SACLA Users' Meeting 2021
March 9-11, 2021 (online)

Facility Update

Kensuke Tono
on behalf of SACLA

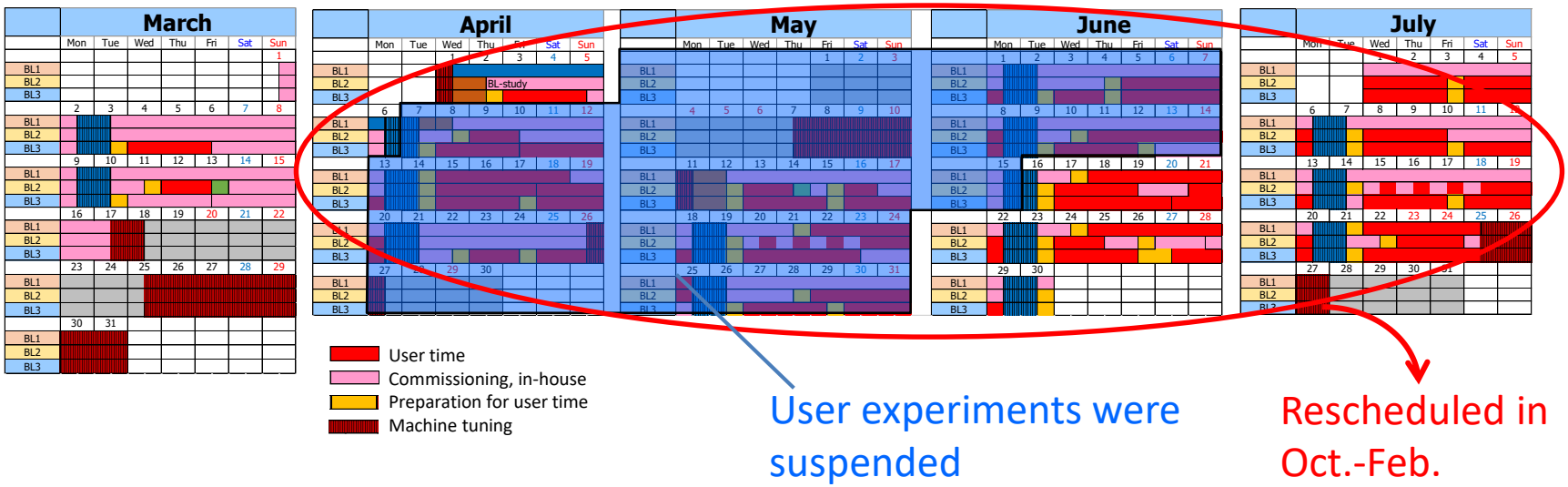
Contents

- Current status of user operation
  - Impact of COVID-19
  - Updates on user experiments
- Technical updates
  - Accelerator and beamlines
    - Beam injection to SPring-8
    - Undulator replacement at BL1
    - Automated tuning
  - Experimental stations
- Summary

Impact of COVID-19 (1)

- SACLA could keep operation for COVID-19-related research even under the first state of emergency (April 7 - May 21, 2020).
- However, regular user experiments were suspended between April and mid June, 2020.
- Most of the user experiments of 2020A were rescheduled in the latter half of FY2020, where some new proposals were additionally approved.

March – July, 2020



Impact of COVID-19 (2)

After the resumption of user experiments, most of the domestic users could come to SACLA, but international users are still facing the strict travel restrictions.

Domestic users

- Most of the domestic users could perform experiments just as before, although the number of onsite participants were reduced.

