Facility Update

Toshinori Yabuuchi
on behalf of SACLA

SACLA Users' Meeting 2025
March 3-4, 2025@SACLA

Outline

- Highlights of activities after the last users' meeting
  - Machine operation status and proposal applications
  - Recent research activities

- Platform developments: current status and prospects
  - SACLA Basic Development Program
  - Developments at beamline and accelerator

- Recent measures to attract potential users

- Summary

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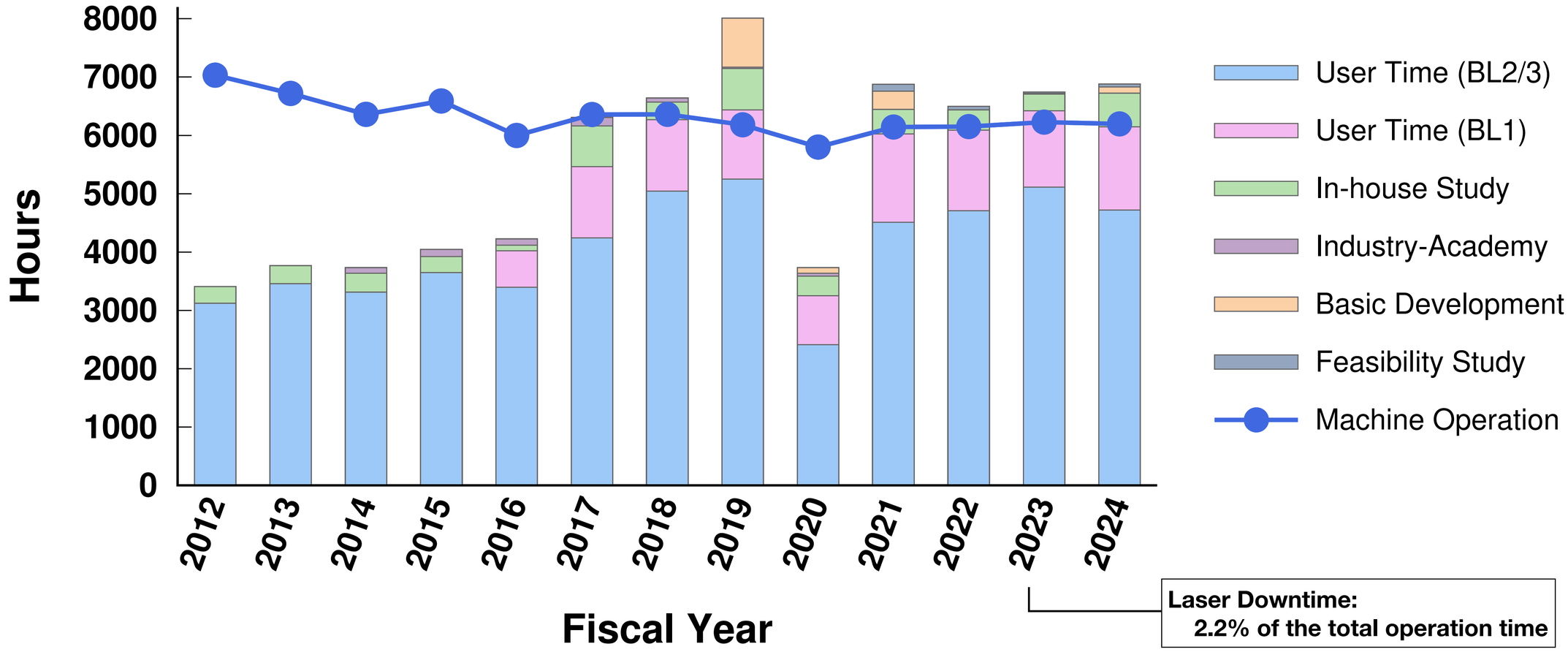
The machine has been operated throughout this year for more than 6,000 hours as scheduled



