SACLA Users' Meeting 2017

SPring-8 Angstrom Compact free electron LAser

Overview of SACLA

Makina YABASHI
SACLA
yabashi@spring8.or.jp

Dec 11 2017 @SACLA

Key targets

1. To expand experimental opportunities for enabling various applications
2. To provide high-quality, stable XFEL light for enhancing unique outcomes
3. To continue developments for exploring novel capabilities
4. To promote industrial innovations, international communication/collaboration, and engagement of young generation

Contents

1. Facility updates

   To expand experimental opportunities for enabling various applications

2. Statistics & highlights

   To provide high-quality, stable XFEL light for increasing outcomes

3. Unique capabilities with new developments

   To explore novel capabilities for unique science

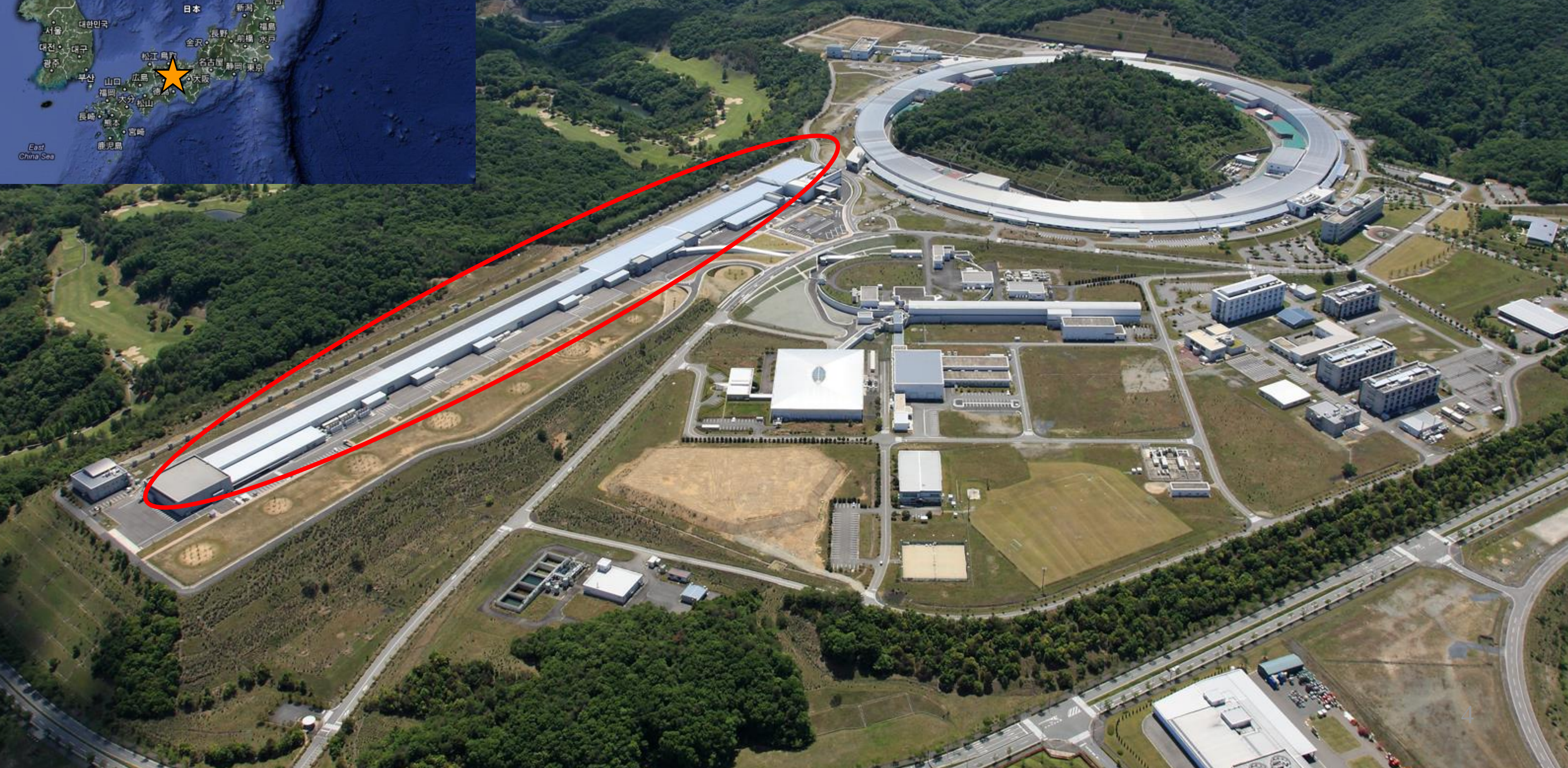
4. Programs

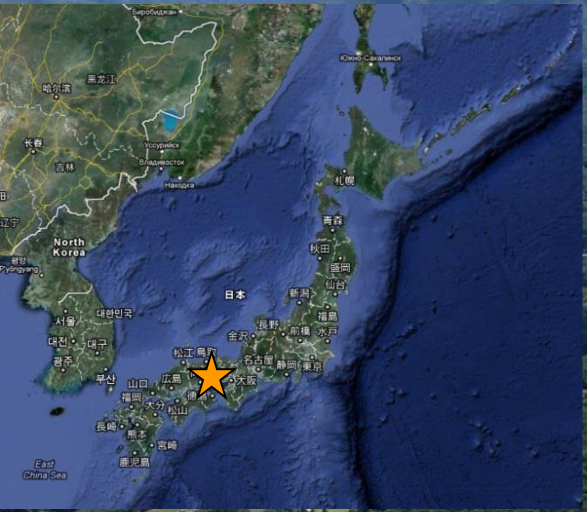
   To promote industrial innovations, international communication/collaboration, and engagement of young generation

5. Summary

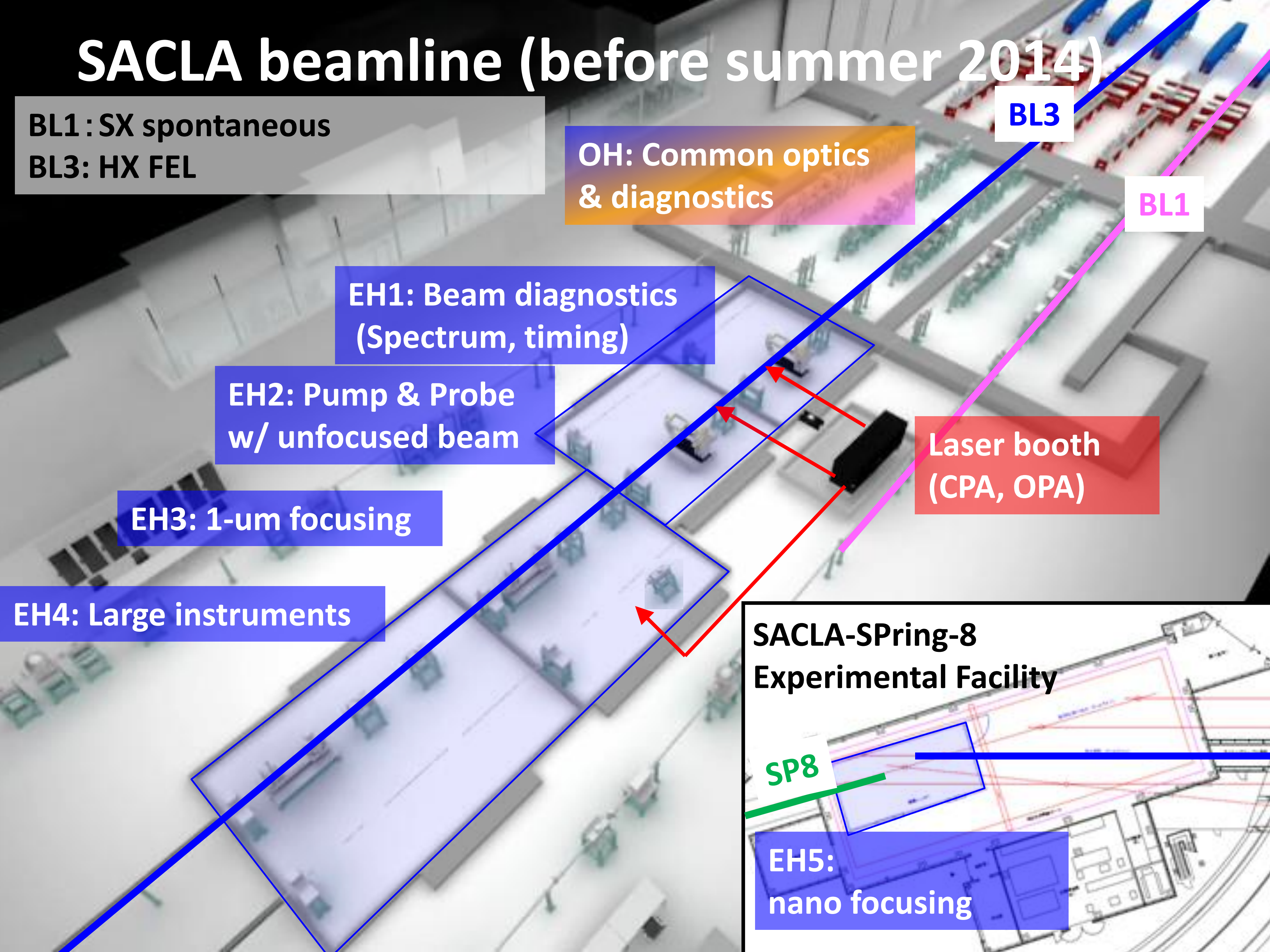
SACLA @SPring-8

First Compact XFEL
Construction: FY2006~2010
First lasing: June 7, 2011
User Operation: March 2012~