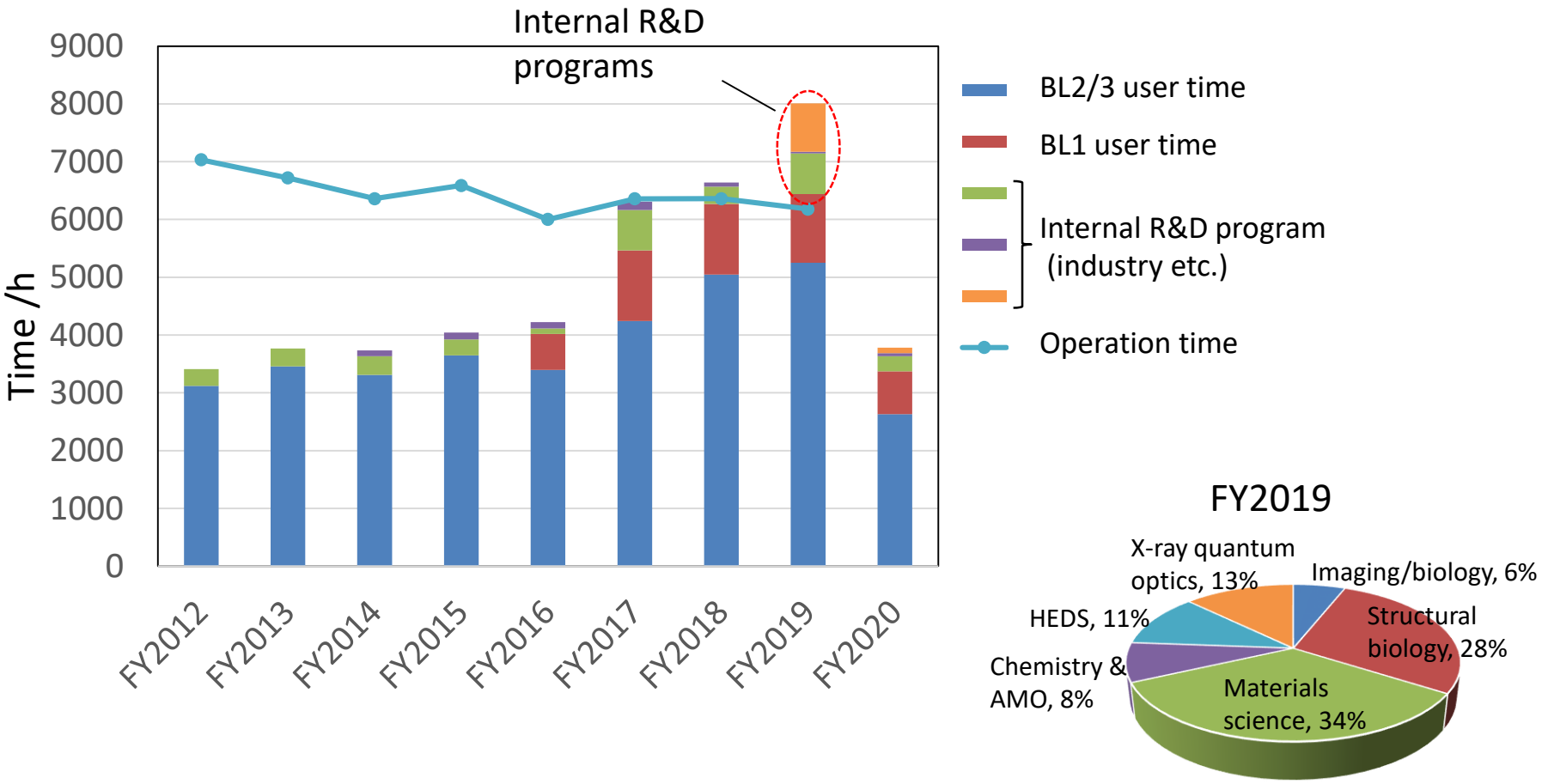
International users

- Almost no chance to come to SACLA.
- Considerable number of projects were cancelled in 2020A.
- About half of the international-users' projects were conducted, where collaborators in Japan worked onsite.

2020A		Domestic		International	
No. of projects	cancelled	Projects	Cancelled	Projects	Cancelled
64	12	41	1	23	11

User time & Operation time

User time in FY2020 will be roughly a half of that in FY2019.

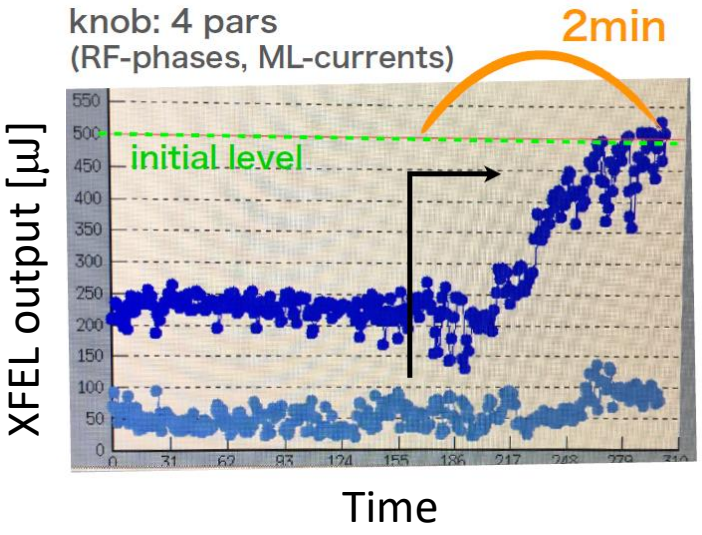


User operation in *New Normal*

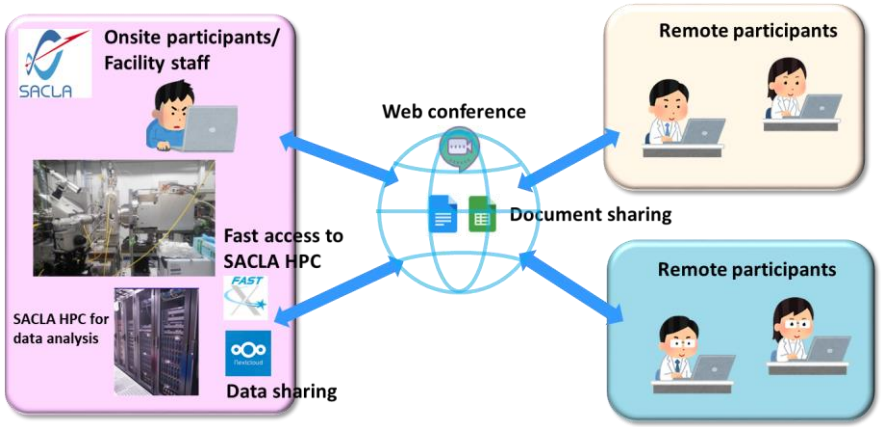
SACLA accelerates R&D for automation and remote operation to keep the facility activities with limited onsite presence of users and facility staff.

- Automated tuning of the accelerator and beamlines
- Remote experimentation (=> following presentations by Yabuuchi-san and Joti-san)

Accelerator operation using machine learning



Remote experiment using online tools



New category/systems for user proposals

- Urgent proposals
  - For non-proprietary experiments of great public significance.
  - Can be submitted anytime.
- Additional approval of proposals on the waiting list to fulfill canceled beamtimes (2021A)
  - The candidates for the additional approval will be selected from the unapproved proposals.
  - The total shifts for the candidates are up to about half the total shifts of unapproved proposals at each beamline.
- SACLA Feasibility Study Program (next slide)

To invite new users

- SACLA Feasibility Study Program (from 2021A).
  - To provide opportunities to experience XFEL experiments on a trial basis (max. 1 shift).
  - Target: Users who need feasibility study to prepare for regular proposals
  - Two systems are available now.
    - DAPHNIS for SFX
    - Experimental platform using the high-power nanosecond laser
  - 15 proposals were submitted for 2021A.
    - SFX: 6
    - High-power nanosecond laser: 7
    - Others: 2
- Development of new instruments.
  - SACLA Basic Development Program for R&D in collaboration with users (=> Reports from PIs on Thursday).
    - Platform for opto-spintronics researches at BL1, sample delivery system for SFX, CMOS image sensor for soft X-ray, etc.

