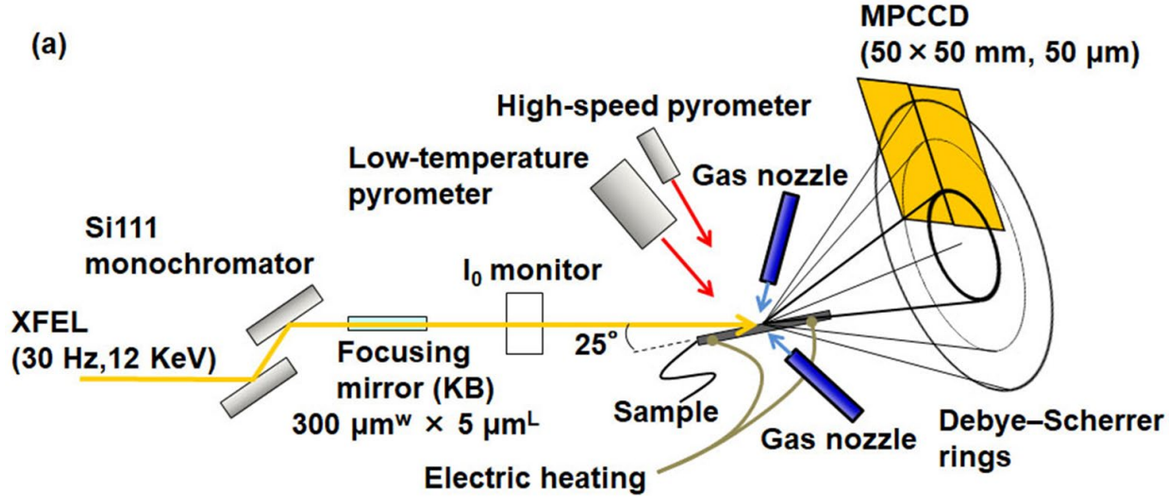
Figures are removed

https://doi.org/10.1021/acs.nanolett.1c04392

scientific reports

Fine microstructure formation in steel under ultrafast heating and cooling

M. Yonemura (Nippon Steel Corp.) et al.,
Sci. Rep., **12**, 2237 (2022)



https://doi.org/10.1038/s41598-022-06280-x

The contribution of SACLA to Sustainable Development Goals (SDGs) will be discussed more in the special session tomorrow (in Japanese).

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Prompt developments have been achieved by significant user contributions through "Basic Development Program"

- The Basic Development Program (BDP) has supported the development of state-of-the-art instruments at SACLA since FY2018.
- BDP now also targets SPring-8.

Seven projects awarded for SACLA BDP 2022

B. Albertazzi (LULI) "*Study of magnetized solids/plasmas in the near and above high energy density regime*"

S. Iwata (Kyoto U.) "*Measurement systems for biomolecular movies using X-ray free electron lasers*"

T. Arima (U. Tokyo) "*Development of a wide-dynamic-range and high-frame-rate CMOS image sensor for soft X-ray III*"

K. Yamauchi (Osaka U.) "*Precise wavefront control of focused hard X-ray FEL at SACLA*"

T. Kimura (U. Tokyo) "*Development of soft X-ray focusing and imaging systems using precise rotational mirrors*"

A. Ikeda (UEC) "*X-ray experiment in pulsed ultrahigh magnetic field beyond 100 T with a portable single turn coil system 'PINK'*"

H. Iwayama (NINS) "*Development of a time-resolved soft X-ray absorption, reflection and fluorescence spectroscopy station for liquid samples*"

Project summaries will be presented in this afternoon.