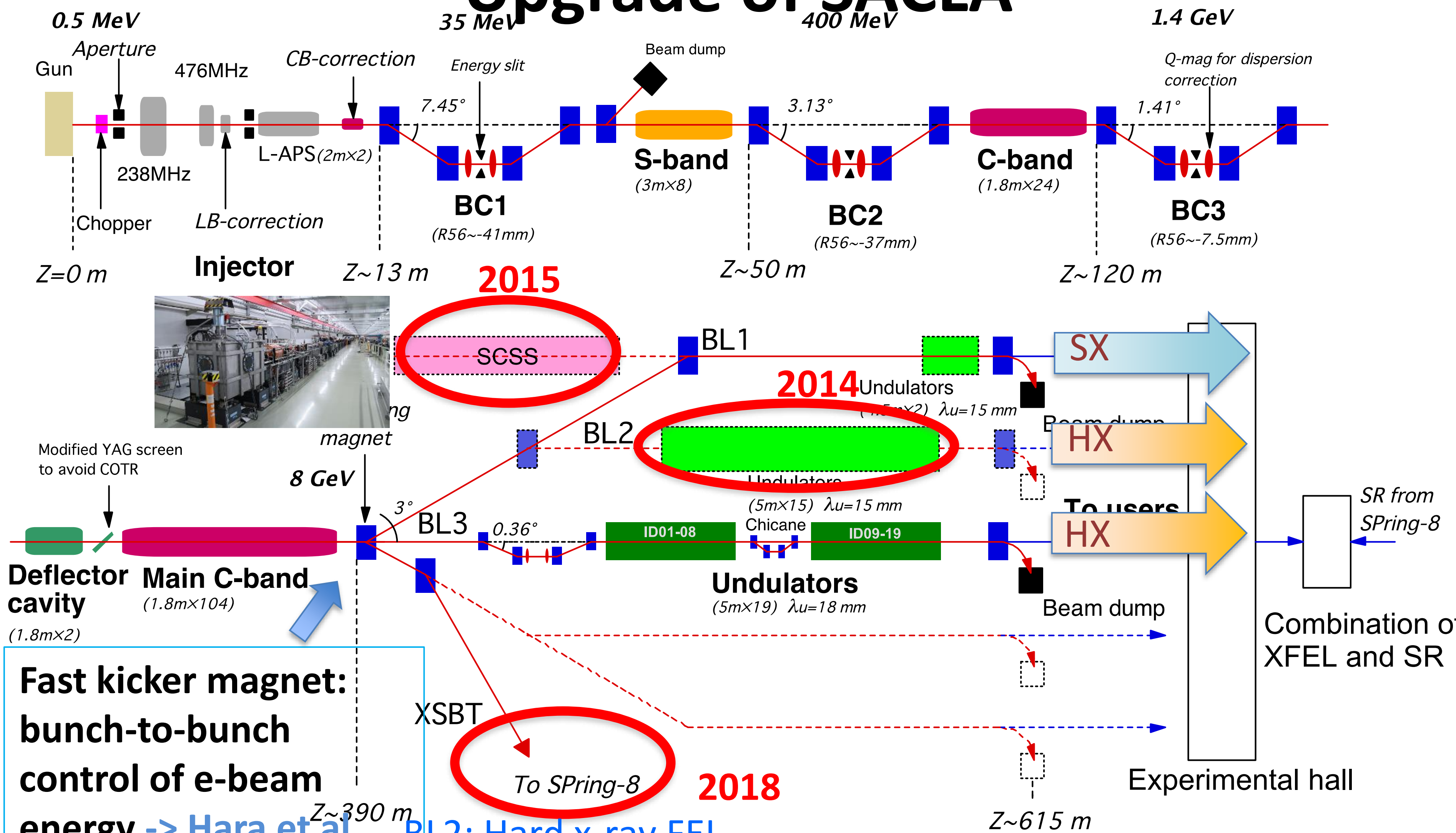




SACLA beamline (before summer 2014)



Upgrade of SACLA



Fast kicker magnet: bunch-to-bunch control of e-beam energy -> Hara et al, PRST 16, 080701 2013

BL2: Hard x-ray FEL

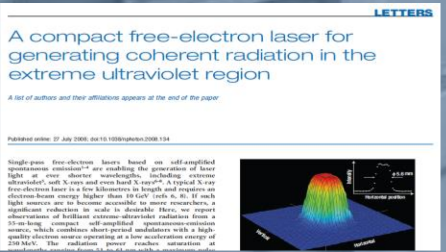
BL1: Soft x-ray FEL with relocation of SCSS+; independent e-beam driver

SCSS (SPring-8 Compact SASE Source)

Prototype of SACLA
R&D for compact XFEL machine & XFEL utilization

2005 Construction & Commissioning
2006 First lasing at 49 nm
2007~ User operation
2013 Decommissioned
2015 Move to SACLA undulator hall
2016 Start user operation
& upgraded to 800 MeV (SCSS+)

	SACLA	SCSS
Beam energy	8 GeV	250 MeV
Length	700 m	60 m
# of Accel. unit	64	2
# of Undulator	18	2
Wavelength	<~ 0.1 nm	50-60 nm


LETTERS

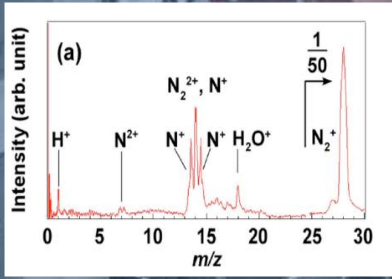
A compact free-electron laser for generating coherent radiation in the extreme ultraviolet region

A list of authors and their affiliations appears at the end of the paper

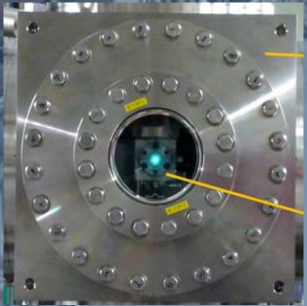
Published online: 27 July 2008; doi:10.1038/nphoton.2008.134

Single-pass free-electron lasers based on self-amplified spontaneous emission[1–4] are enabling the generation of laser light at ever shorter wavelengths, including extreme ultraviolet[5], soft X-rays and even hard X-rays[6–8]. A typical X-ray free-electron laser is a few kilometres in length and requires an electron-beam energy higher than 10 GeV (refs 6, 8). If such light sources are to become accessible to more researchers, a significant reduction in scale is desirable. Here, we report observations of brilliant extreme-ultraviolet radiation from a 55-m-long compact self-amplified spontaneous-emission source, which combines short-period undulators with a high-quality electron source operating at a low acceleration energy of 250 MeV. The radiation power reaches saturation at

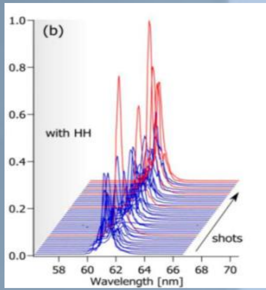
Amplification of EUV-FEL
Shintake et al. Nature Photon. 2008