Research highlights

Structural biology

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

Im, Iwata, Shimamura, et al., *Nat. Commun*. 11, 6442 (2020).

Ultrafast science

Tracking wavepacket trajectories during photo-induced bond formation of $[Au(CN)_2^-]_3$.

J.G. Kim, S. Adachi, H. Ihee *et al., Nature* 582, 520 (2020).

Industrial application

Fine structure formation in steel under ultrafast heating at ~10^4 K/s

M. Yonemura *et al., Sci. Rep.* 9, 11241 (2019).

**SACLA Industry-Academy Partnership Program*

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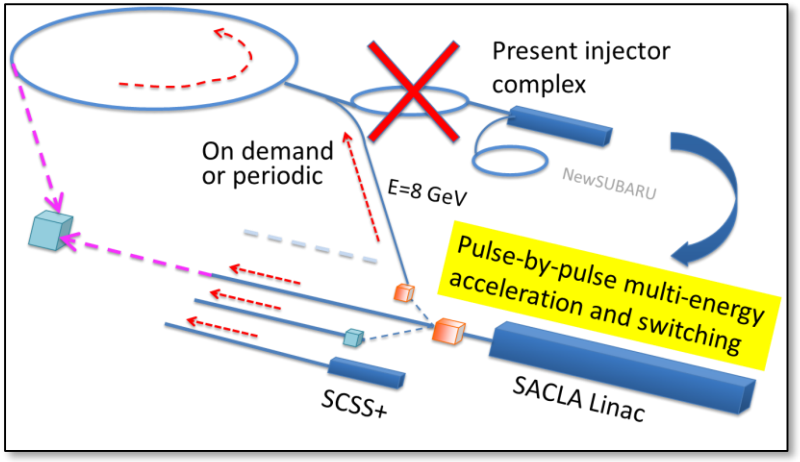
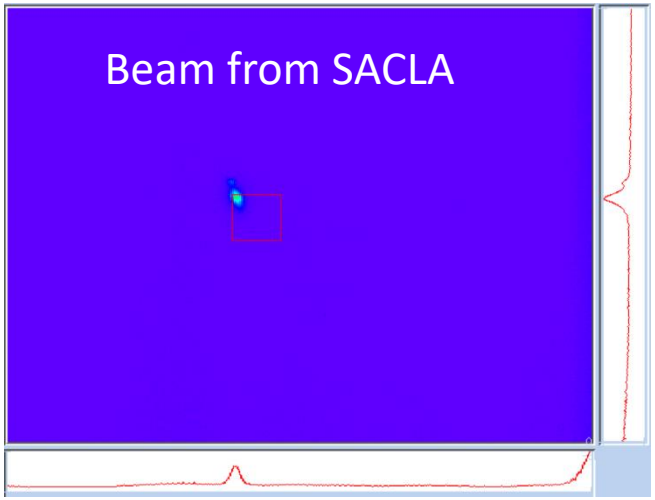
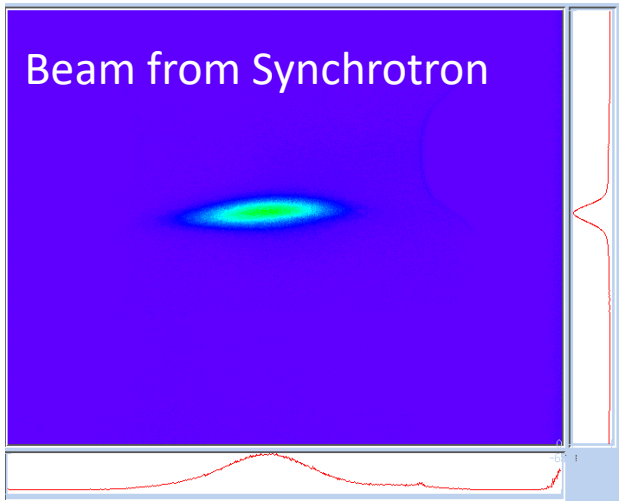
Beam injection to SPring-8 (1)

- Use SACLA as a low emittance injector for SPring-8-II.
- Shut down existing 1 GeV LINAC and 8 GeV synchrotron to save electricity and maintenance cost (April 2021).
- SACLA has been used as an injector during the SPring-8 user time since April 2020 (full replacement is scheduled for April 2021).