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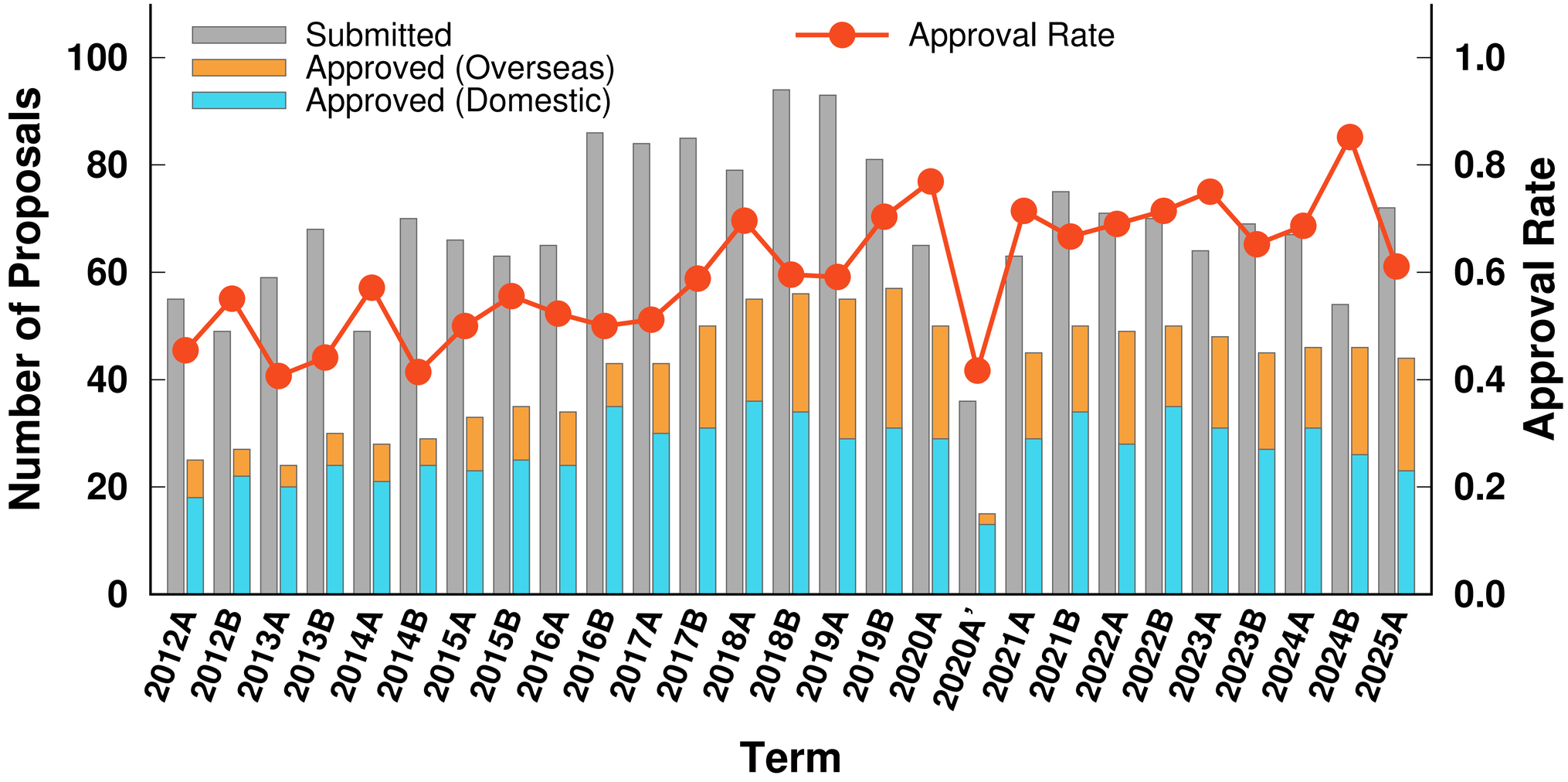
40-50 proposals were approved to conduct experiments each term



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Publications in the last 12 months

nature photonics nature physics nature materials

- J. Yamada et al., *Extreme focusing of hard X-ray free-electron laser pulses enables 7 nm focus width and 10^{22} W cm^{-2} intensity*, Nat. Photon. **18**, 685 (2024).
- A. Verma et al., *Picosecond volume expansion drives a later-time insulator–metal transition in a nano-textured Mott insulator*, Nat. Phys. **20**, 807 (2024).
- A. S. Johnson et al., *All-optical seeding of a light-induced phase transition with correlated disorder*, Nat. Phys. **20**, 970 (2024).
- V.A. Stoica et al., *Non-equilibrium pathways to emergent polar supertextures*, Nat. Mater. **23**, 1394 (2024).

nature communications

- K. Barlow et al., *Tracking nuclear motion in single-molecule magnets using femtosecond X-ray absorption spectroscopy*, Nat Commun **15**, 4043 (2024).
- B. Maity et al., *Real-time observation of a metal complex-driven reaction intermediate using a porous protein crystal and serial femtosecond crystallography,* Nat Commun **15**, 5518 (2024).
- H. Sawada et al., *Spatiotemporal dynamics of fast electron heating in solid-density matter via XFEL*, Nat Commun **15**, 7528 (2024).
- Q. Bertrand et al., *Structural effects of high laser power densities on an early bacteriorhodopsin photocycle intermediate*, Nat Commun **15**, 10278 (2024).
- S. Berkowicz et al., *Supercritical density fluctuations and structural heterogeneity in supercooled water-glycerol microdroplets*, Nat Commun **15**, 10610 (2024).

PHYSICAL REVIEW X

- Y. Huang et al., *Nanometer-Scale Acoustic Wave Packets Generated by Stochastic Core-Level Photoionization Events*, Phys. Rev. X **14**, 041010 (2024).

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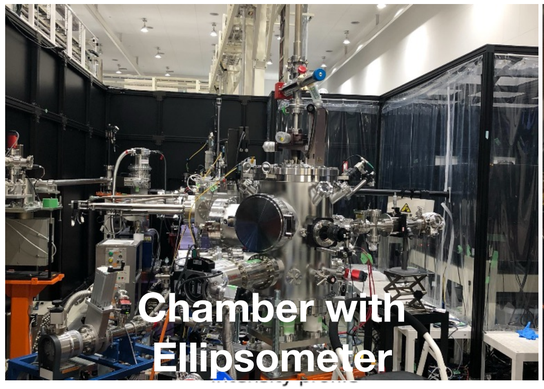
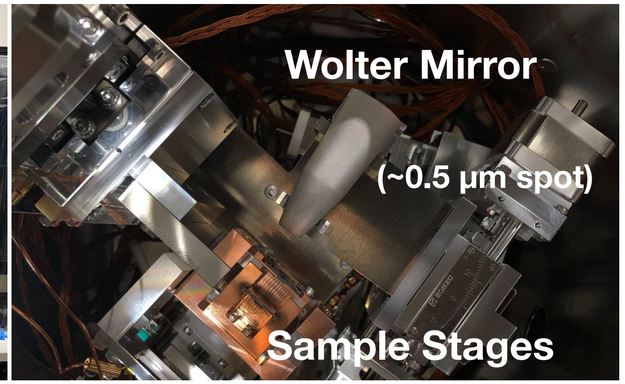
Platforms and instruments implemented through the Basic Development Program provide unique capabilities at SACLA