First scientific results: Multi ionization of N2
Sato et al. APL 2008

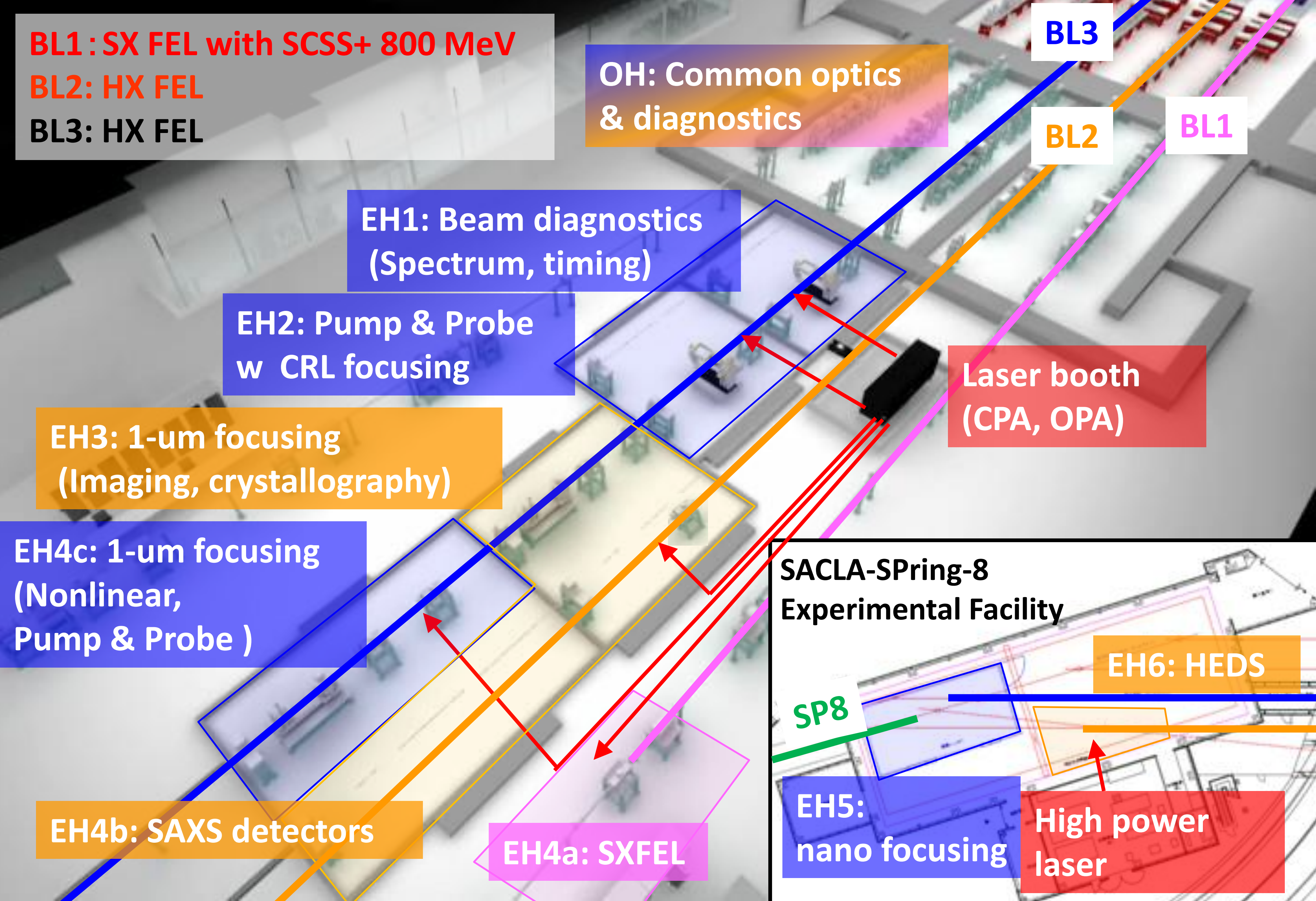


Superradiance with EUV excitation
Nagasono et al., PRL 2011

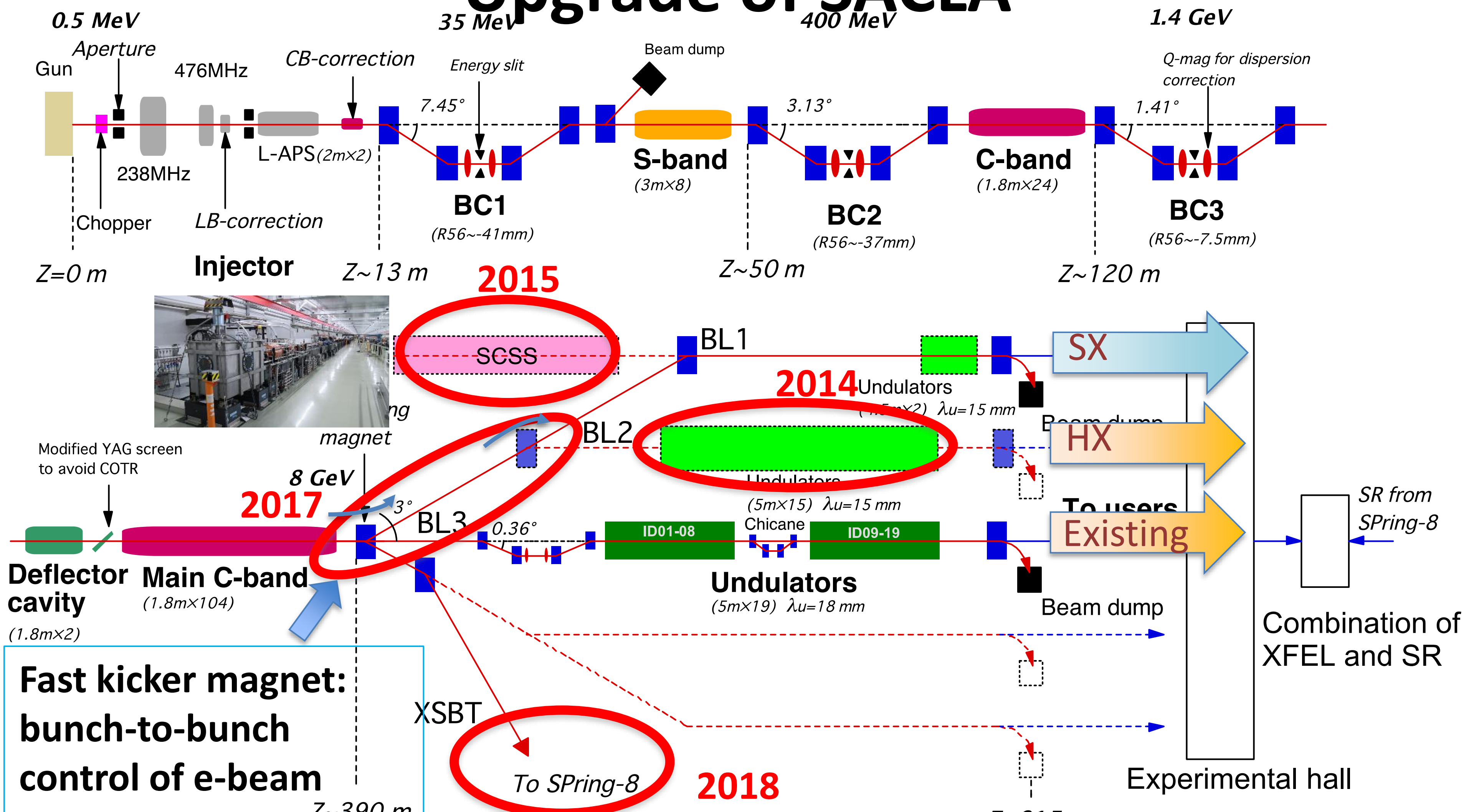


HHG-seeded FEL in EUV
Togashi et al., OE 2011

SACLA beamline (after summer 2016)



Upgrade of SACLA



Fast kicker magnet: bunch-to-bunch control of e-beam energy -> Hara et al, PRST 16, 080701 2013

BL2: from static to dynamic (pulse-to-pulse) switching while keeping independent tunability of photon energies in a wide range (by both e-beam energies & undulator K-values)

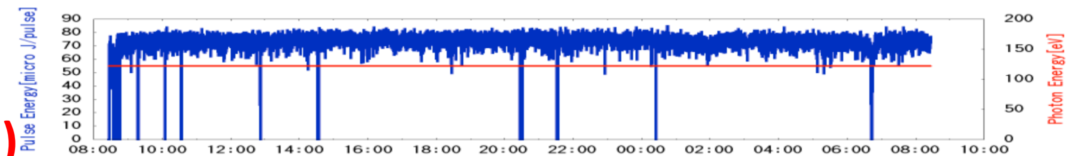
BL1: relocation of SCSS+; independent e-beam driver

Nov 29, 2017
Simultaneous operation of 3 beamlines

	CLA Operation Status	08:26:20

Operation Mode	
BL1 Study	
Hutch in Use	
BL1 EH4a	
	Photon Energy / Wavelength
	122.3 eV / 10.1 nm
	Intensity Fluctuation in 30 shots (STD)
	19.2 %

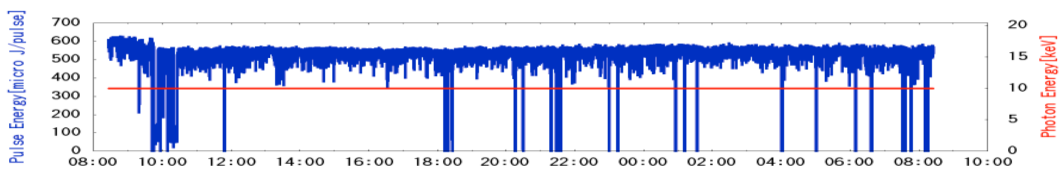
BL1
72 uJ@122 eV
60 Hz, <100 fs (?)