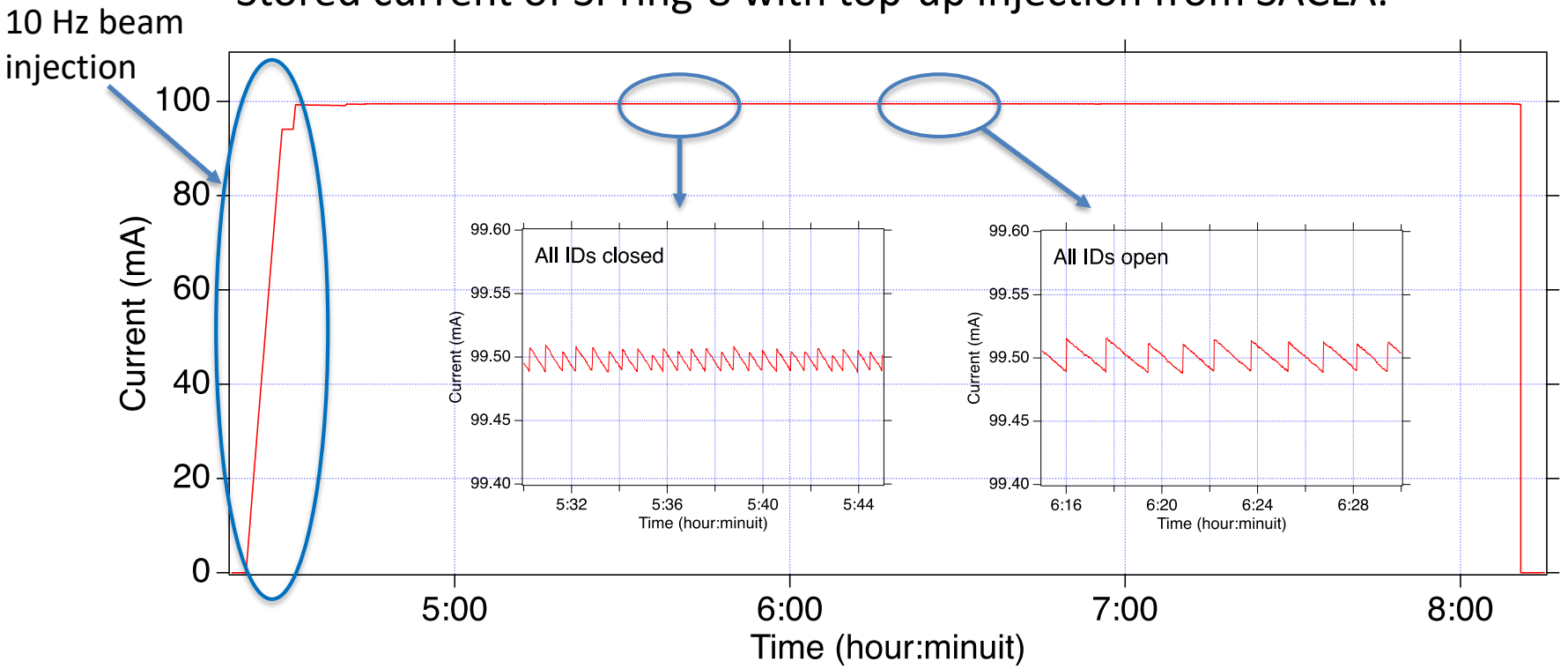
Electron beam profiles observed at the septum magnet of SPring-8.





Beam injection to SPring-8 (2)

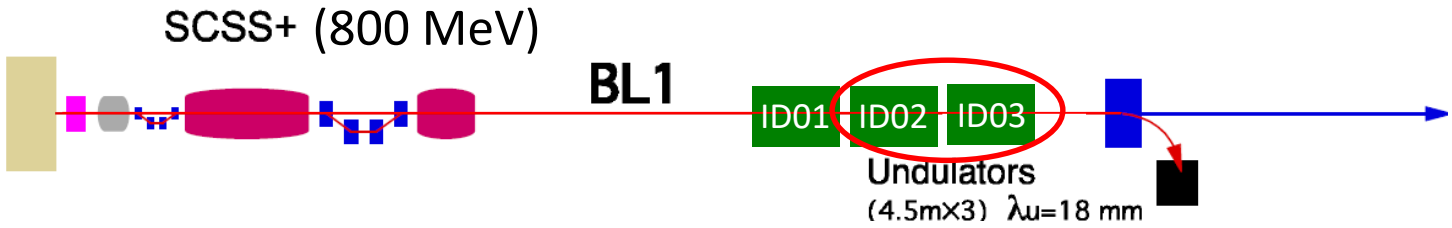
Stored current of SPring-8 with top-up injection from SACLA.



- During the 10 Hz beam injection from 0 mA (200 pC/bunch), XFEL operation is suspended for 10-15 min.
- During the top-up operation, the electron beam is injected a few times/min with the XFEL beamlines keeping operation.

Undulator replacement at BL1

- Demagnetization of magnets of the three undulator units.
  - FEL output was reduced significantly in 2020A (to ~10 uJ/pulse).
- Tentative countermeasures
  - Field correction for the 1st unit.
  - Replace the 2nd and 3rd units with those on BL2 and BL3.



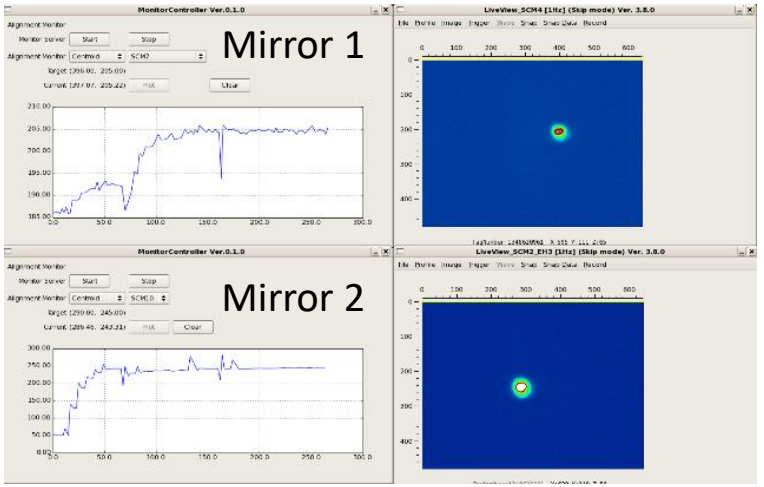
Automatic tuning: accelerator and photon beamlines

- Highly reproducible tuning without depending on the skill of operation staff.
- To facilitate remote operation by the staff.

- XFEL optimization based on machine learning.

