Present Status of PLS-II and PAL-XFEL

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Changbum Kim
Pohang Accelerator Laboratory

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- PAL-XFEL Status

Pohang Accelerator Laboratory

History of PAL

I. PLS

▪ Project started	April	1988
▪ User service started	Sept.	1995

II. Major Upgrade of the PLS (PLS-II)

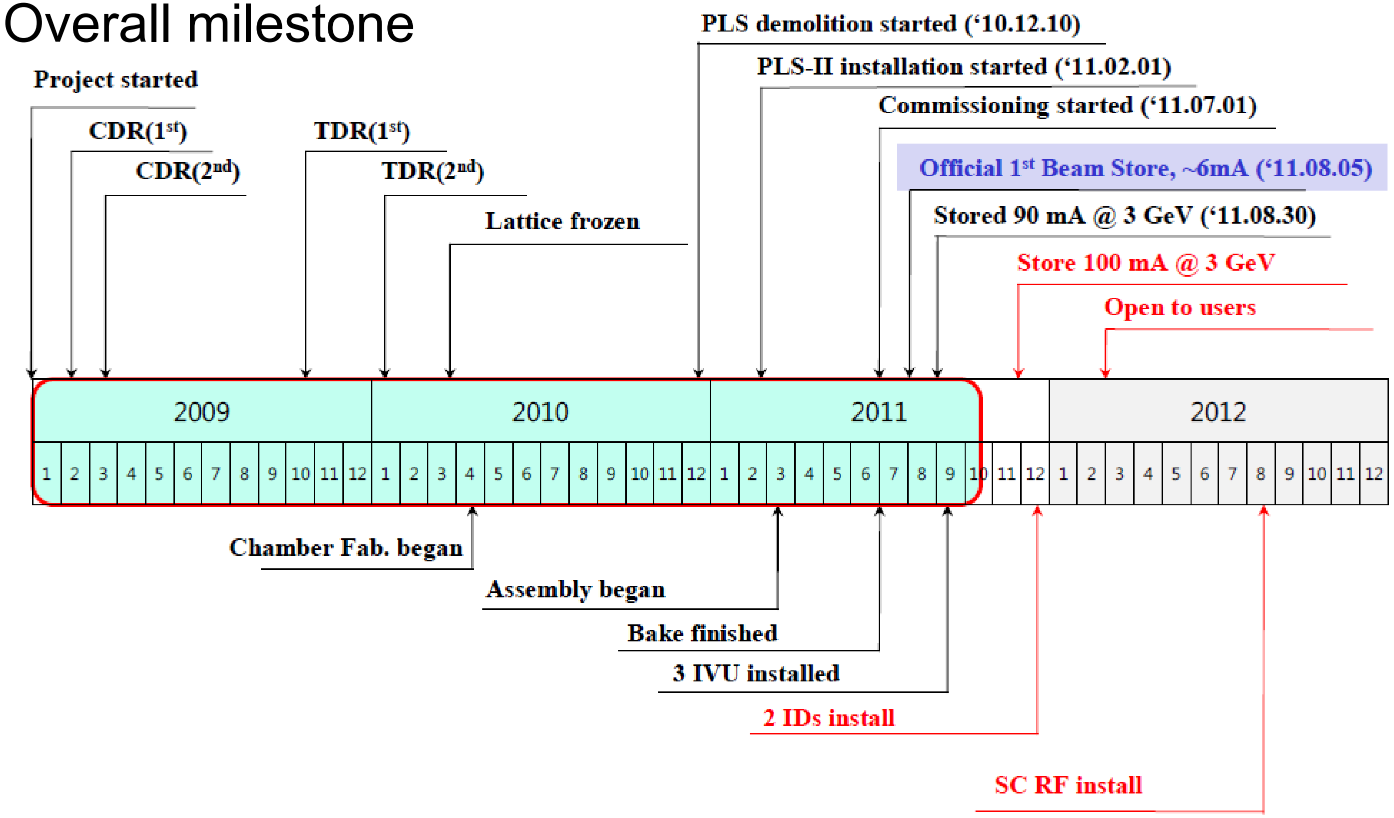
▪ 3.0 GeV PLS-II upgrade begin	Jan.	2009
▪ 3.0 GeV PLS-II upgrade completed	Dec.	2011
▪ User service started	Mar.	2012
▪ 3.0 GeV 400 mA top-up operation	July	2015