2017/11/29	SACLA Operation Status	08:25:40

Operation Mode	
BL2 User Operation	
Hutch in Use	
BL2 EH3,4b	
Pulse Energy	Photon Energy / Wavelength
568.3 micro J/pulse	10.0 keV / 0.124 nm
Repetition Rate	Intensity Fluctuation in 30 shots (STD)
30 Hz	7.6 %

BL2
570 uJ@10 keV
30 Hz, <10 fs

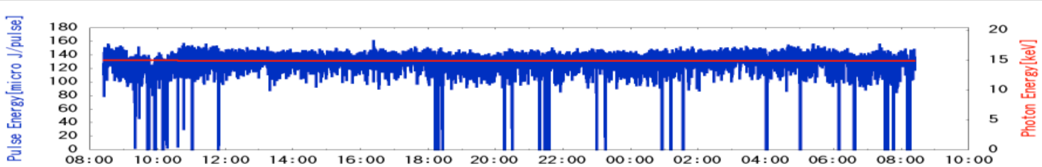


[BL1] [BL2] [BL3]

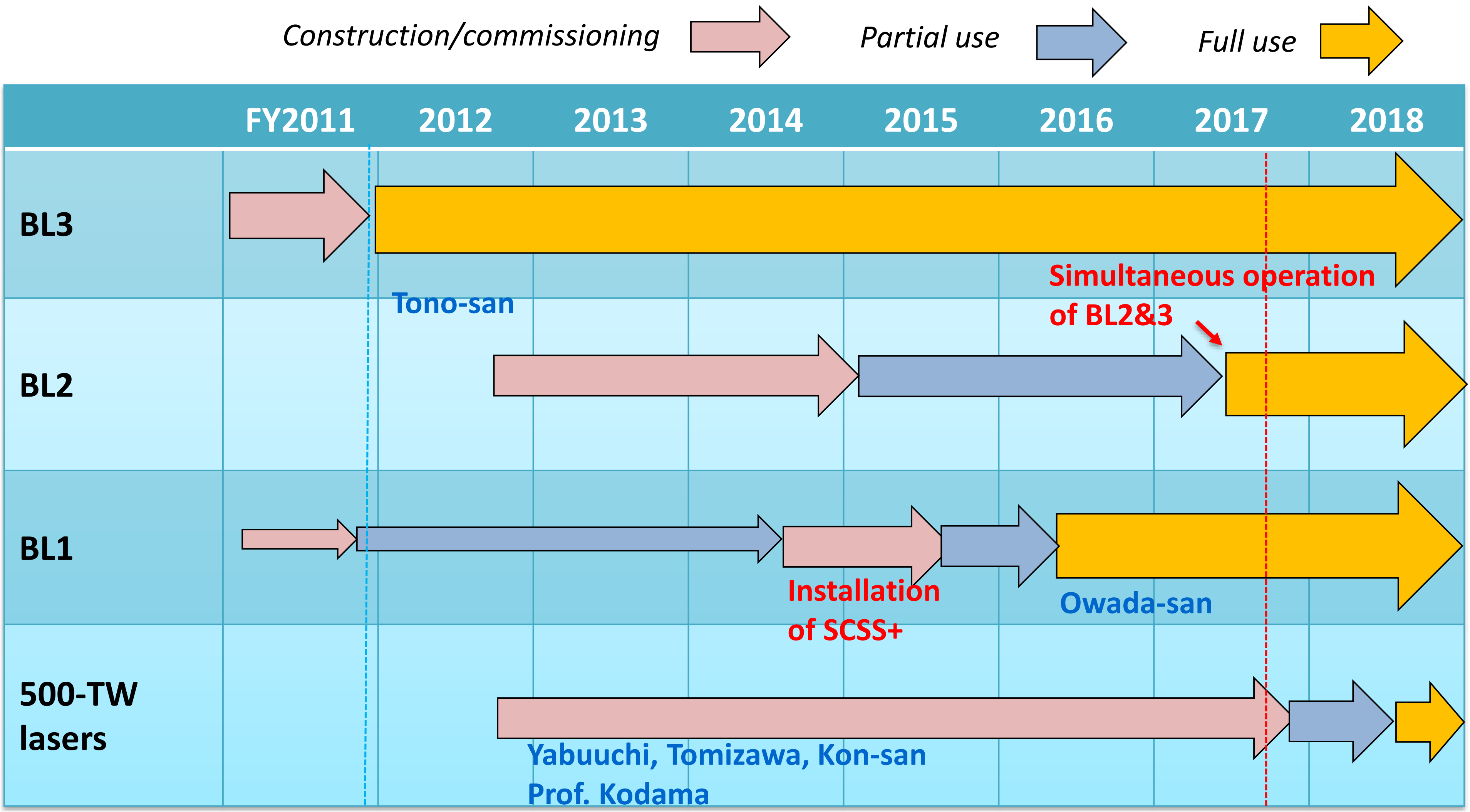
2017/11/29	SACLA Operation Status	08:24:30

Operation Mode	
BL3 User Operation	
Hutch in Use	
BL3 EH4	
Pulse Energy	Photon Energy / Wavelength
133.5 micro J/pulse	14.9 keV / 0.083 nm
Repetition Rate	Intensity Fluctuation in 30 shots (STD)
30 Hz	17.0 %

BL3
130 uJ@15 keV
30 Hz, ~7 fs



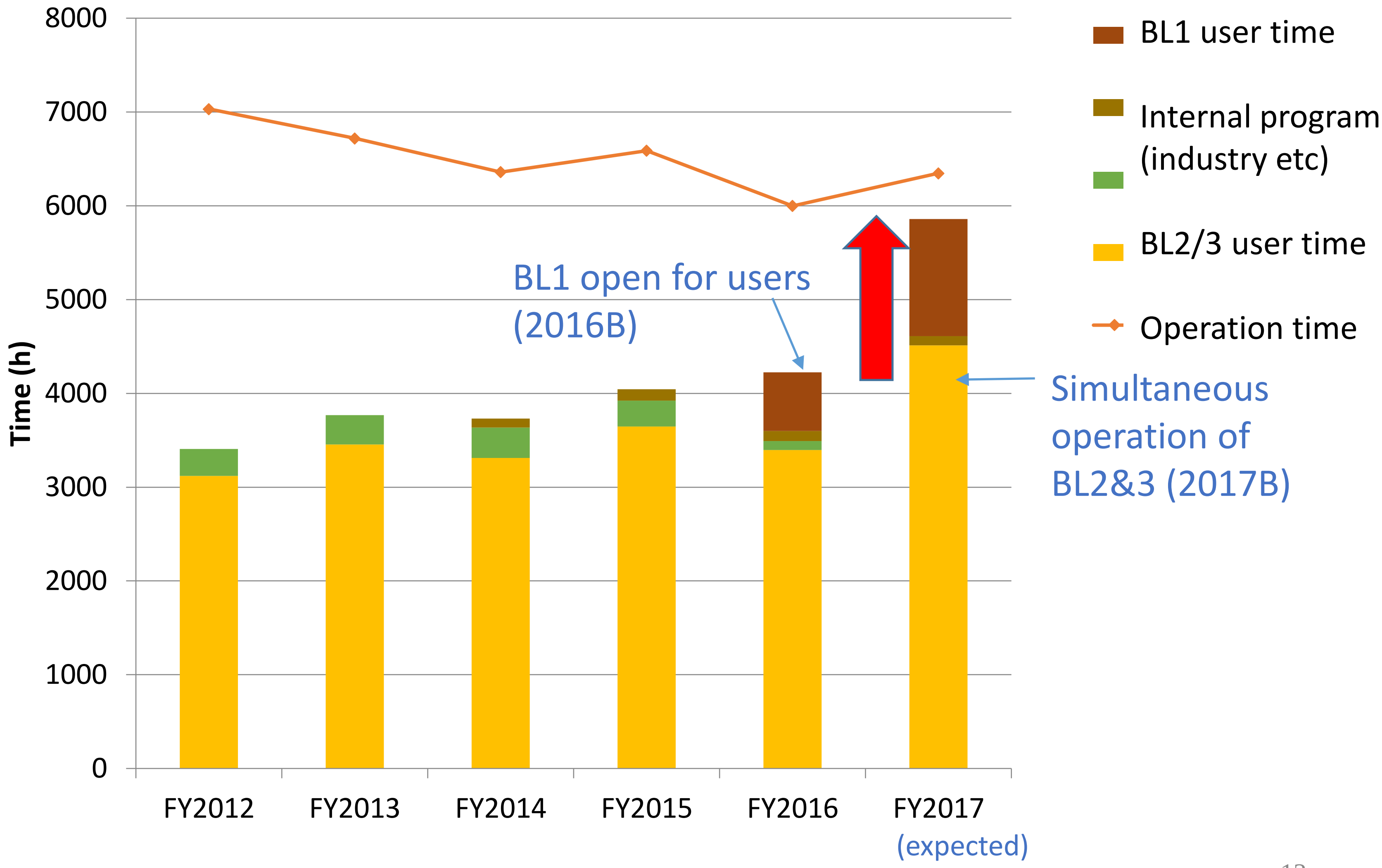
Development on beamlines & infrastructures