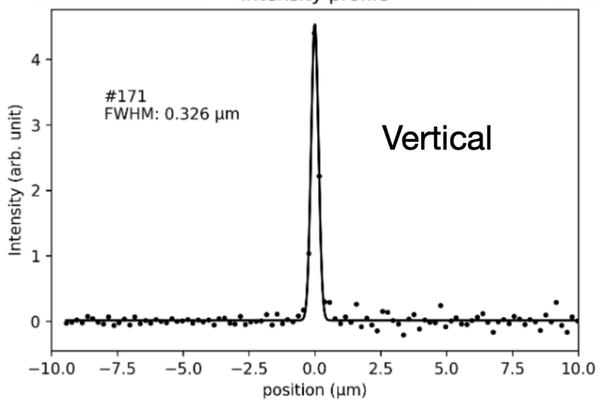
Opto-Spintronics Platform@BL1

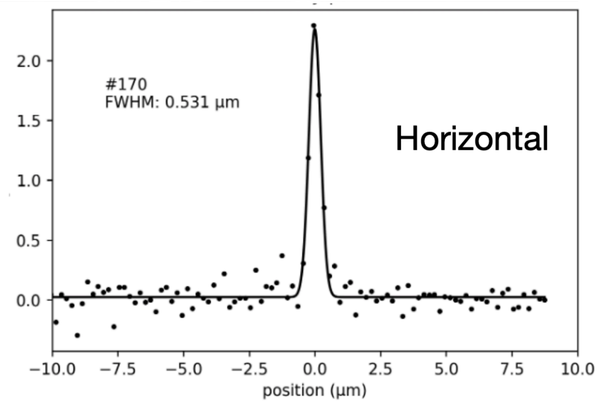
Profs. I. Matsuda and H. Mimura (Tokyo Univ.)

The platform is widely used for multiple purposes in most experiments of materials science at BL1





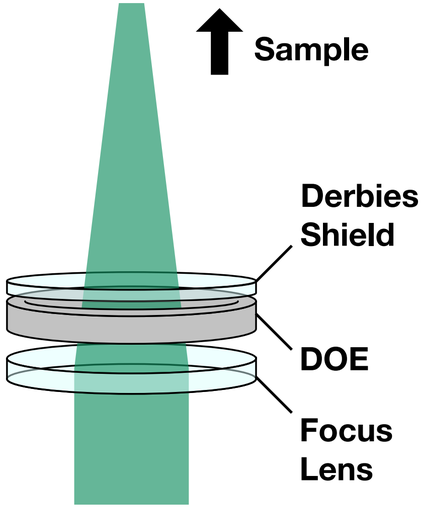


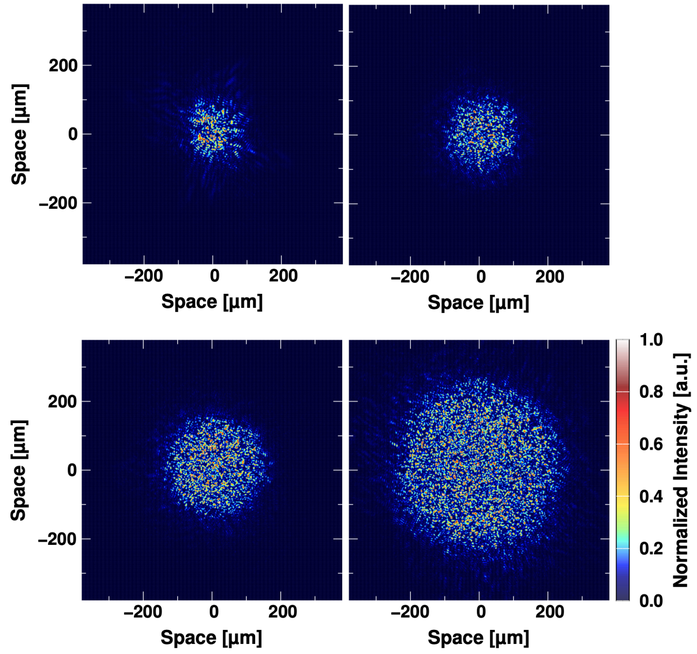


Smooth Profile of High-power NS Laser@BL3

Prof. N. Ozaki (Osaka Univ.)

Optical systems making smoothed beam profiles are used in almost all experiments at the platform.





Ongoing projects supported under Basic Development Programs are also expected to enhance the potential of research capabilities

- **Portable single turn coil system for pulsed magnetic field beyond 100 T**
  PI: Akihiko Ikeda, The University of Electro-Communications
- **Structure analysis and chemical reaction tracking system**
  PI: Daisuke Kosumi, Kumamoto University (→ Reported by Keisuke Kawakami, RIKEN)
- **Measurement systems for biomolecular movies**
  PI: So Iwata, Kyoto University (→ Reported by Eriko Nango, Tohoku University)
- **Systems for structural dynamics studies with CITIUS**
  PI: Bo B. Iversen, Aarhus University
- **Mini-coil system for magnetized solids/plasmas studies with high-power ns laser**
  PI: Bruno Albertazzi, LULI — CNRS — Ecole Polytechnique

Progress of the projects will be reported in the next session.