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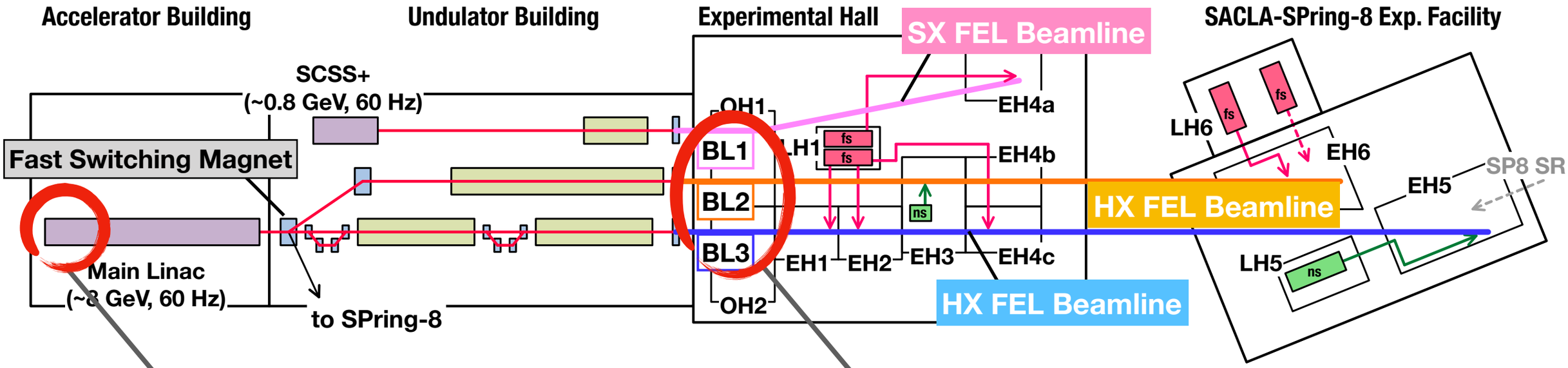
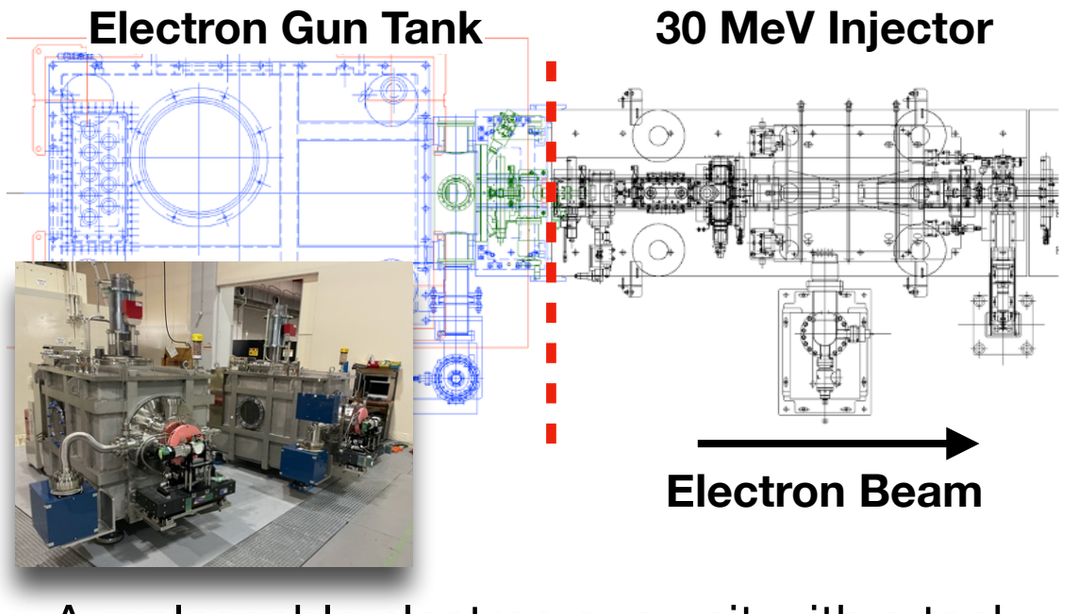
Improvements for stable XFEL operation



Quick Exchange System of Electron Gun



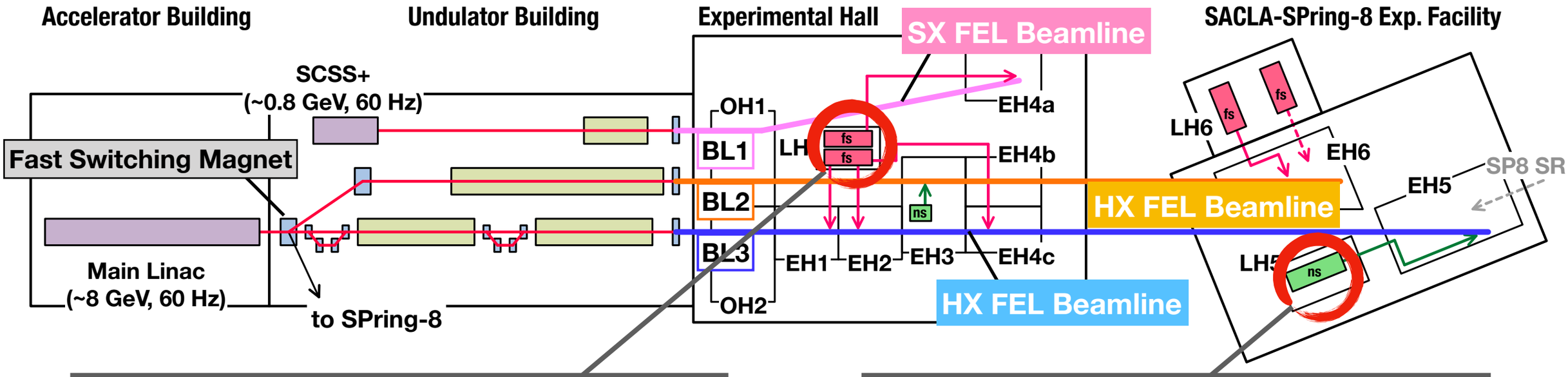
A replaceable electron gun unit with a tank for insulator oil was installed to minimize downtime of the facility (SP8 and SACLA).