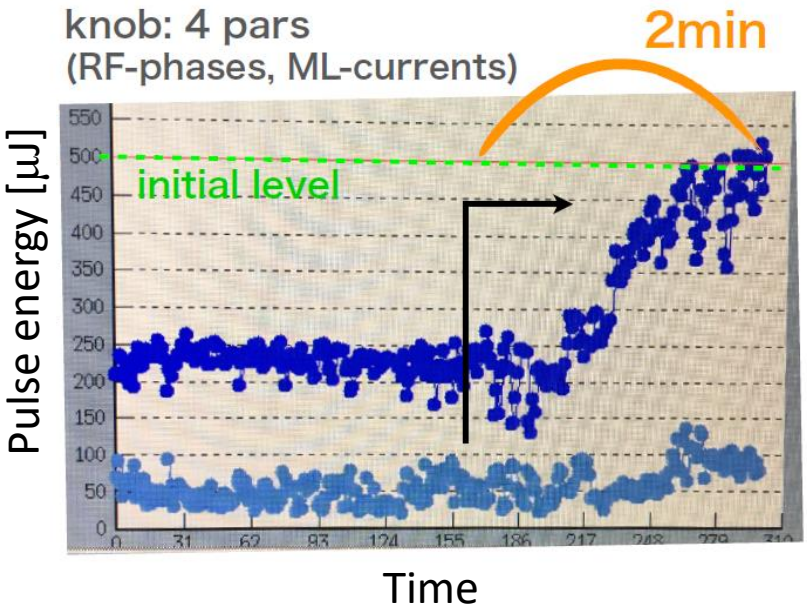
- Tuning of the beamline optics.
  - Photon-beam transport mirrors.
  - Double crystal monochromator.
  - 100 nm-focus KB-mirror system.
  - Operation from Oct. 2020.

Auto-tuning software for the beam-transport mirrors

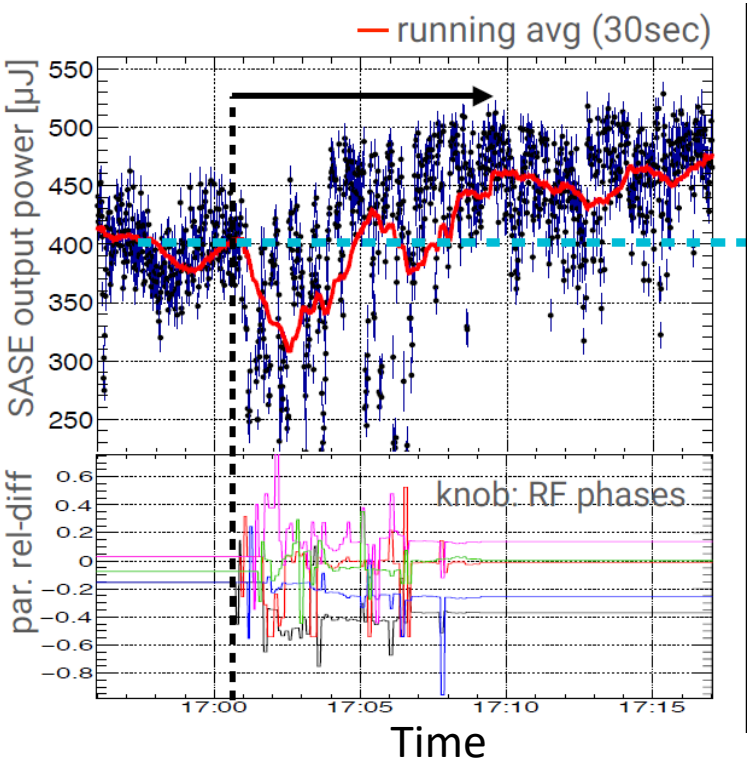


Machine-learning based optimization

Recovery of pulse energy from an intentionally-degraded condition (for demonstration)



Compensation for RF-phase drift



- Already applied to the daily operation to maximize the pulse energy.
- Developing for multi-parameter optimization (bandwidth, spatial profile, etc.)

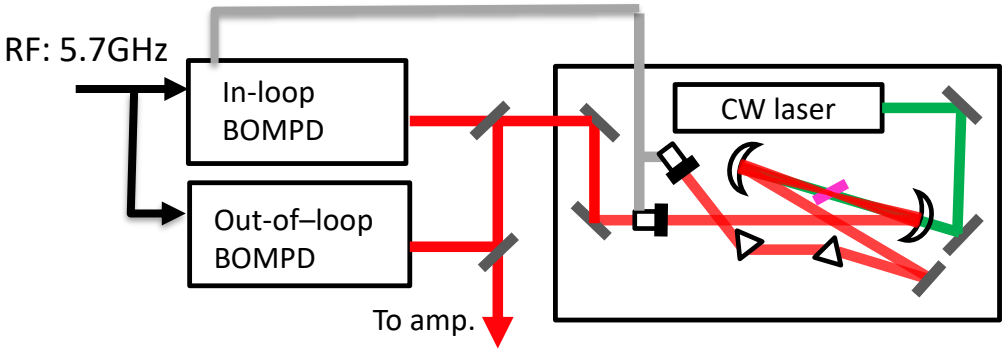
=> Breakout session B1 (Wednesday)

Major updates of beamline optics & experimental instruments

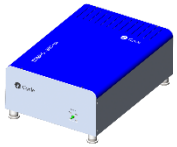
- Synchronized fs optical lasers
  - New system for timing synchronization
- Experimental systems with high-power lasers
  - Laser stability improved
  - Development for more efficient operation
- Detectors
  - New detector development

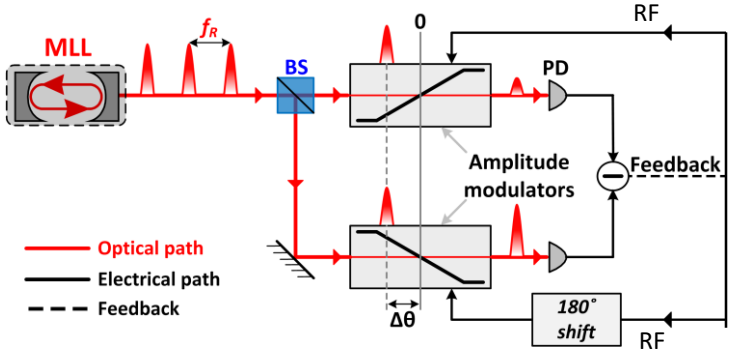
Synchronized fs laser system: Improved timing synchronization with XFEL