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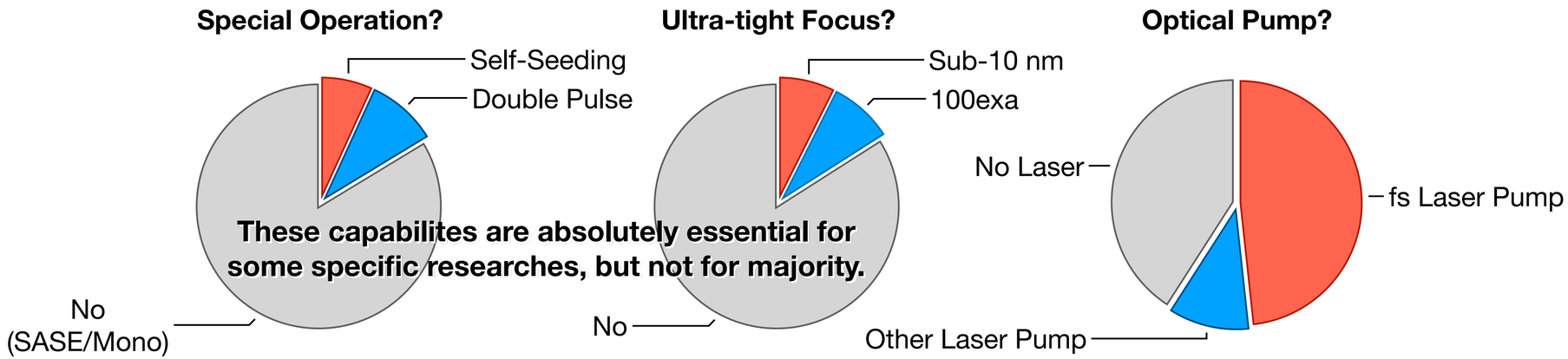
The expansion of ultra-fast pump capabilities with fs-laser is our major topic to be implemented in the near term

Presented in Users' Meeting 2024

Underlying reasons why users tend to submit proposals to BL3

Potential reasons (Major capabilities available at BL3 but not BL2)

1. Special operation modes of XFEL (i.e. self-seeding, two-color&double-pulse, etc)
2. Capabilities of ultra-tight focusing (i.e. sub-10 nm focus, 100exa system)
3. Ultra-fast pump capabilities using femtosecond optical laser



Shown breakdown is based on the approved proposals for BL3 in FY2022 and FY2023.

➡ **Ultra-fast pump capabilities with fs-laser to be implemented to EH3 BL2.**

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Femtosecond laser operation has started at EH3 in 2024A

FY2023 (Apr. 2023 – Apr. 2024) | FY2024 (Apr. 2024 – Apr. 2025) | FY2025 (Apr. 2025 – Apr. 2026) | FY2026

Preparation

Construction of New Laser Hutch (LH2)

Relocated #2 fs Laser to LH2 and Started Operation for EH4a at BL1

Today

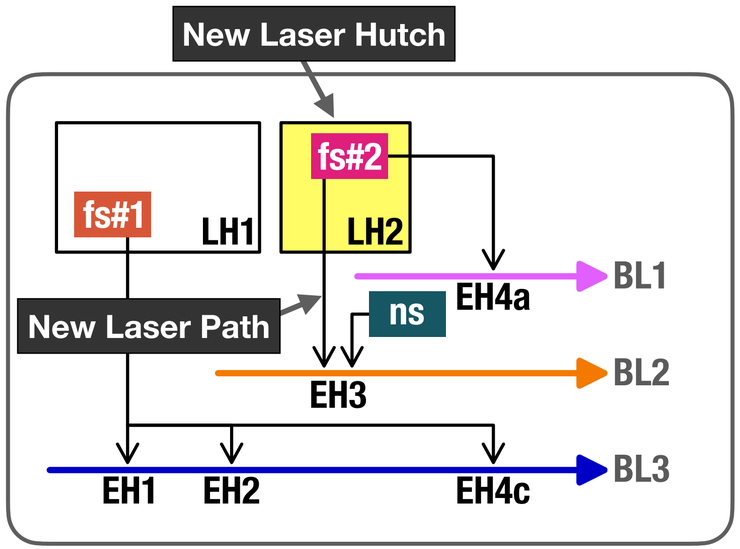
Phase I

Started #2 fs Laser Operation for User Experiments for EH3 at BL2 (June 2024)

User Operation without Timing Monitor (Temporal Resolution: ~1 ps)

Phase II

User Operation with Timing Monitor (Temporal Resolution: Sub-ps)



7 user experiments (38 shifts) have been conducted with the fs laser

Installation and Start Commissioning of Timing Monitor System

The timing monitor will be available for user experiments after its commissioning.

The time synchronizations (i.e. jitter) of #2 fs laser will be improved from **~300 fs** rms to **~50 fs** rms level by the end of FY2025.

*Synchronization system used in #1fs laser system, BOM-PD, will be applied for #2fs.