Autotuning System for HX and SX Beamlines

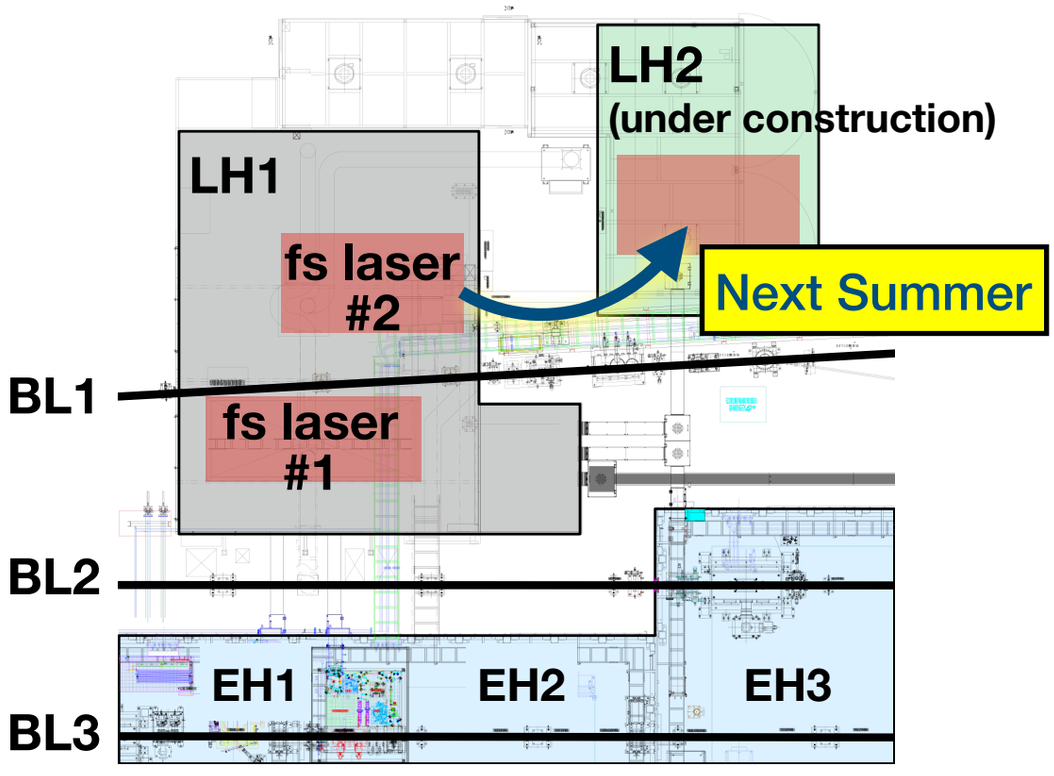
- **Tuning of SACLA Accelerator**
  - Major parameters of HX FELs have been optimized by utilizing an auto-tuning system based on machine learning.
- **Tuning of Beamline Optics**
  - An automatic tuning system for beamline optics has been used in HX beamlines and is now transferred to the SX beamline.

Technical Updates by T. Osaka

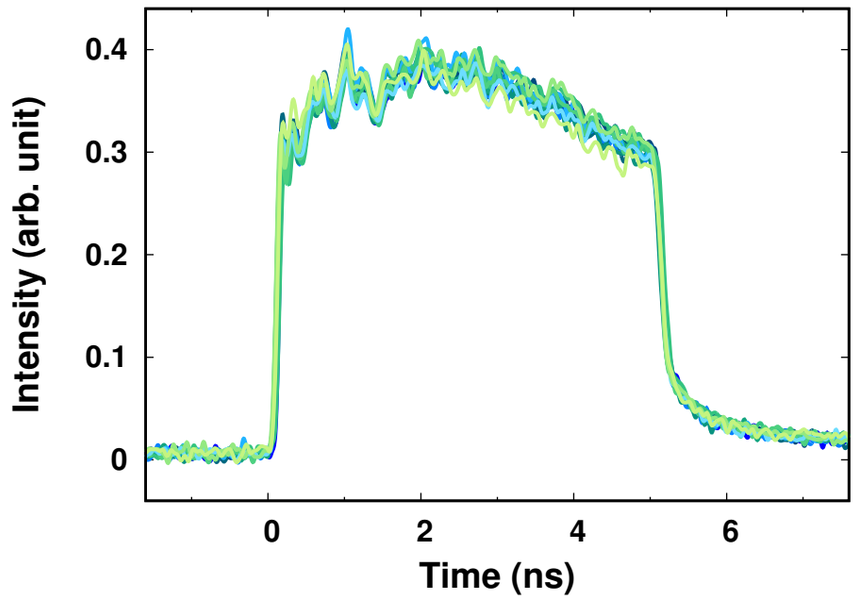
Work to improve stability of optical laser operations



Individual Booth for Synchronized Lasers



High-power Nanosecond Laser System



The laser system is under upgrade to reduce shot-to-shot fluctuations in pulse shape and energy.