III. PAL-XFEL

▪ Project started	April	2011
▪ Beam commissioning started	April	2016
▪ Saturation of FEL (0.1 nm)	Nov.	2016
▪ User service started	June	2017

PLS Upgrade Project: PLS-II

1. Period : 3 year (One year break in user service)
2. Budget : 100 M $
3. Critical path : All 30 beamlines should be operated in PLS-II after one year shutdown.
4. Overall milestone



Goal of PLS-II

○ Main goals
- Beam energy : 2.5 → 3.0 GeV
- Current : 200 → 400 mA
- Storage ring emittance : 18.9 → 5.8 nmrad
- No. of insertion device : 10 → 20
- Top-up operation mode

○ Important improvement
- Introduction of superconducting RF
- In-vacuum undulator development
- New instrumentations: Libera BPM, etc.
- Improved beamline environment
- PAL-DCM development

PLS

PLS

Dismantling

DEC. '10

Re-installation

JAN. '11

PLS-II

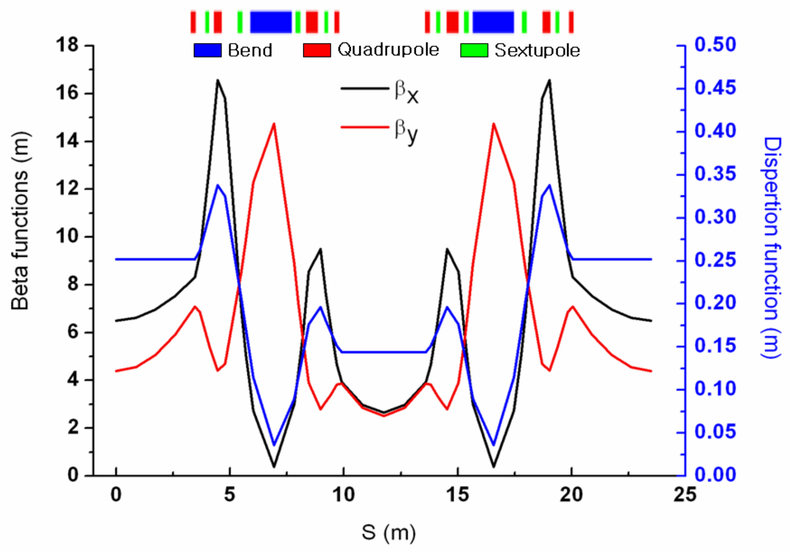
PLS-II

PLS-II Linac

- Thermionic electron gun
- 17 pulse modulators (200 MW, 7.5 μs)
- 17 klystrons (80 MW, 4 μs)
- 16 energy doublers (gain = 1.5)
- 46 accelerating sections

- Length = 170 m
- 3.0 GeV, full energy injection
- 2,856 MHz (S-band)
- 10 Hz, 1.5 ns, 1 A pulsed beam
- Norm. Emittance : 150 μmrad