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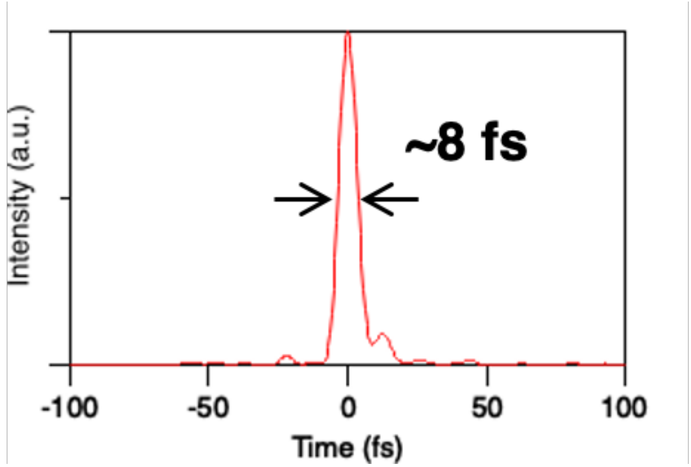
Fast pump capabilities with fs-laser pulses have also been extended at other beamlines

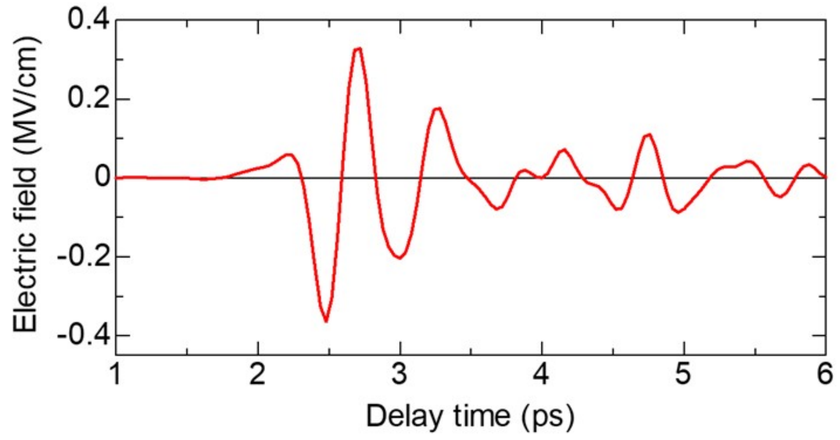
Shorter Pulse

- Few-cycle near-infrared pulses are available for use at EH2 (BL3) and EH4a (BL1).
- The spectra is broadened with Ar-filled hollow-core fibers.
- The typical pulse duration is ~8 fs, which is ~3-4 cycles of the NIR light.



THz Wave

- Intense THz pulses generated from an organic crystal with 1.5 μm OPA pulses.
- The characteristics of THz pulses have been confirmed recently.
- The electric field was ~0.4 MV/cm at the focus.



Details will be discussed in breakout session 2B

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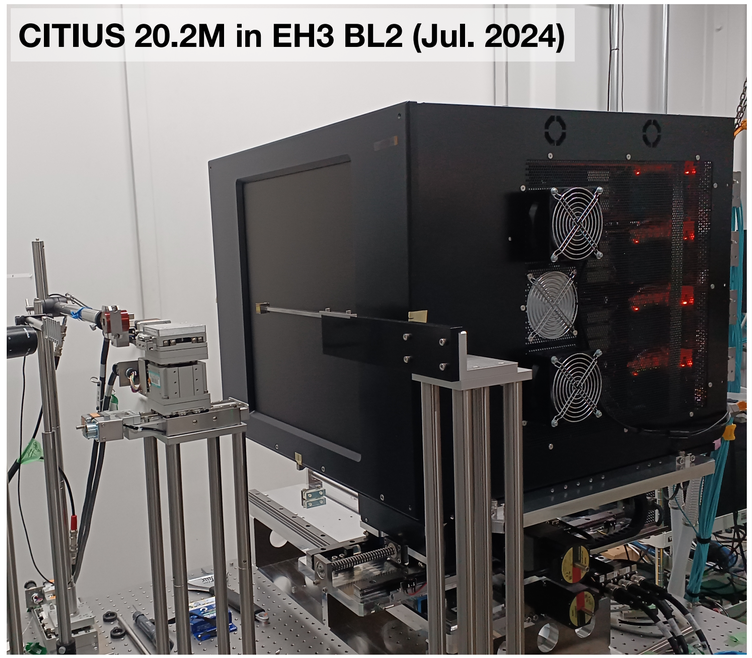
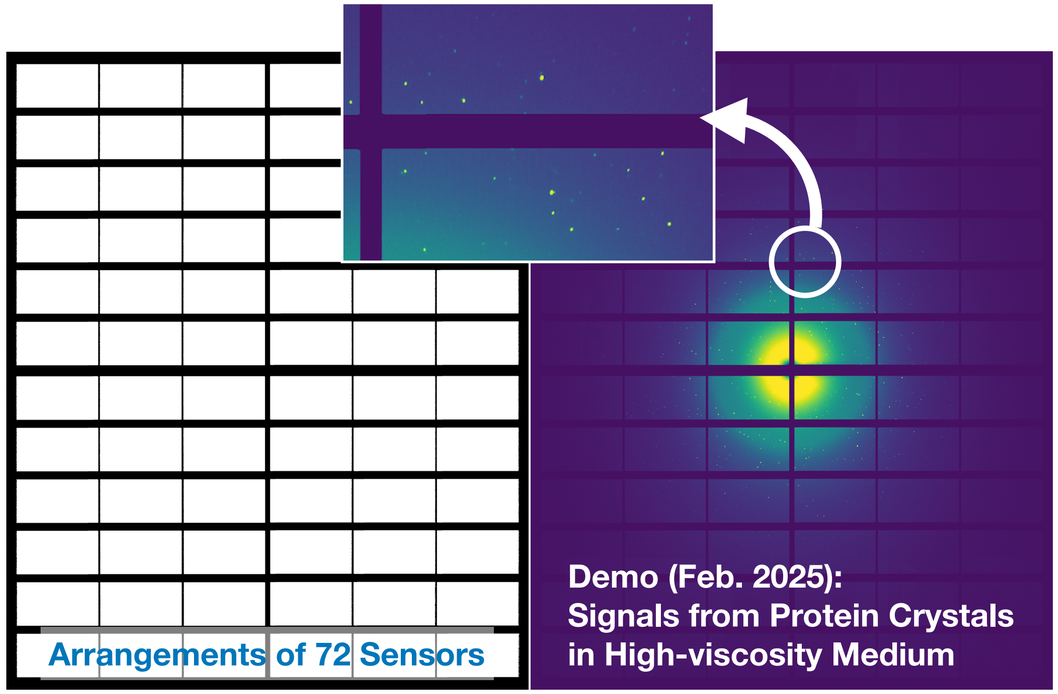
CITIUS 20.2M, our new imaging detector with an area of ~30 cm squared, has recorded the first signals from XFELs