Technical Updates by T. Togashi and K. Miyanishi

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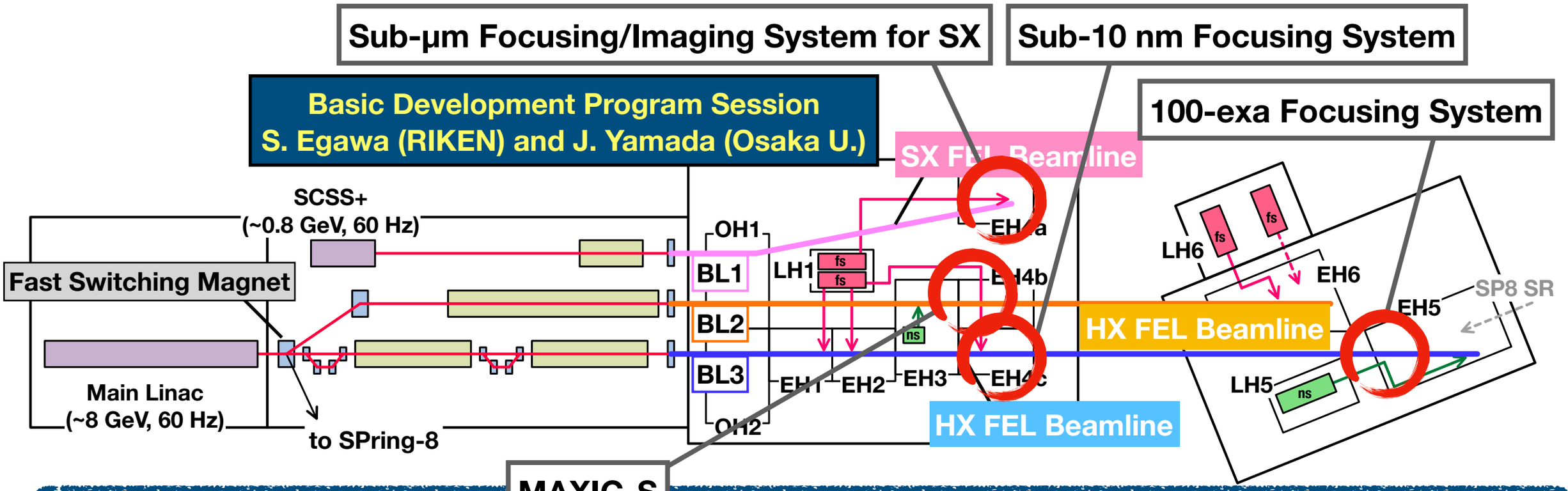
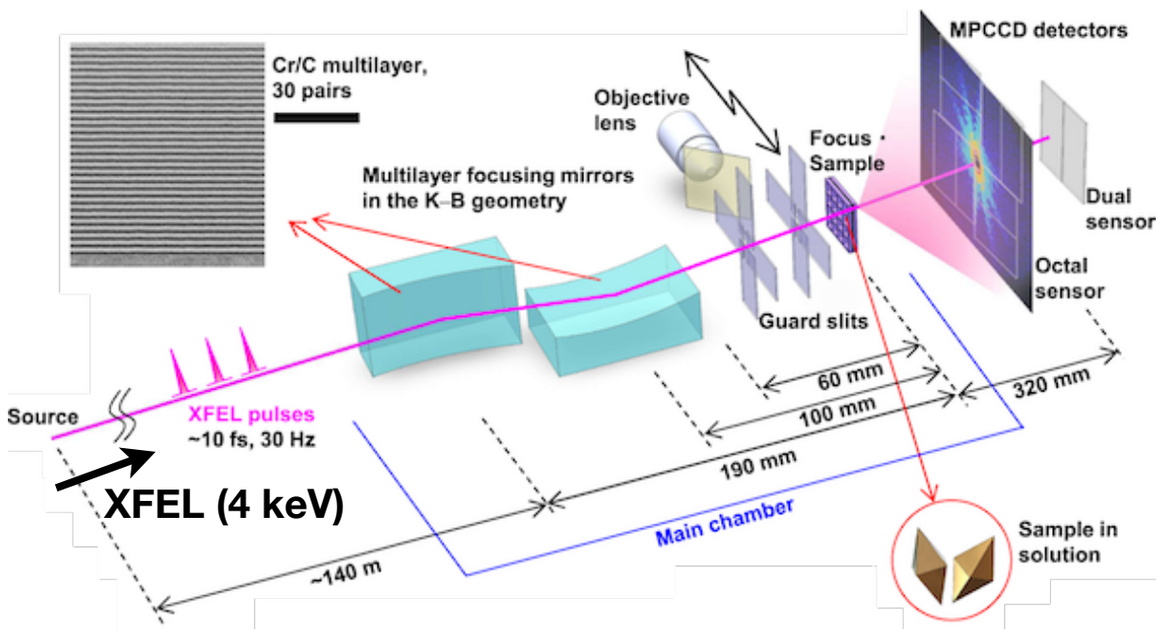
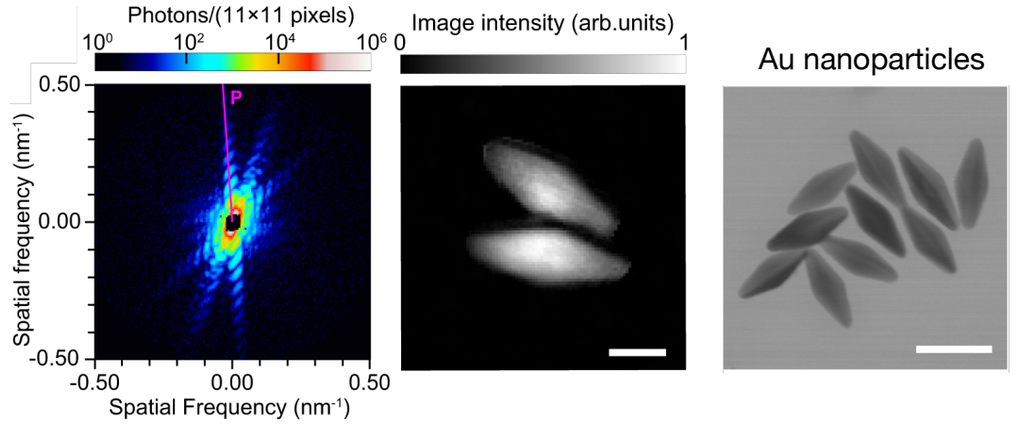
Nano-scale focusing capabilities for HX and SX FELs