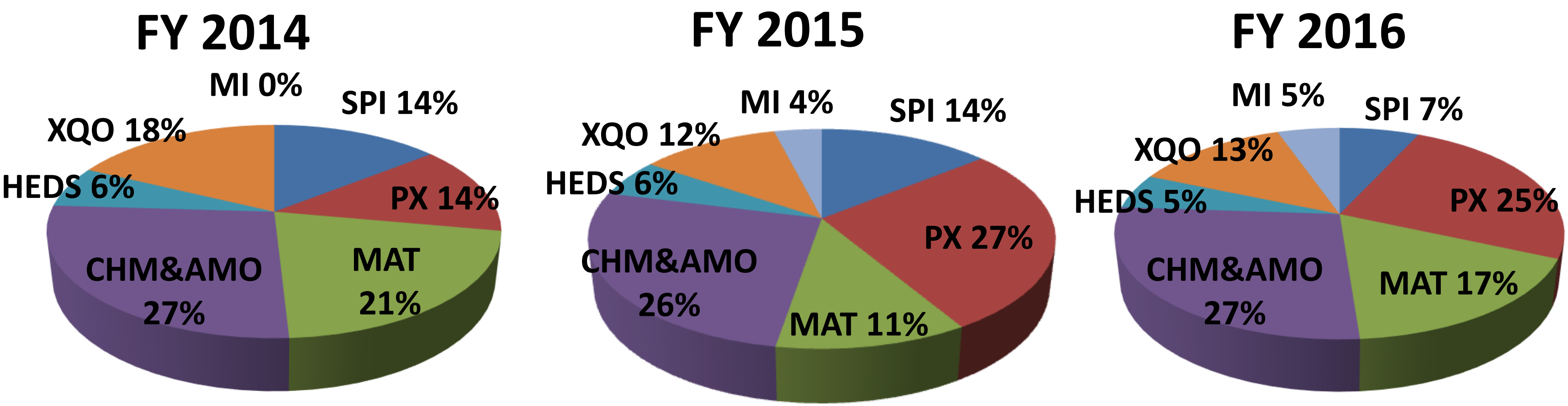
Contents

1. Facility updates
2. Statistics & highlights
3. Unique capabilities with new developments
4. Programs
5. Summary

Trend of operation/user time



Research Fields



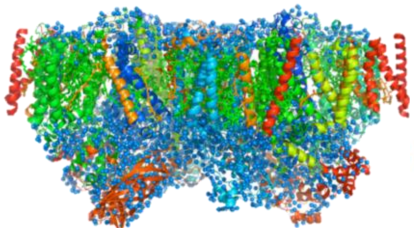
SPI:	Single Particle Imaging
PX:	Protein crystallography
MAT:	Ultrafast materials science
CHM:	Ultrafast chemistry
AMO:	Atom, Molecule, Optics
HEDS:	High energy density science
XQO:	X-ray quantum optics
MI:	Methods and instrumentation

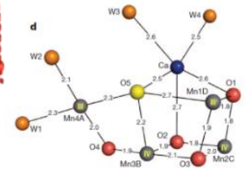
Research highlights

→ afternoon session

Damage-free structure determination of PS-II

Prof. Shen
(Okayama U)

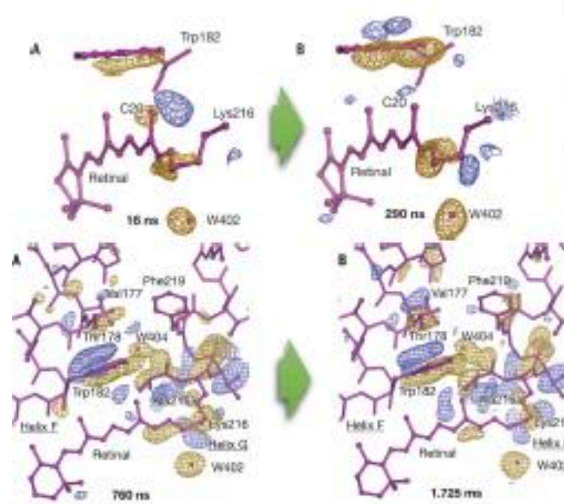




Photosystem II:
key catalysis for photosynthesis

***M. Suga, et al., Nature* 517, 99 (2015);**
***M. Suga, et al., Nature* 543, 131 (2017)**

Molecular movie of membrane protein



Prof. Iwata
(Kyoto U/RIKEN)

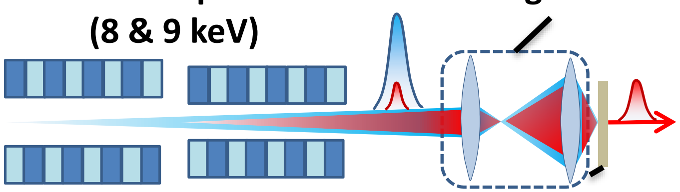
***E. Nango, et al, Science* 354, 1552 (2016).**

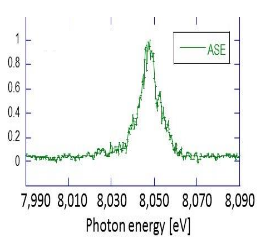
Hard X-ray Cu-Kα atomic laser

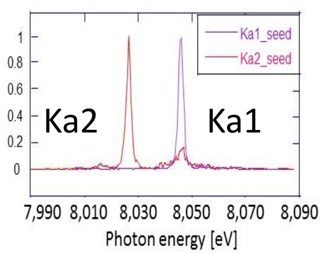
Prof. Yoneda (UEC)

Two-color operation (8 & 9 keV)

Two-stage focus

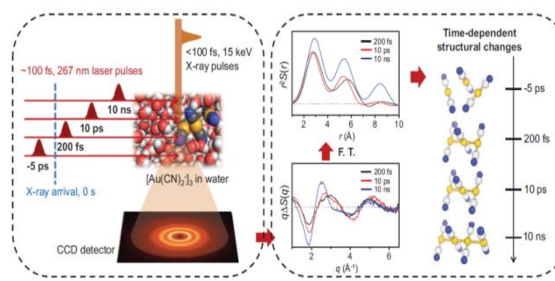






***H. Yoneda, et al, Nature* 524, 446 (2015).**

Observation of creation moment of gold complex



Prof. Adachi
(KEK)