- The commissioning of CITIUS20.2M started in July 2024 with XFELs in EH3 at BL2.
- In FY2024, significant progresses were made in the integration to SACLA's DAQ system and the procedures of detector alignment.
- The commissioning will be continued in developments, for example, of data processing (calibration, data compression, etc) and pipelines for typical applications.

Sensor	Sensor Material	Silicon
	Thickness	650 μm
	Pixel Size	72.6 μm
	Pixel Number	0.28 Mpix (Sensor Module ea.)
	Peak Signal	17,000 phs/pix (6 keV)
	Typical Noise	25 e- rms
	Frame Rate	60 Hz
	Data Rate	1.6 GB/s (Digital Out)
System	Imaging Area	321 x 393 mm^2
	Pixel Number	20.2 Mpix
	Data Rate	107 GB/s (Digital Out)



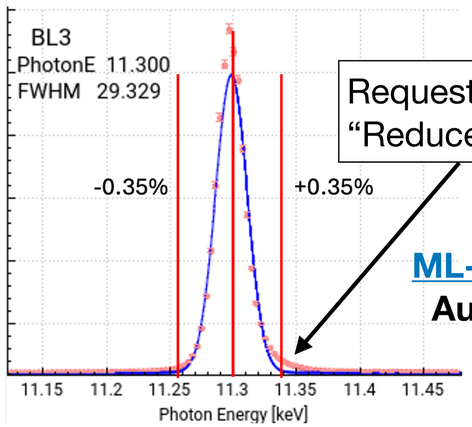


→Poster by Nishino-san

Developments of key systems has been started for future upgrades of SACLA

Recent Updates

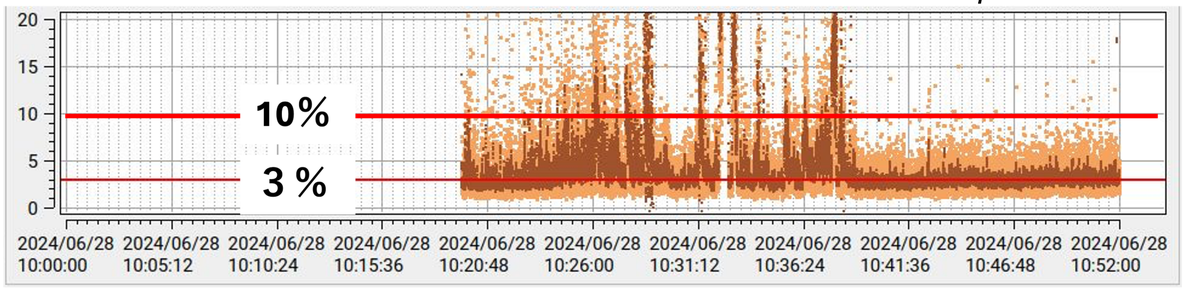
“Taylor-made XFELs”



Request:
“Reduce shoulder components”

ML-based System of Automatic System

Initial Condition *After Optimization*

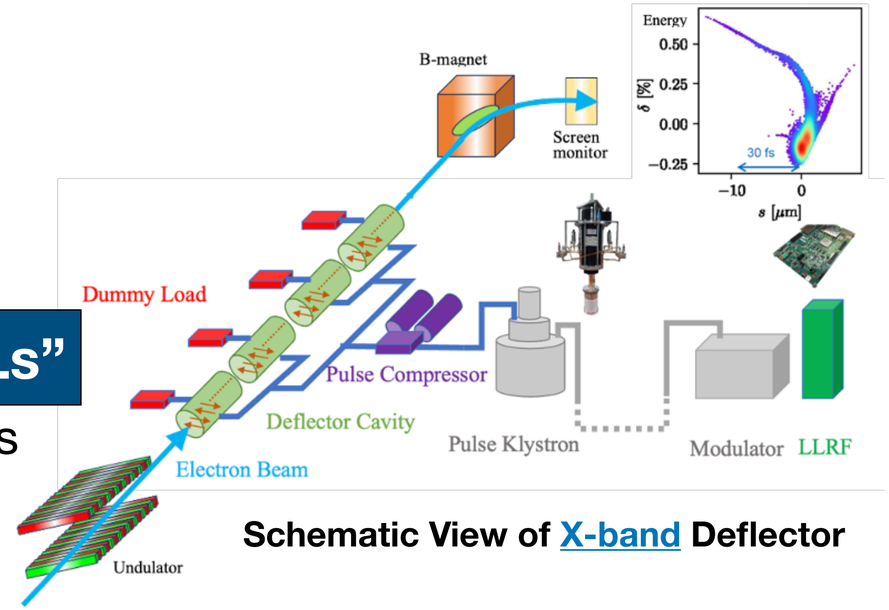


Intensity Ratio of Shoulder Components to Peak

Compress pulse in time

“Shorter Pulse XFELs”