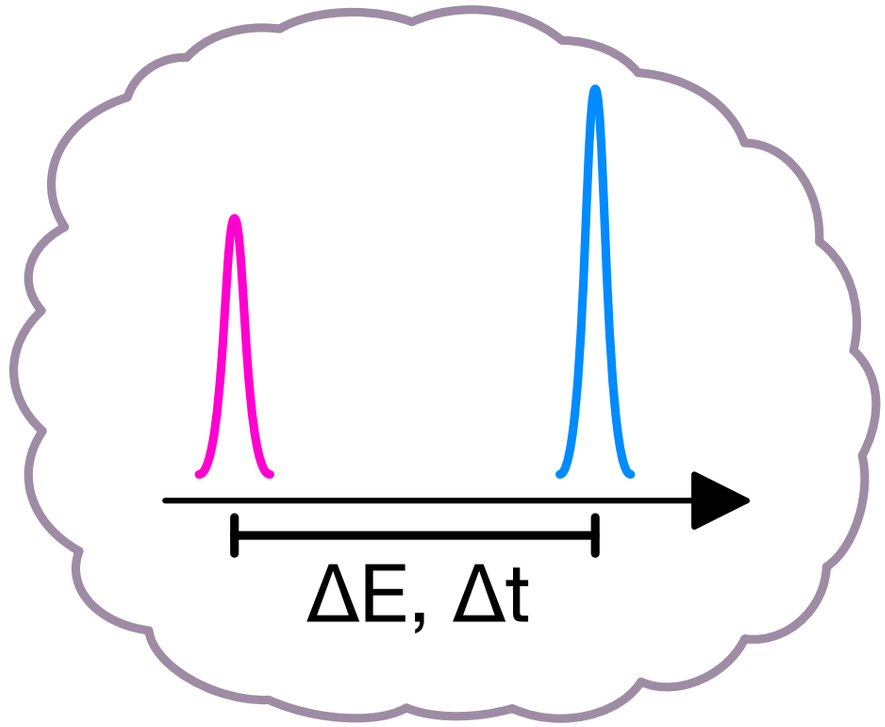
MAXIC-S: Experimental platform for coherent diffractive imaging (CDI) with the best achieved spatial resolution of ~2 nm using a ~100 nm focusing beam.

H. Yumoto et al., Nat. Commun. **13**, 5300 (2022).

Prior confirmation is required to submit proposals using advanced instruments or operation schemes

List Copied from Call for Proposals 2023A

- **Advanced XFEL operation at BL3**
  - Two-color XFEL
  - Reflection self-seeding system
  - Split-and-delay optics (SDO)
  - Sub-10 nm focusing system
- **Unique capabilities of optical pump**
  - Broadband THz pulses
  - High-power optical laser platforms (fs/ns)
- **Relatively new experimental platforms**
  - Nano-beam CDI system (MAXIC-S) at BL2
  - Opto-spintronics platform at BL1



Two-color XFEL??

➧ **Please check the list when the proposal call is published online. If you plan to use one of them, please contact BL staff well in advance.**