Synchronization using BOMPD

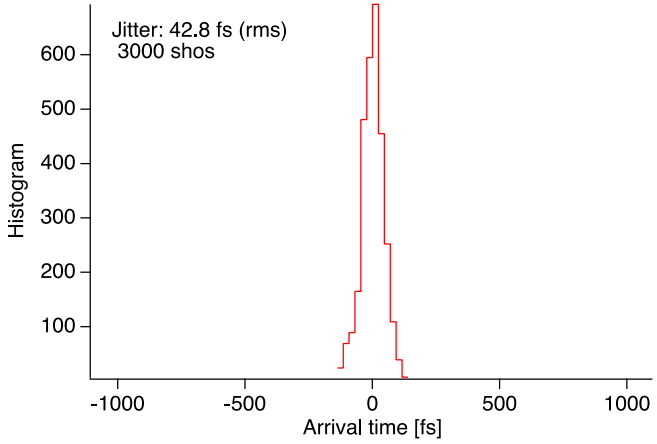


BOMPD (Cycle GmbH)

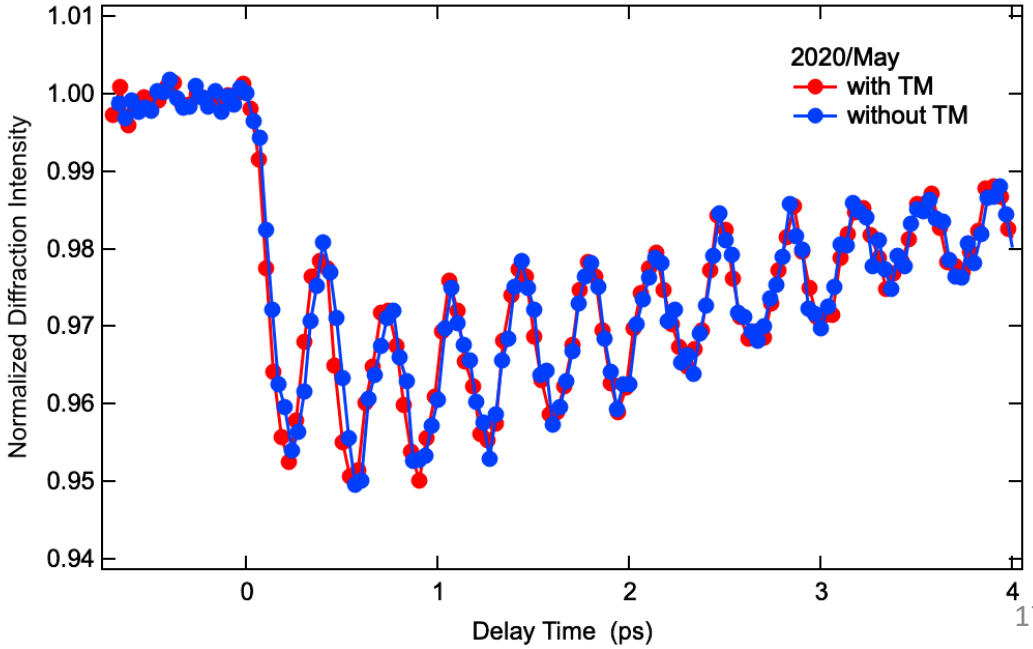




Jitter: 40 ~ 50 fs (rms, 5 minutes)
Drift: ~ ±0.5 ps (24 hours)



Time-resolved XRD of Bi

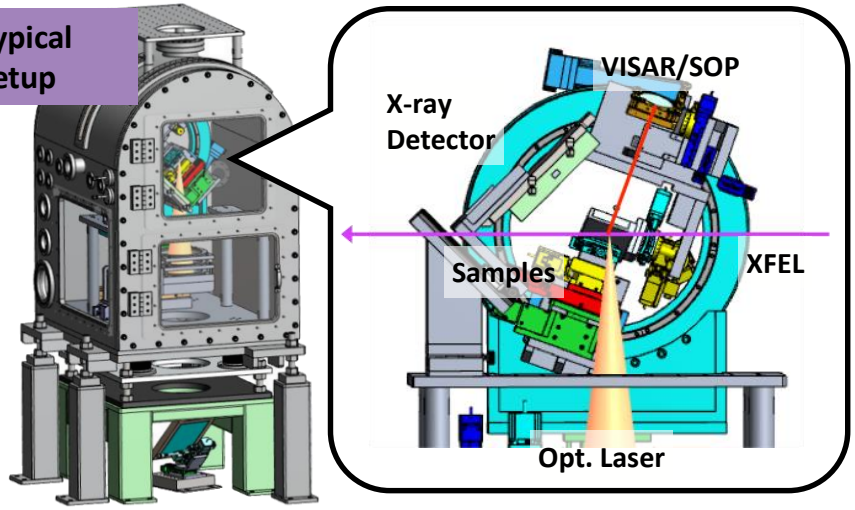


Instruments for XFEL experiments with high-energy nanosecond laser

Experimental platform specifically developed for laser-shock experiments

Hutch		EH5 at BL3
Optical Laser	Max. Energy (typ.)	15 J
	Pulse Duration (typ.)	5 ns
	Wavelength	532 nm
	Rep. Rate	0.1 Hz
XFEL	Focus with KB Mirrors	0.5-1 μm

Typical Setup



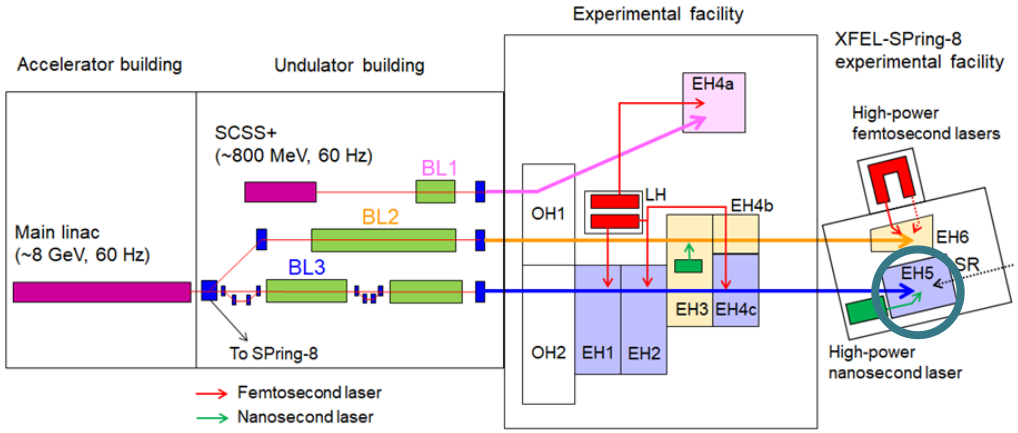
Y. Inubushi et al., Appl. Sci. 10, 2224 (2020).