Ongoing Developments



Schematic View of X-band Deflector

Increase rep. rate

etc.

“SACLA-II Upgrade”

Future Prospects

Details will be presented by Iwai-san

Special Talk: Recent updates and prospects of SACLA (accelerator)

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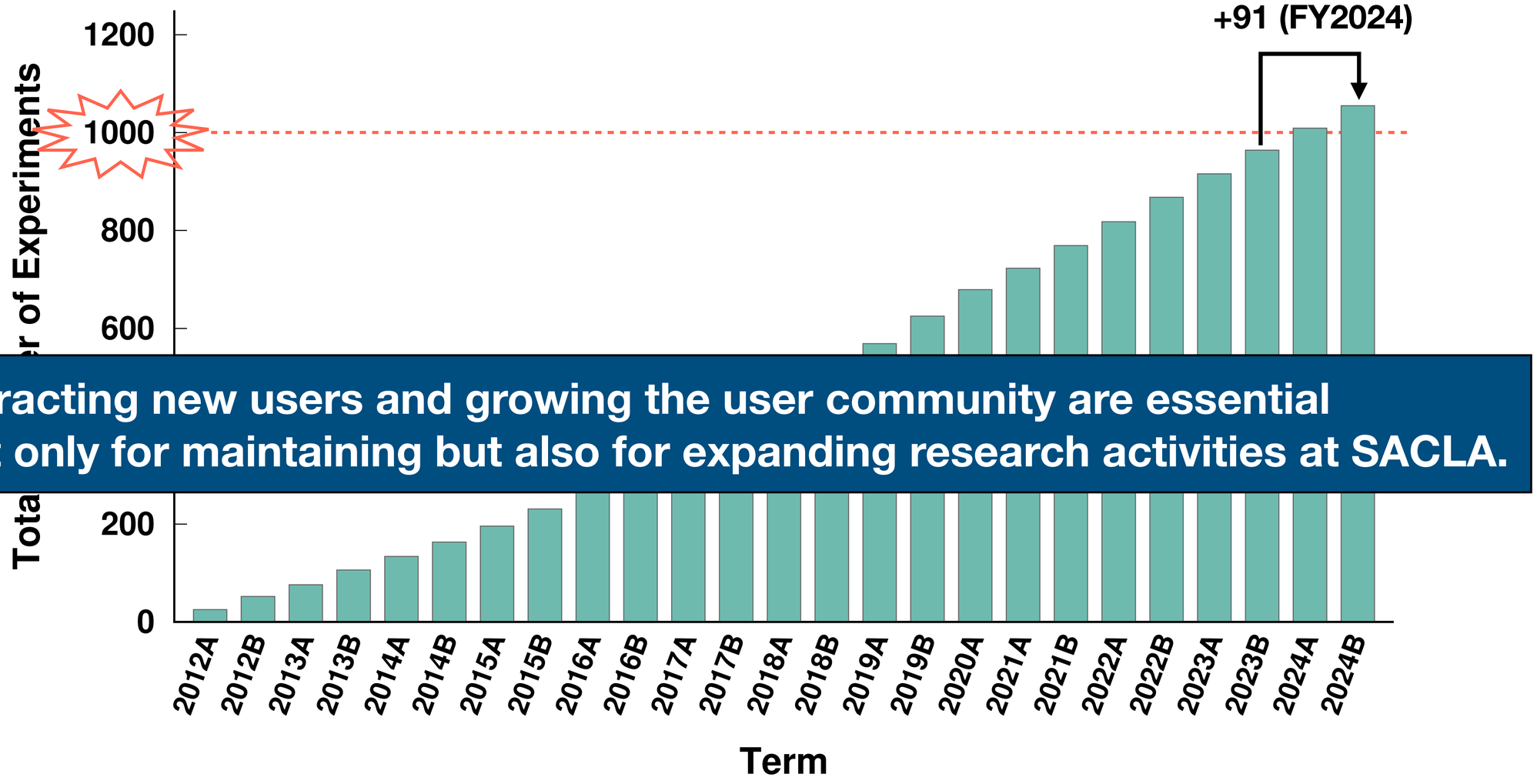
To date, more than 1,000 user experiments have been performed since we welcomed the first user in March 2012



Attracting new users and growing the user community are essential not only for maintaining but also for expanding research activities at SACLA.

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A two-day hands-on lecture was held primarily for SR users to learn about XFEL experiments

Hands-on lecture on serial femtosecond crystallography (SFX) for structural biology

- The first lecture of this kind was held at SACLA.
- The lecture was held in February 2025 in collaboration with the external lecturers, Profs. Nango and Fujiwara (Tohoku Univ.).
- SFX was selected as the first target because of its well-established platform, DAPHNIS.
- Participants were both from academia (including grad students) and industry.