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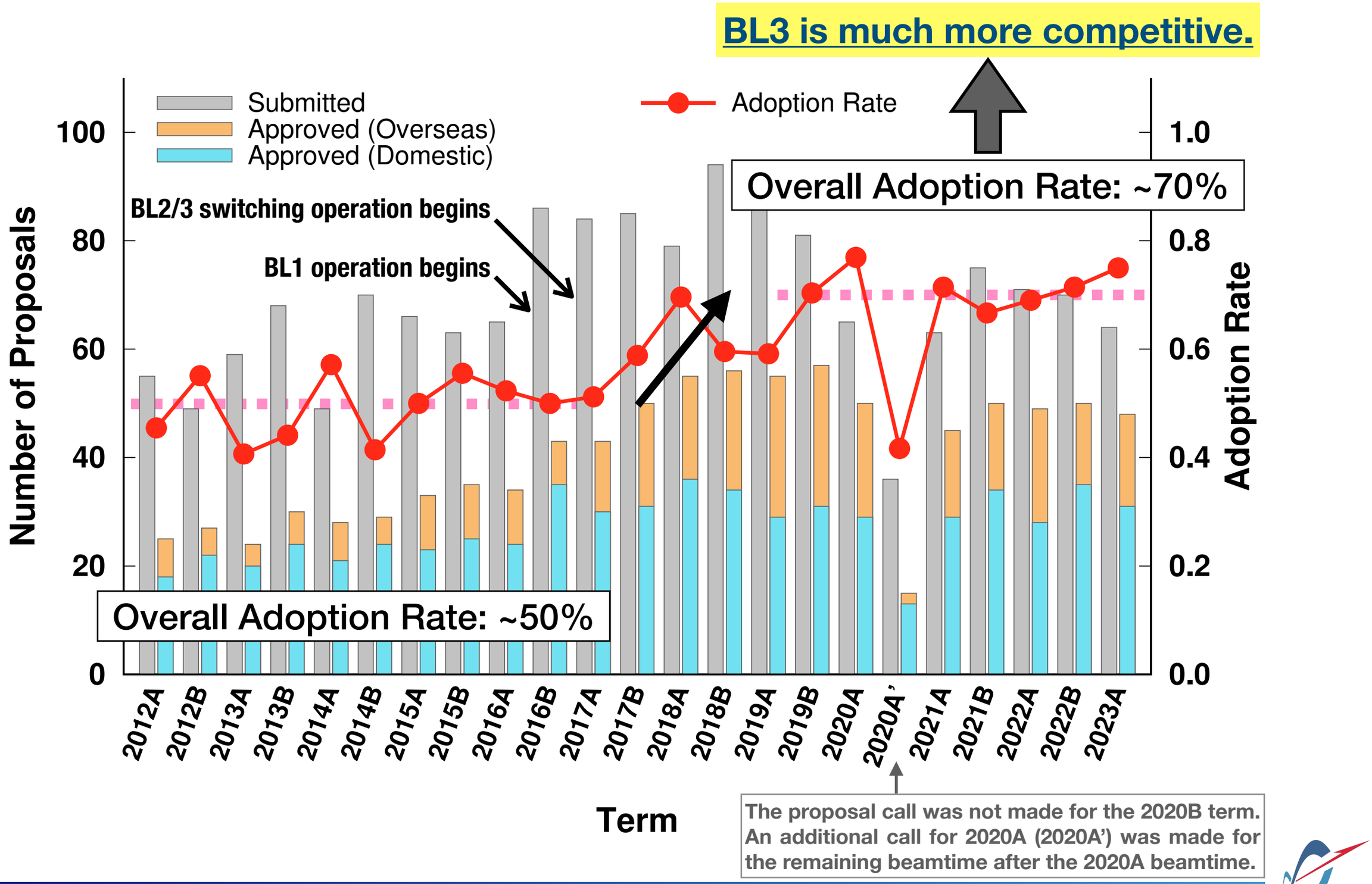
Beamtime allocation is not "too much" competitive, but we like to make some extra slots for HX users



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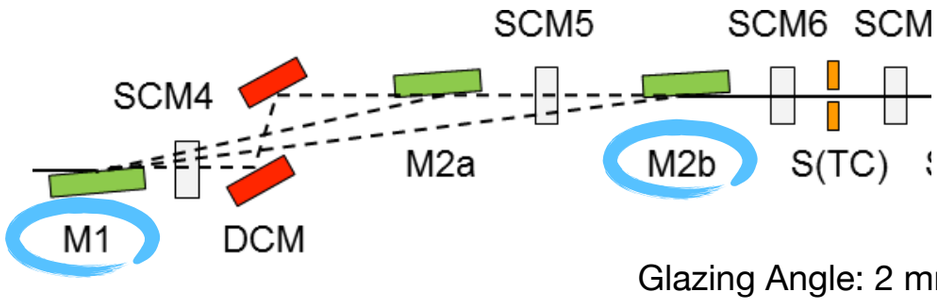
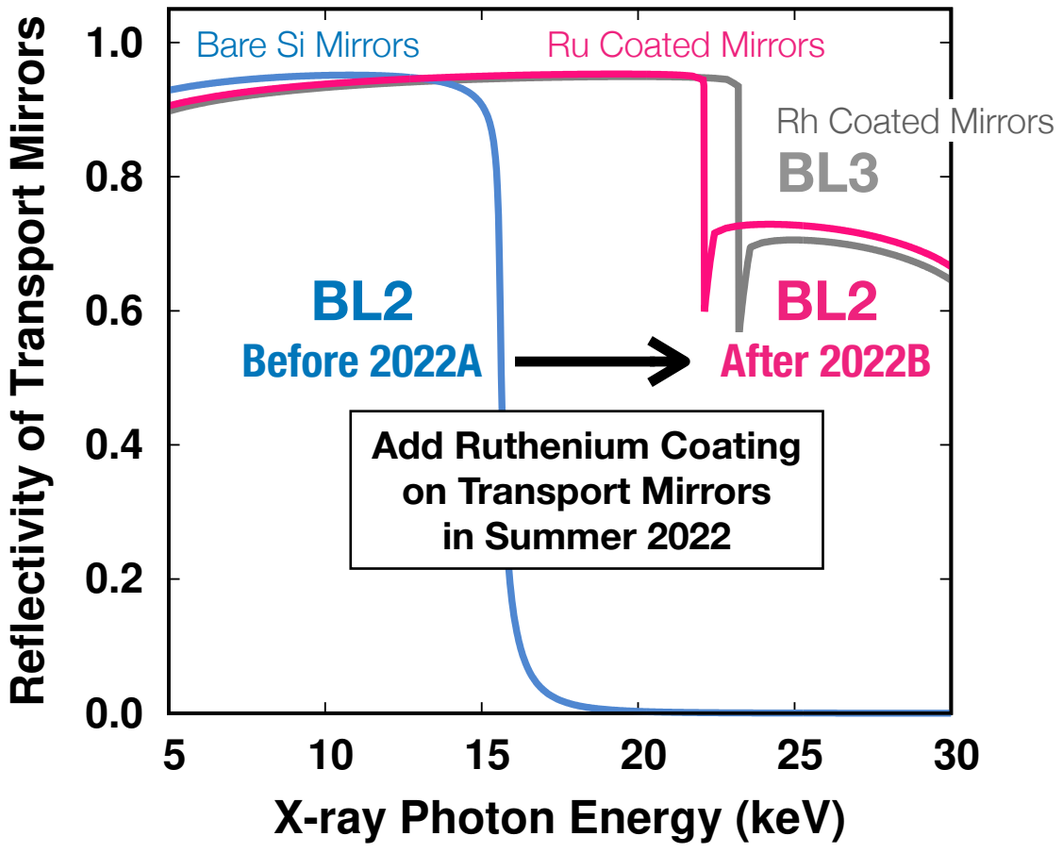
More user experiments are expected to be carried out by implementing new capabilities to BL2