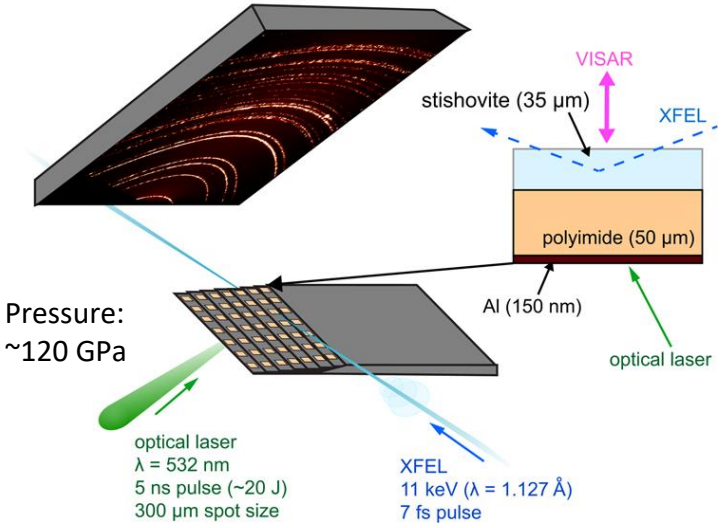
Recent Remarks

*M.O. Schoelmerich, T.Tschentscher et al., "Evidence of shock-compressed stishovite above 300 GPa", Sci. Rep. **10**, 10197 (2020).*

OSAKA UNIVERSITY

High-energy optical laser has been installed in collaboration with Osaka University.





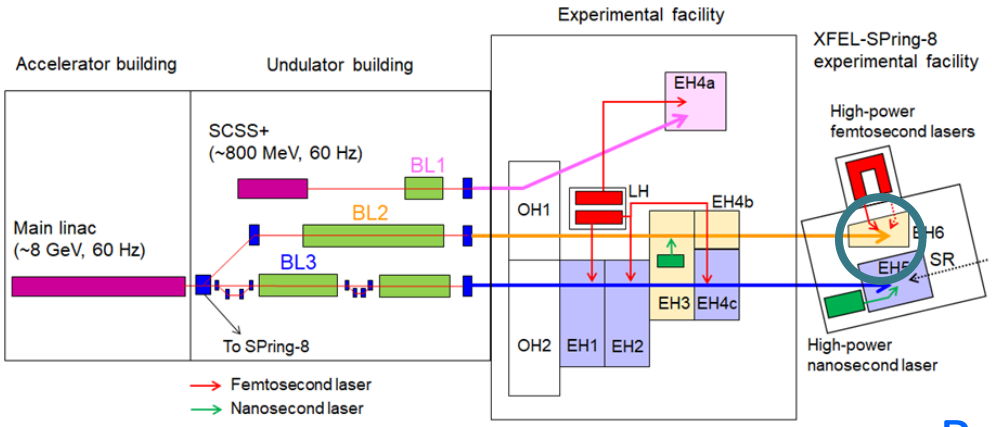
Instruments for XFEL experiments with high-intensity femtosecond lasers

*T. Yabuuchi et al., J. Synchrotron Rad. **26**, 585 (2019).*

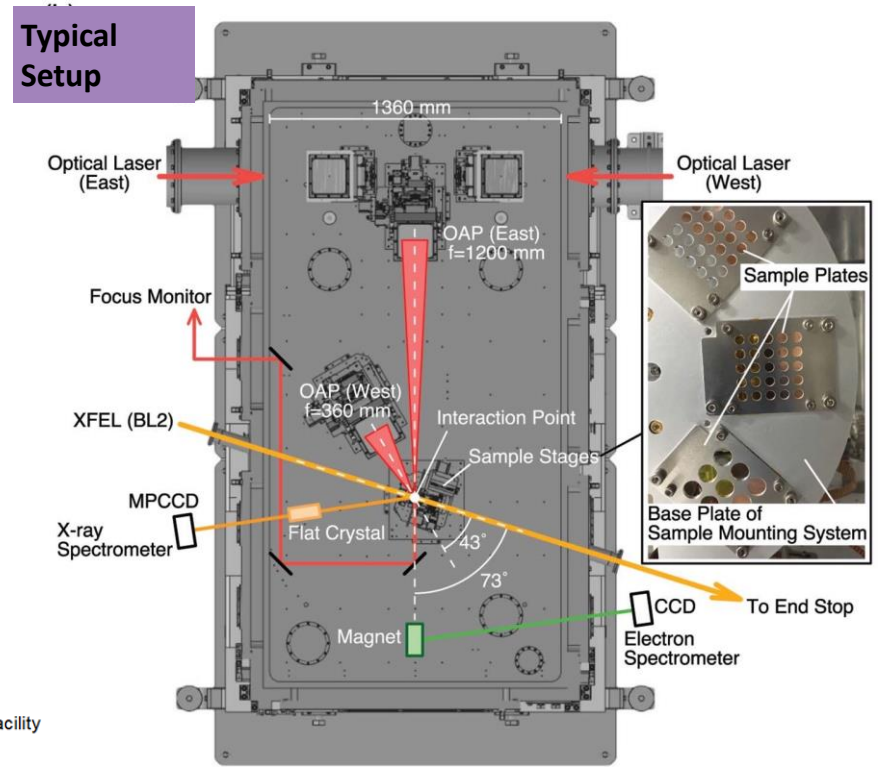
Experimental platform developed for high energy density science (HEDS)

Hutch		EH6 at BL2
Optical Laser	Max. Energy (typ.)	8 J
	Pulse Duration (typ.)	40 fs
	Wavelength	800 nm
	Rep. Rate	1 Hz
XFEL	Focus with CRLs	a few µm

Single beam (east beam) of the laser system is currently operational for user experiments.