Program of Lecture

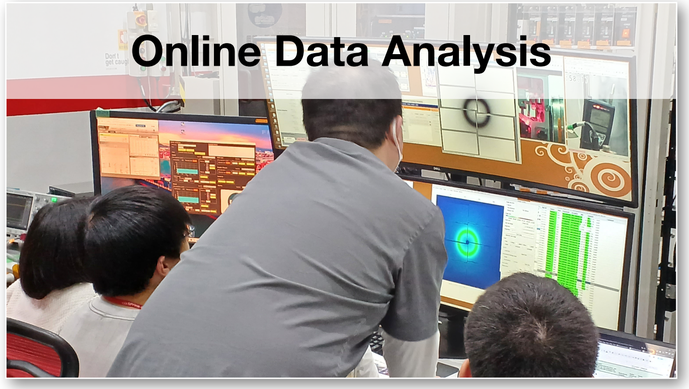
Lecture (2 hours) — *Introduction of SFX, Crystallization, Data Processing*

Demo (2 hours) — *XFEL Measurements*

Practice (8 hours) — *Crystallization, Sample Preparation, Measurements, Data Collection, Data Processing*

Sample Handling with DAPHNIS

Online Data Analysis



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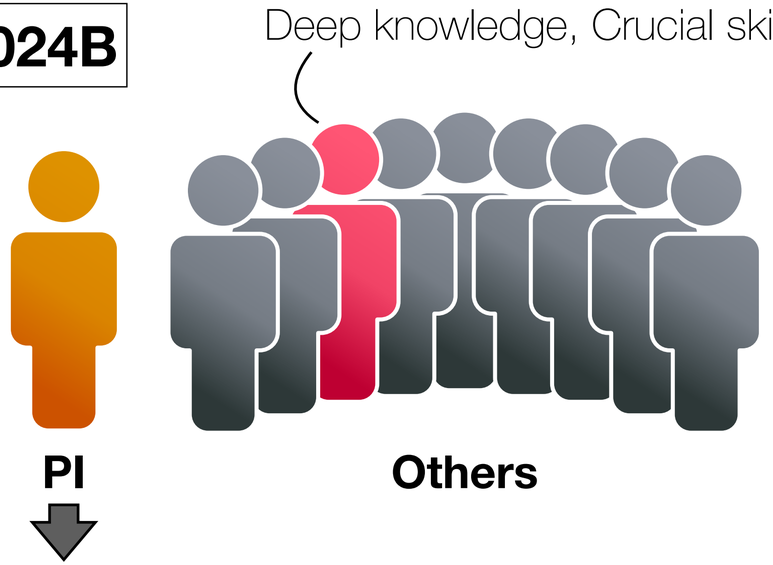
“Co-PIs” have been officially introduced in the proposal application system from the call for 2025A

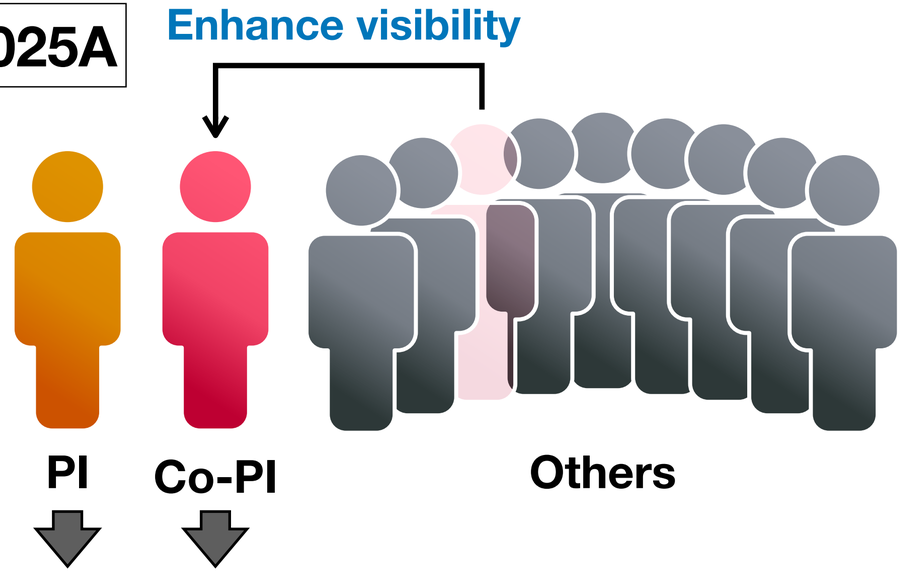
PI: Principle Investigator

Before 2024B



Owe responsibilities to lead the project

After 2025A



Share the responsibilities

Examples of Roles of Co-PI(s)

- Supervising multiple related projects based on deep knowledge and expertise in experimental instruments, methodologies, and techniques.
- Acting as the primary contact for communication with beamline scientists at the facility to ensure smooth execution of the proposed research.

Notes: SACLA’s beamline scientist can be a Co-PI.

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Summary

- SACLA has been operated stably throughout this fiscal year, supporting 91 user experiments.

- In FY2024, new experimental capabilities, particularly in optical pumping, have been established. Unique platforms recently developed through the Basic Development Program, including the sub-10 nm focusing system, are (or will be) made available to general users.

- Further developments of key technologies are ongoing, not only in the beamlines but also in the detectors and accelerators.