Higher Photon Energies

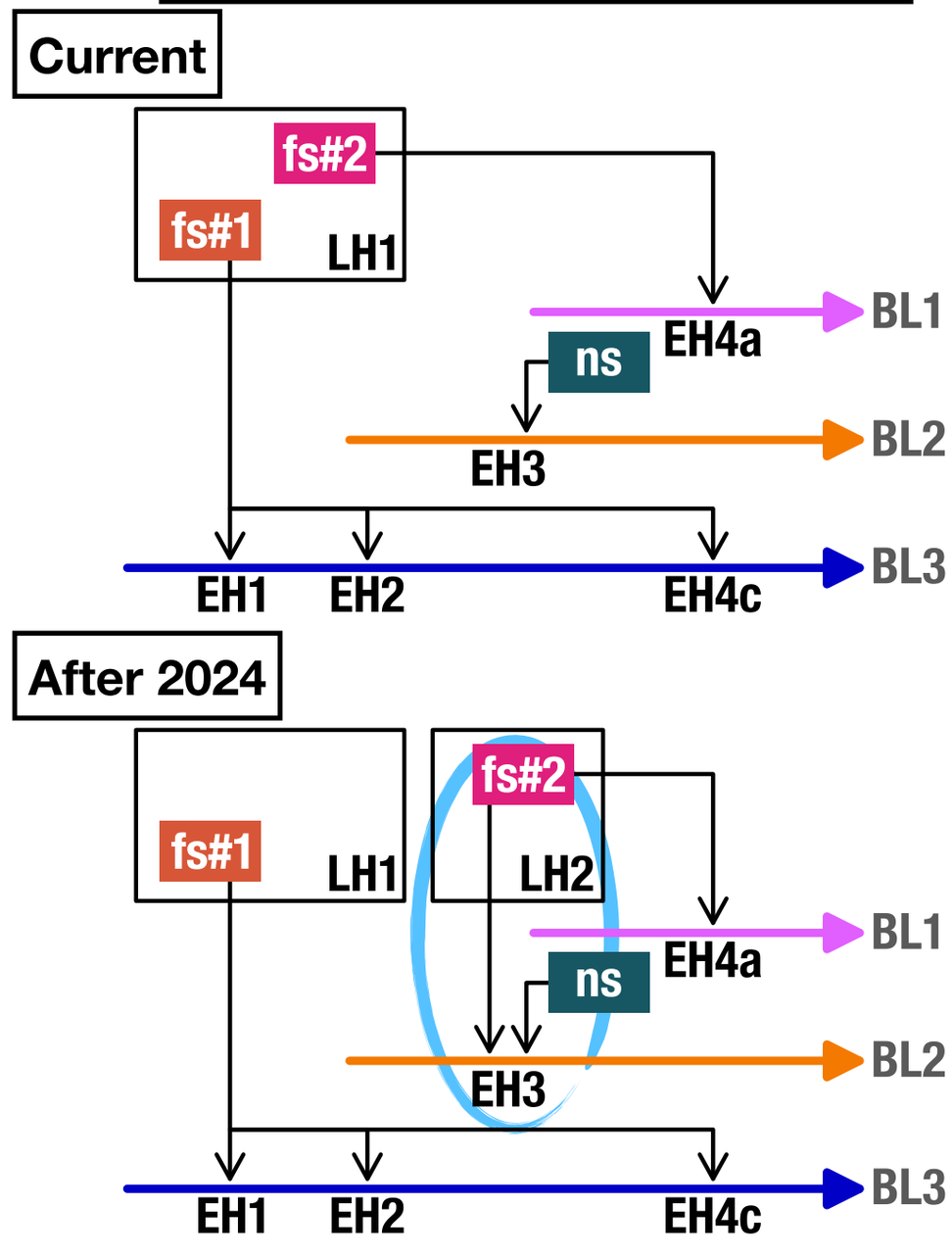
Transport Mirrors for BL2 in OH



Glazing Angle: 2 mrad

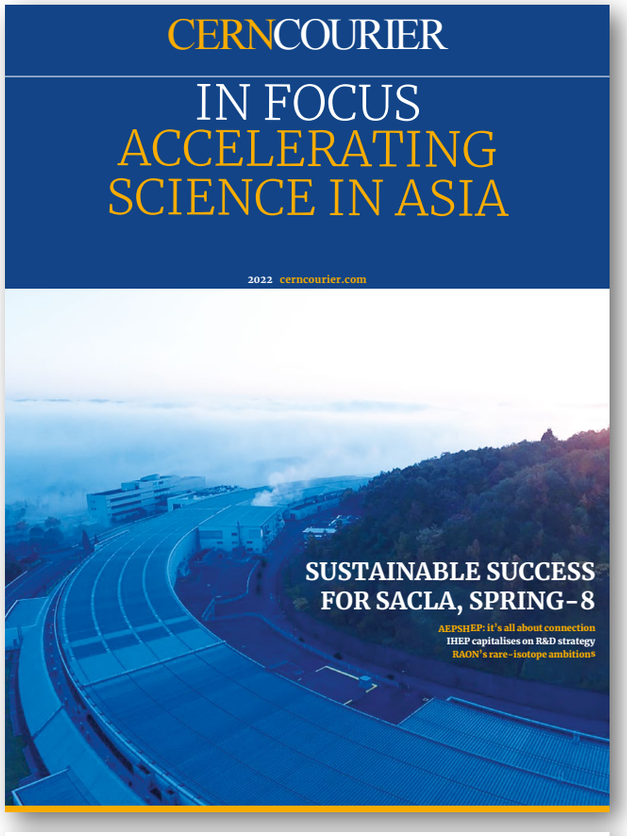


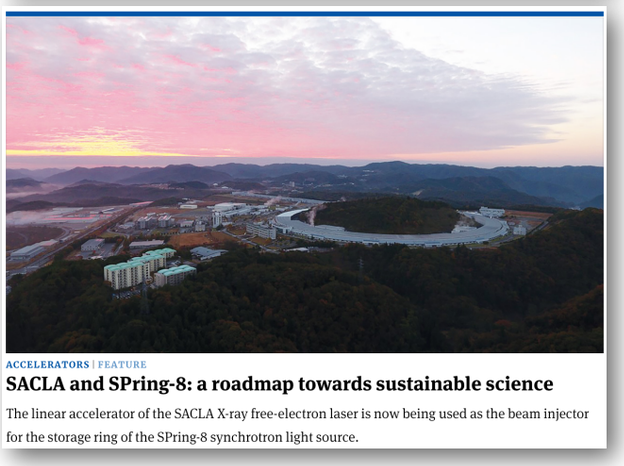
Femotosecond Pump Laser



Technical Updates by T. Osaka and T. Togashi

Future facility upgrade is not just to improve research capabilities but also should meet public sustainability





CERN Courier In Focus
Accelerating Science in Asia
2022

2021

SACLA has fully started electron beam injection to SPring-8.

- The dedicated injector for SPring-8 (linac and synchrotron) was shut down in early 2021.
- Electricity consumption to support SPring-8 operation is reduced by ~20%.
- Moreover, the beam quality is remarkably enhanced, which will be a key to generate a brighter light source, SPring-8-II.

2030s

Repetition rates of SACLA XFEL will be increased to >1 kHz with an advanced system of normal conducting accelerator.

- The repetition rate is increased by 20x while maintaining the electricity consumption no higher than the current level.
- Key technologies to realize the accelerator with targeted specs will be studied.

https://cerncourier.com/p/in-focus/accelerating-science-in-asia/

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Facility updates in 2022, 10th anniversary year

- CY2022 was the 10th anniversary year of user operation at SACLA after the first user operation started on March 7th, 2012.
- We have almost recovered from the COVID-19 pandemic. The experiment procedure has finally got back to normal.
- Significant developments have been continuously made both in the operation scheme of the facility and in the experimental instruments at the beamlines in the last few years.
- We have started developments and discussions for the next phase.
  - Optimization of beamtime allocation in HX FEL beamlines
  - Improvements in XFEL beam parameters

Thank you for your participation.
Enjoy the meeting!

Toshinori Yabuuchi

SACLA