Typical Setup



=> Breakout session A2 (Wednesday)

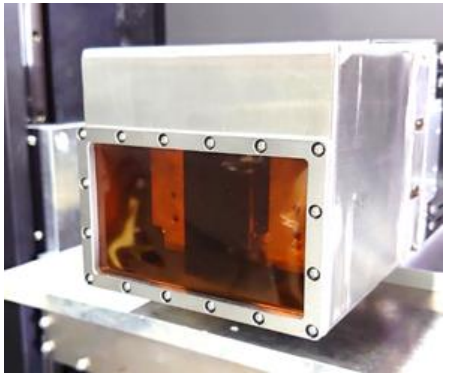
CITIUS Detector: XFEL variants

Architecture [1-3]

Integration Pixel & High Frame Rate

Feature

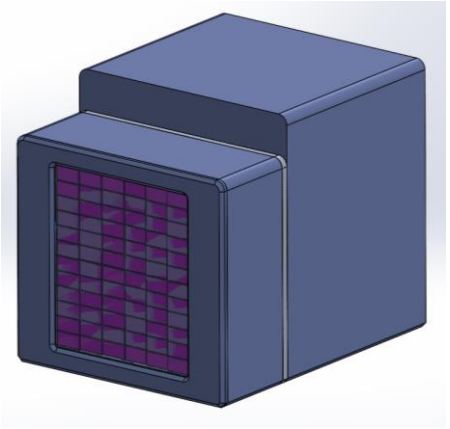
Zero Noise	Spectro-Imaging	High Spatial Resolution	High Dynamic Range	Ultralow Systematic Error



First detector under evaluation

Confirmed Performance at the Component level

Parameters		Value
Sensor	Photodiode thickness	650 µm
	Pixel Size	72.6 µm
	Noise	0.02 phs.@12 keV
	Peak Signal	9,000-10,000 phs.@12 keV
	Frame Rate	60 Hz (max. 5 kHz)
	Pixel Number	0.28 Mpixel/sensor
Largest System	Pixel Number	20.2 Mpixel
	Image Area	322 x 364 mm^2



20.2 Mpixel system for SACLA

Schedule

2013:	Project started
2015:	Partners agreed
2020 Sep:	First light of one modular system in final form
2021 Dec:	Start of the assembly of 20.2M pixel system
2022:	In-kind user operation

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

March 9th, 2021

=> Breakout session A3 (Wednesday)

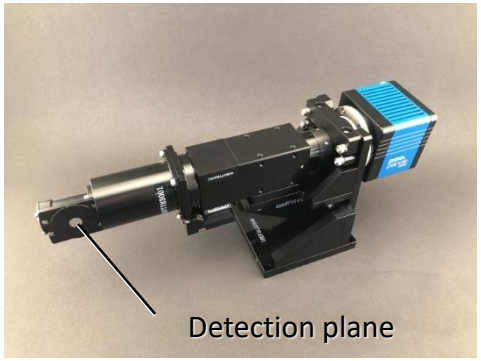
Indirect high resolution X-ray detectors

T. Kameshima et al., Opt. Lett. 44, 1403 (2019).

=> Poster P8

Standard unit

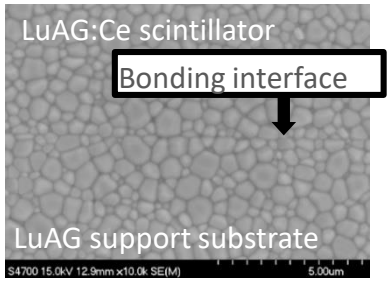
Off-axis unit



- 5 µm-thick LuAG:Ce scintillator layer (min.)
- Scintillator replaceable
- Objective lens replaceable
- Camera optionality (c-mount)
- Proximity imaging design (min. 0.3 mm w.d.)
- Off-axis camera mount

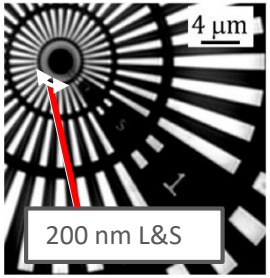
Transparent thin-film scintillator

5-µm-thick LuAG:Ce



SEM image of bonding area

Resolving power



Optical configuration

		100x	50x	20x	10x	5x	2x
Resolution	[µm]	~ 0.4	~ 0.5	~ 0.70	~ 1.1	~ 2.1	~ 5.3
Field of view	[mm²]	0.13 x 0.13	0.27 x 0.27	0.67 x 0.67	1.33 x 1.33	2.66 x 2.66	6.7 x 6.7
Conversion@10keV	[e-/X-ray]	~ 12	~ 8	~ 3.2	~1.4	~ 0.35	~ 0.06

Configuration to resolve 200 nm L&S patterns

Objective line-up for Standard unit

Objective line-up for Off-axis unit

Summary

- The COVID-19 pandemic has impacted on SACLA.
  - Although many of the staff had to work remotely, SACLA could keep its operation.
  - User experiments were suspended for ~2 months.
  - Domestic users have access to SACLA now, but most international users do not yet.
  - About a half of international users' experiments were cancelled.
- SACLA has been technically upgraded even in the abnormal situation.
  - Automated tuning and remote experimentation to mitigate the COVID impact and to be adapted to New Normal.
  - Beam injection to SPring-8.
  - Beamline optics and experimental instruments.

We would like your input.