***K. Kim, et al, Nature* 518, 315 (2015).**

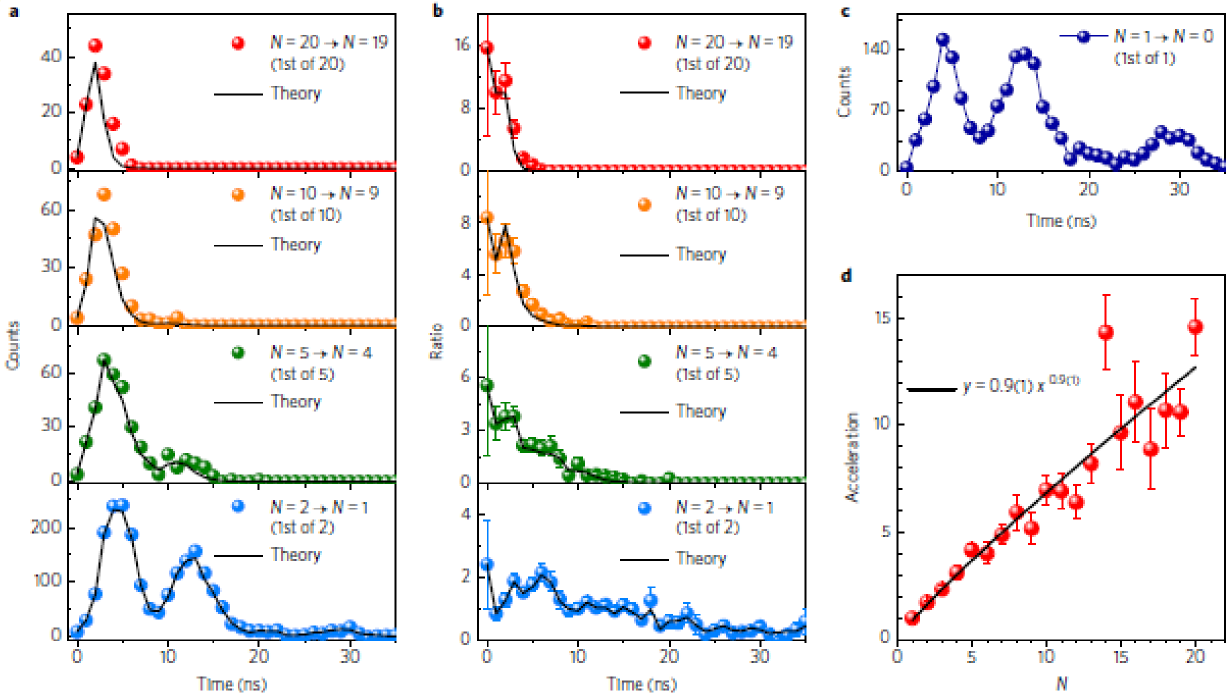
Recent highlight

nature physics
LETTERS
https://doi.org/10.1038/s41567-017-0001-z

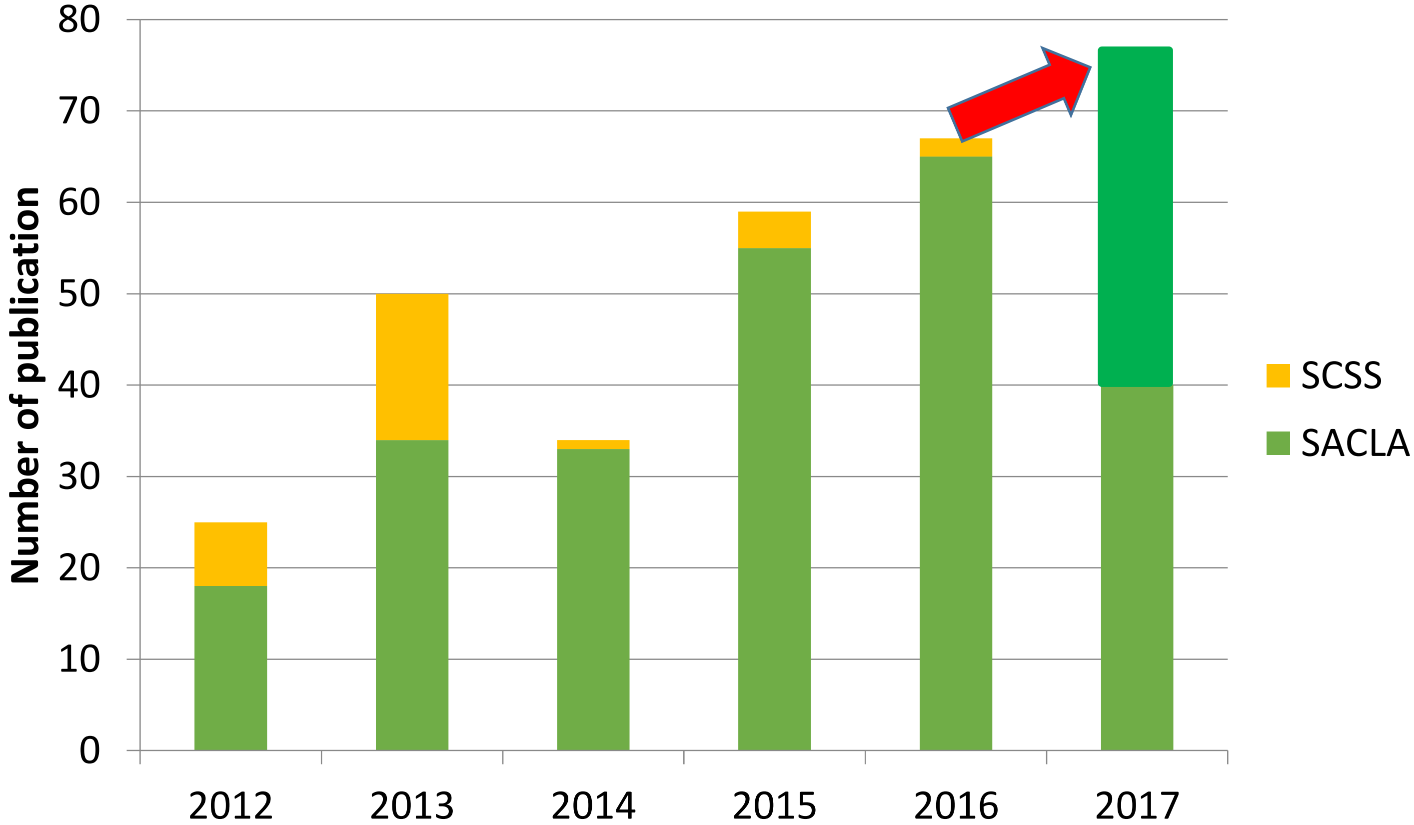
Superradiance of an ensemble of nuclei excited by a free electron laser

Aleksandr I. Chumakov[1,2]*, Alfred Q. R. Baron[3]*, Ilya Sergueev[4], Cornelius Strohm[4], Olaf Leupold[4], Yuri Shvyd'ko[5], Gennadi V. Smirnov[2], Rudolf Rüffer[1], Yuichi Inubushi[6], Makina Yabashi[3], Kensuke Tono[6], Togo Kudo[3] and Tetsuya Ishikawa[3]

68 γ-photons max. !