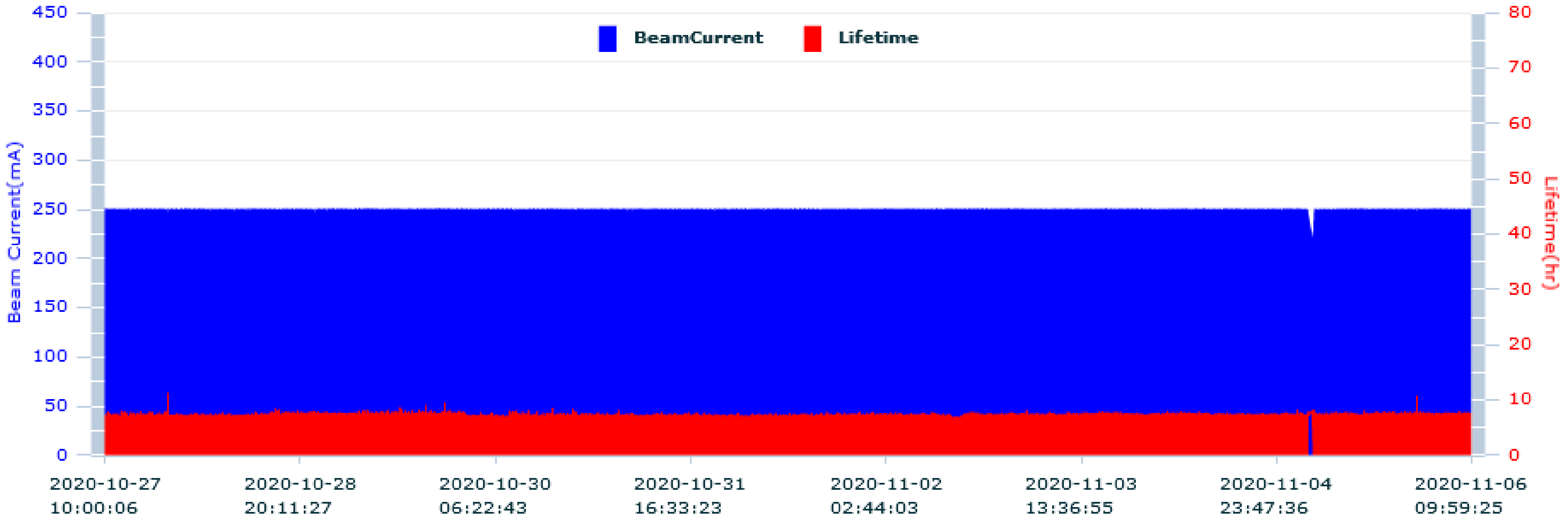
PLS-II Storage Ring



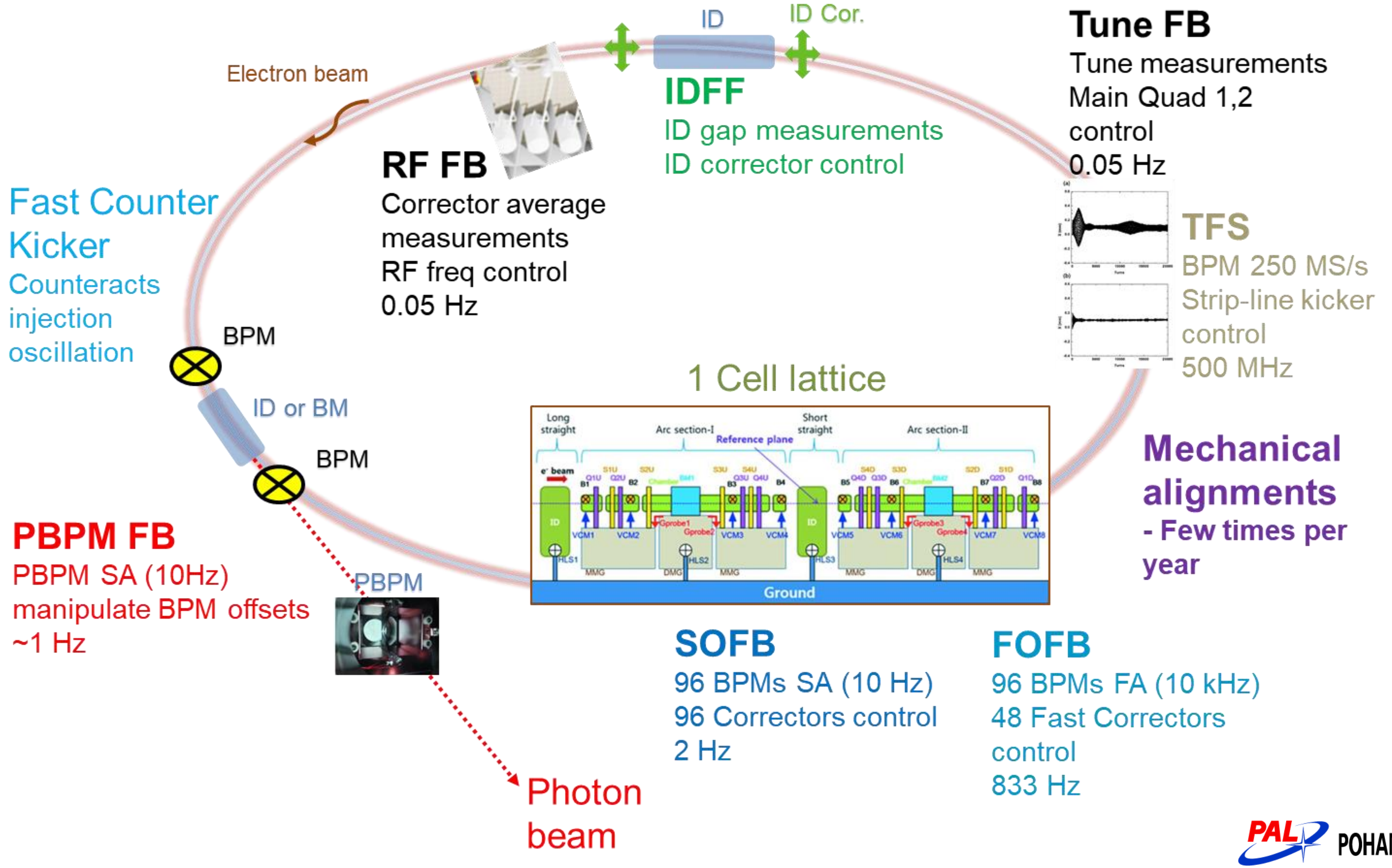
- Beam Energy 3.0 GeV
- Beam Current 400 mA
- Lattice DBA
- Superperiods 12
- Emittance 5.8 nm·rad
- Tune 15.37 / 9.15
- RF Frequency 499.97 MHz
- Circumference 280 m