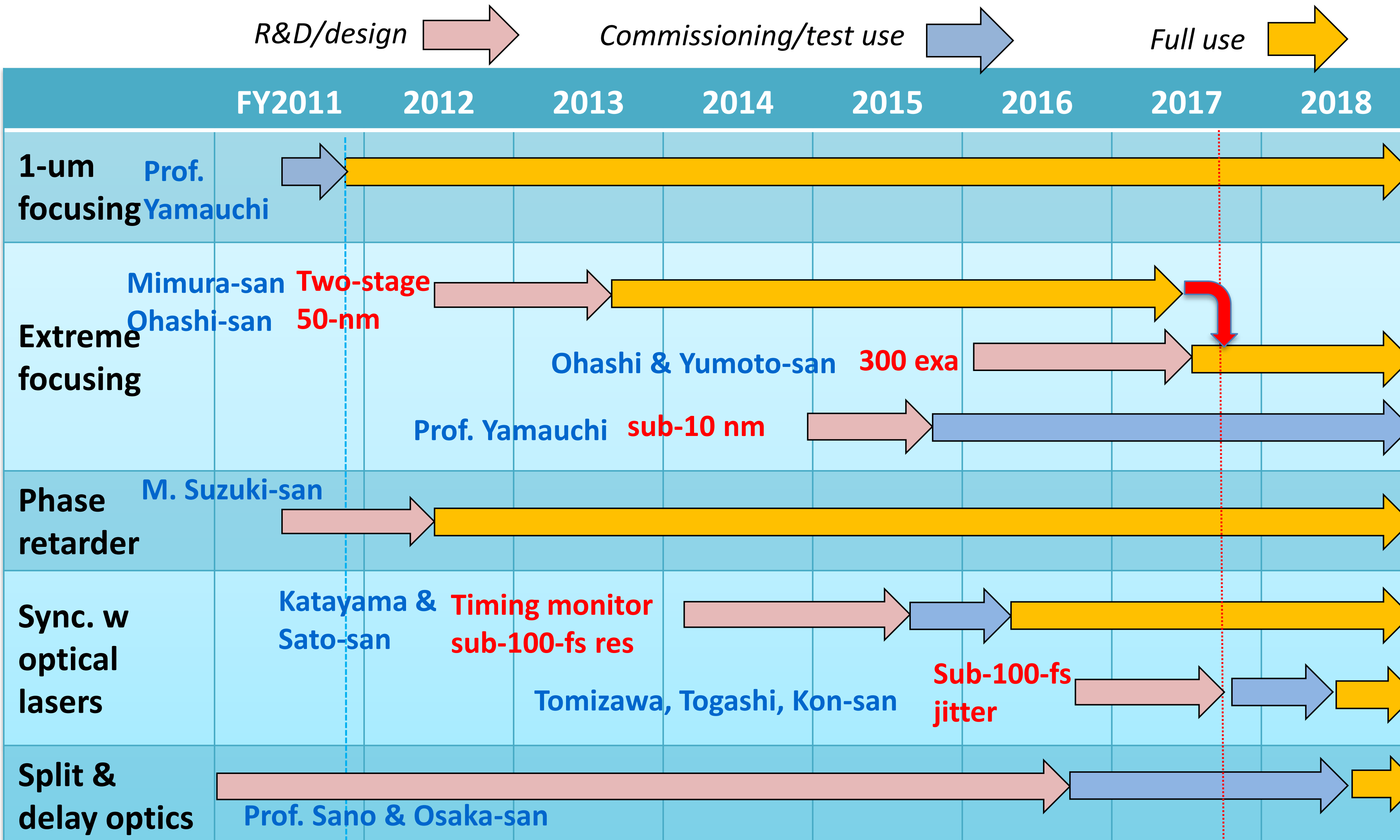
Publication



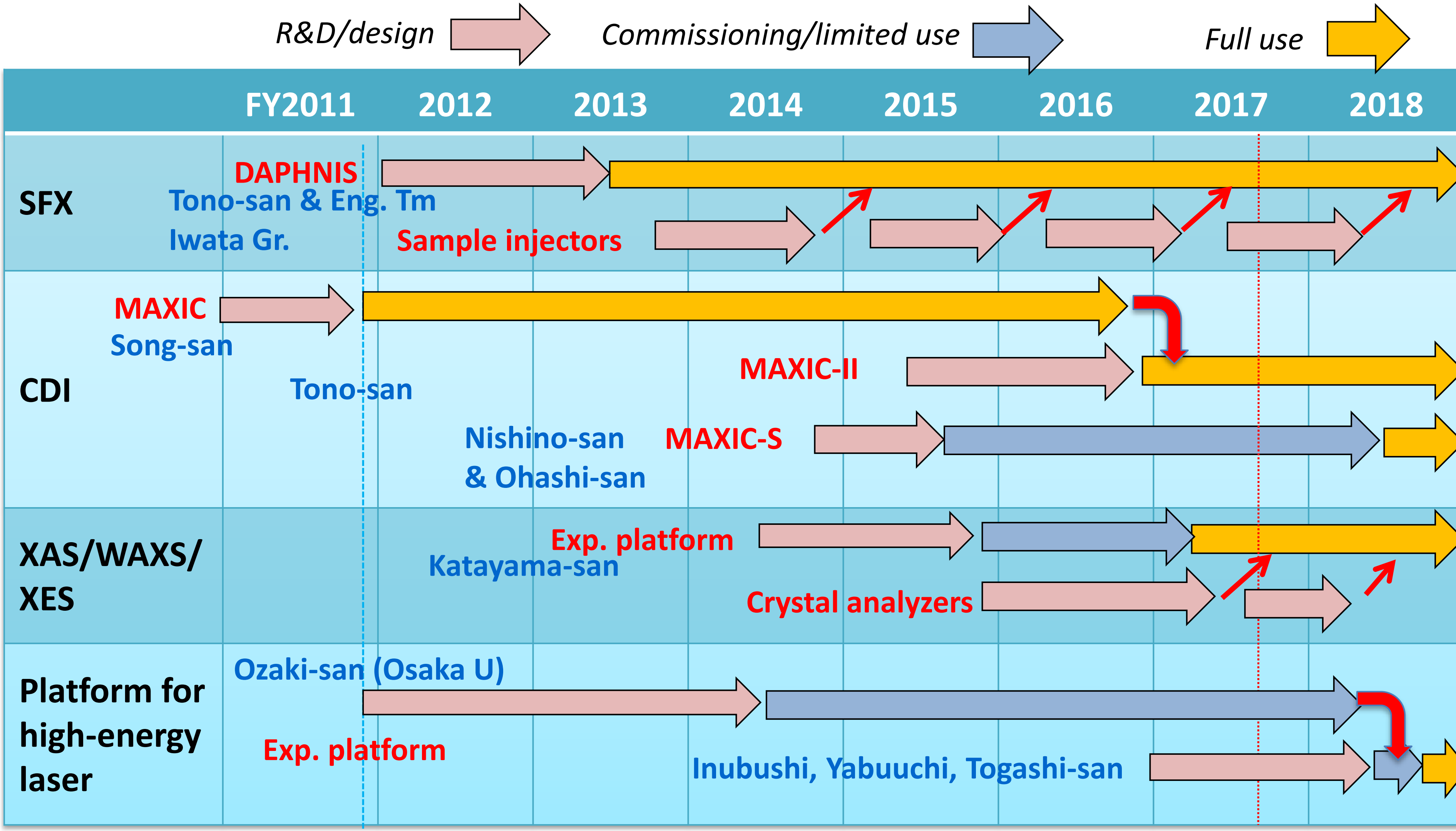
Request by MEXT: > 100 publications/year while keeping high visibilities

Contents

Development on hard X-ray optics & diagnostics



End-station instrument development

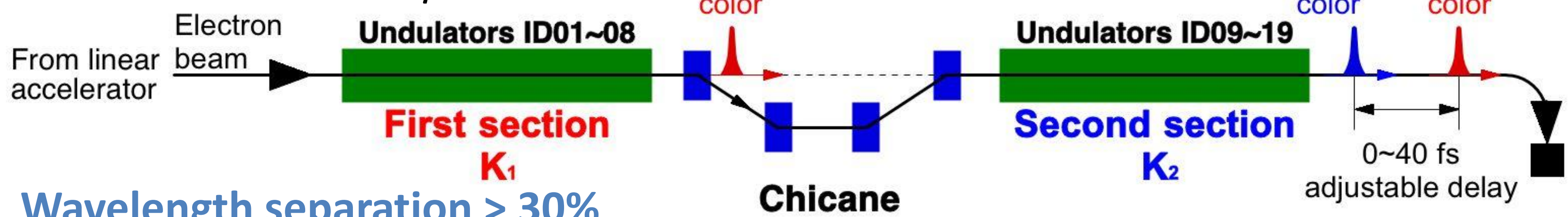


→ morning & afternoon session

Enhanced capabilities of 2-color + tight focus

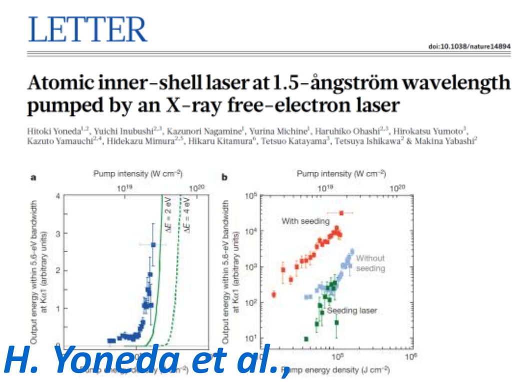
Hara et al, Nature Commun 4, 2919 (2014)

$$\lambda_1 = \frac{\lambda_U}{2\gamma^2}\left(1 + \frac{K_1}{2}^2\right) \qquad \lambda_2 = \frac{\lambda_U}{2\gamma^2}\left(1 + \frac{K_2}{2}^2\right)$$



Wavelength separation > 30%

Max. time interval: 40 fs → 300 fs @ 8 GeV (>10 keV)

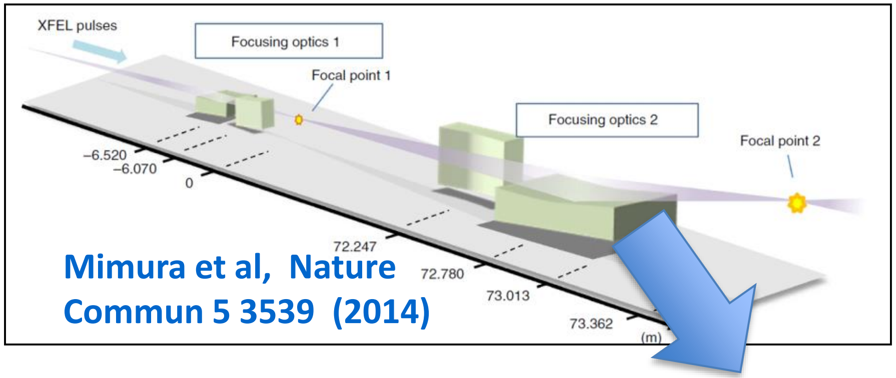

LETTER

doi:10.1038/nature14894

Atomic inner-shell laser at 1.5-ångström wavelength pumped by an X-ray free-electron laser

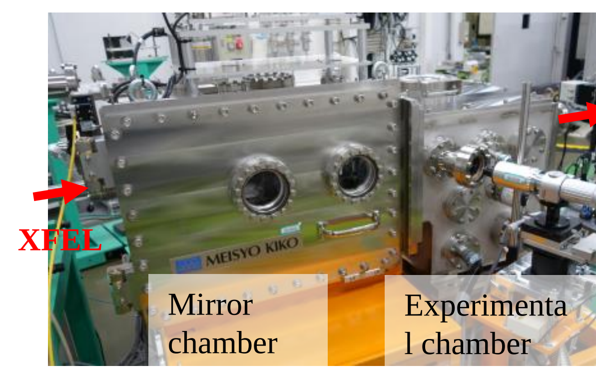
Hitoki Yoneda, Yuichi Inubushi, Kazunori Nagamine, Yurina Michine, Haruhiko Ohashi, Hirokatsu Yumoto, Kazuto Yamauchi, Hidekazu Mimura, Hikaru Kitamura, Tetsuo Katayama, Tetsuya Ishikawa & Makina Yabashi

H. Yoneda et al., Nature 524, 446 (2015).



Mimura et al, Nature Commun 5 3539 (2014)

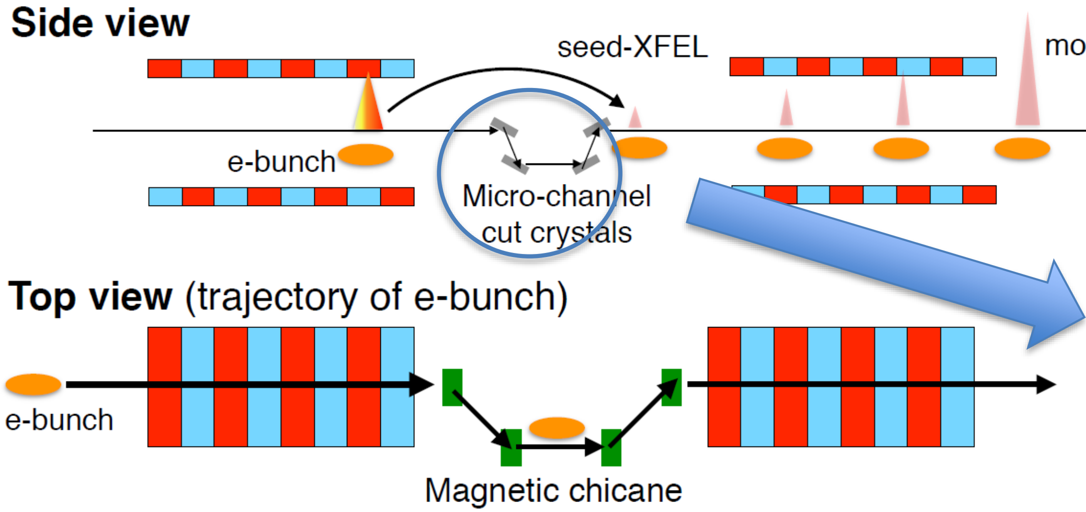
Two-stage 50-nm focusing →
Single-stage "300 exa" (3x10^{20} W/cm^2):
100-nm focusing with wider acceptance;
Tunability & stability drastically
improved with enlarging compatibilities
to various setups



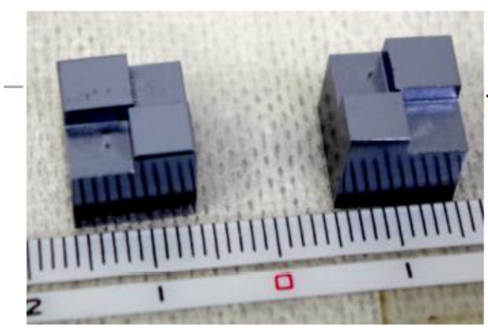
Example of on-going developments: Self seeding

Transmission self-seeding with thin diamond crystal:
Observed seeded signal, though unstable and weak than expected

Reflection self-seeding with micro channel-cut crystals



Inoue, Osaka et al.



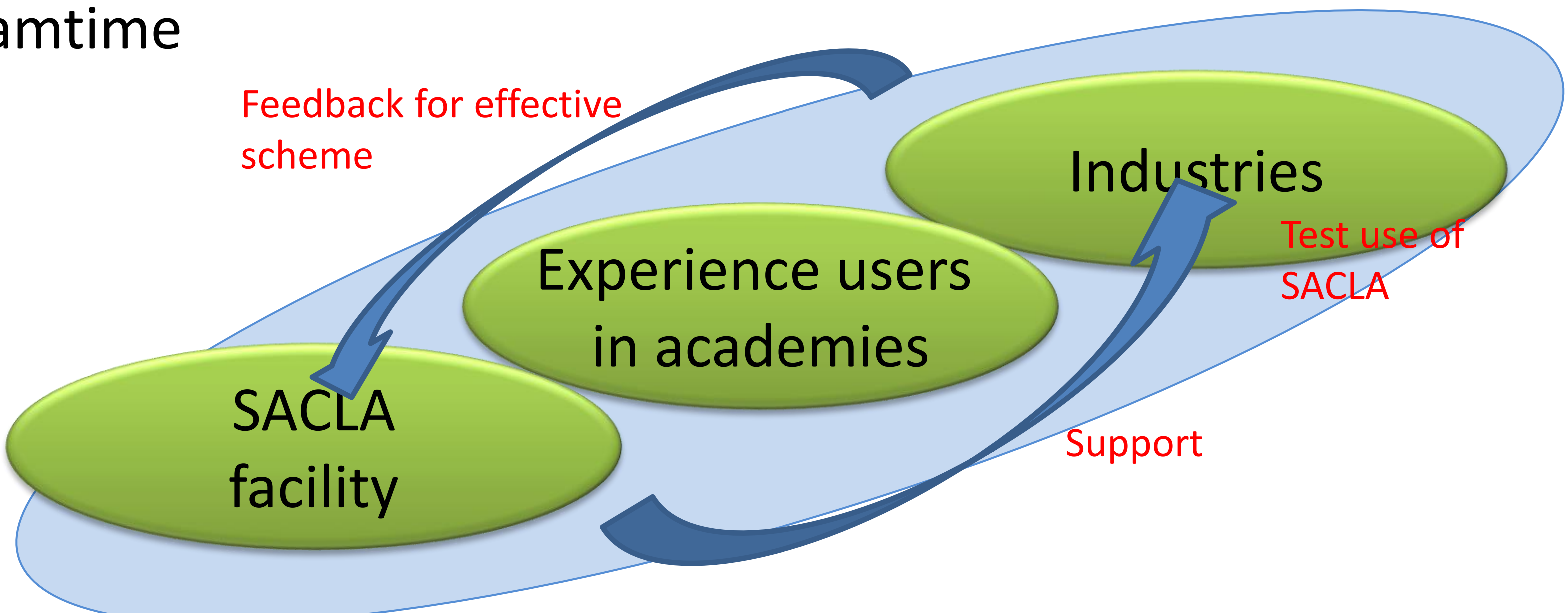
- Enhancement of pulse energy of monochromatic X-rays more than a factor of 10
- Preliminary test is planned in 2018

Contents

1. Facility updates
2. Statistics & highlights
3. Unique capabilities with new developments
4. Programs
5. Summary

1. SACLA Industry-Academy Partnership Program (domestic)　SACLA産業利用プログラム

- To promote industrial use with a help of experienced academic users
- Operated since FY2014
- 6 programs are running in FY2017 (metals, vehicles, soft matters, ceramics …)
- ~8 proposals/year from industrial party are conducted in public beamtime



2. SACLA Research Support Program for Graduate Students

SACLA大学院生研究支援プログラム

- To provide opportunities to stay and learn at SACLA for motivated graduate students
- Program students can access to facility time of SPring-8 & SACLA
- To enhance cooperation between universities & SACLA
- Since FY2014
- Ichiro Inoue (U Tokyo; FY2014-2015), Tomoya Kawaguchi (Kyoto U; FY2014), Hiroto Motoyama (U Tokyo; FY2016-2017), Satoru Egawa (FY2017), Yudai Seino (U Tokyo; FY2017)

  - Development of novel optics for soft x-ray FEL
  - Preparatory study for observation of vacuum birefringence effect

3. SACLA Basic Development Program (new)
SACLA基盤開発プログラム

- To designate key development targets of instruments and methods, we plan to invite proposals from international/domestic users
- To develop uniqueness of SACLA
  - Example:

    Instruments for x-ray pump x-ray probe 2-color experiments

    Development of exotic optical lasers for advanced experiments in materials/chemical science

    Simultaneous use of hard and soft X-ray FELs (BL2 & BL1)
- Not all proposals may be feasible within a short term, while your ambitious proposals would be important for considering future
- Details will be announced soon

Summary

- In 2017B, SACLA operation entered into a new phase (phase-2) by start of simultaneous running of 3 beamlines
- In parallel with steady operation, we continue development of beamlines, system, and instruments for enabling unique science at SACLA
- We would like to enhance communication and collaboration with users for advanced operation and development; we highly appreciate your proposals and inputs

Thank you for your attention
and enjoy the Meeting !

END

Summary: 2-color SASE at SACLA

	Hutch	$h\nu$1 (keV)	$h\nu$2 (keV)	# of ID1	# of ID2	Delay range（fs）	Net pulse energy（uJ）
2012	EH3	9.5	10	7	10	0-40	130
2013	EH5	9	8	12	8	—	100
	EH3	11	10	8	11	0-40	160
	EH3	7.4	7.2	5	13	0-4	180
	EH5	9	8	7	14	—	190
2014	EH5	9	8	7	14	—	190
	EH5	6.1	5.9	5	13	0-35	210
	EH3	9.1	8	5	16	—	300
	EH3	9.1	8	7	16	—	290
	EH3	6.9	6.7	6	13	0-73	180
	EH4	5.8	5.5	6	13	0-20	90
	EH5	6.1	5.9	8	13	0-80	120
	EH4	8	9	6	15	—	190
	EH4	8.9	8.1	6	15	—	160
2015	EH5	9	8	9	12	—	190
	EH5	9	8	7	14	—	200
	EH5	6.9	6.7	5	13	0-70	180