PLS-II Top-up Operation

- Beam availability was higher than 97% in 2020.
- Beam current will be back to 400 mA at the end of 2021 with cryomodule #3

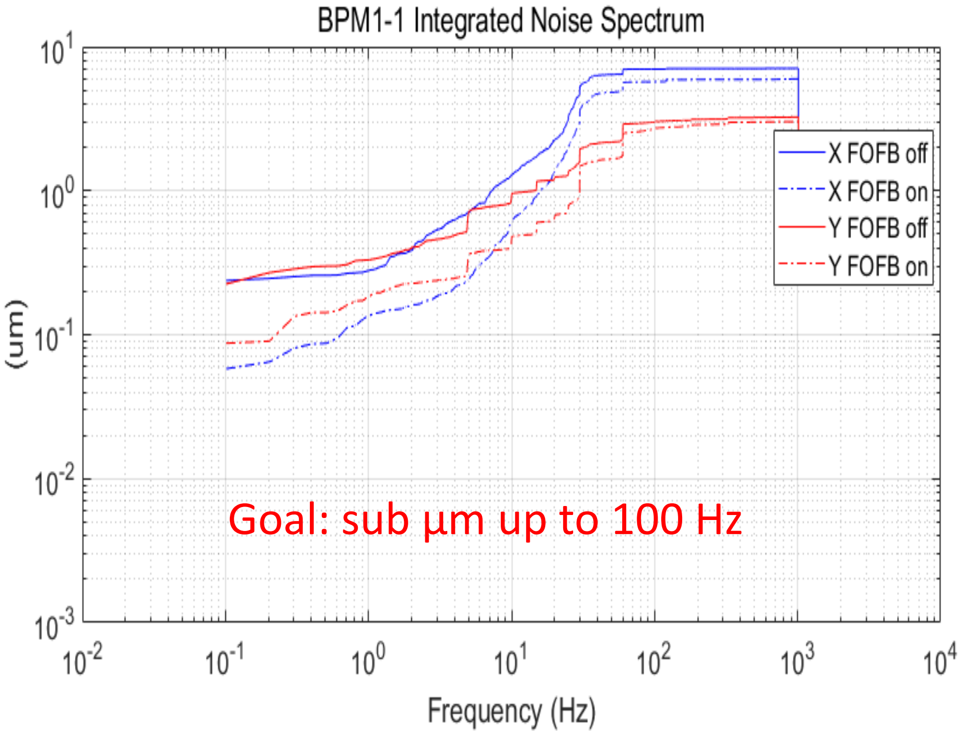


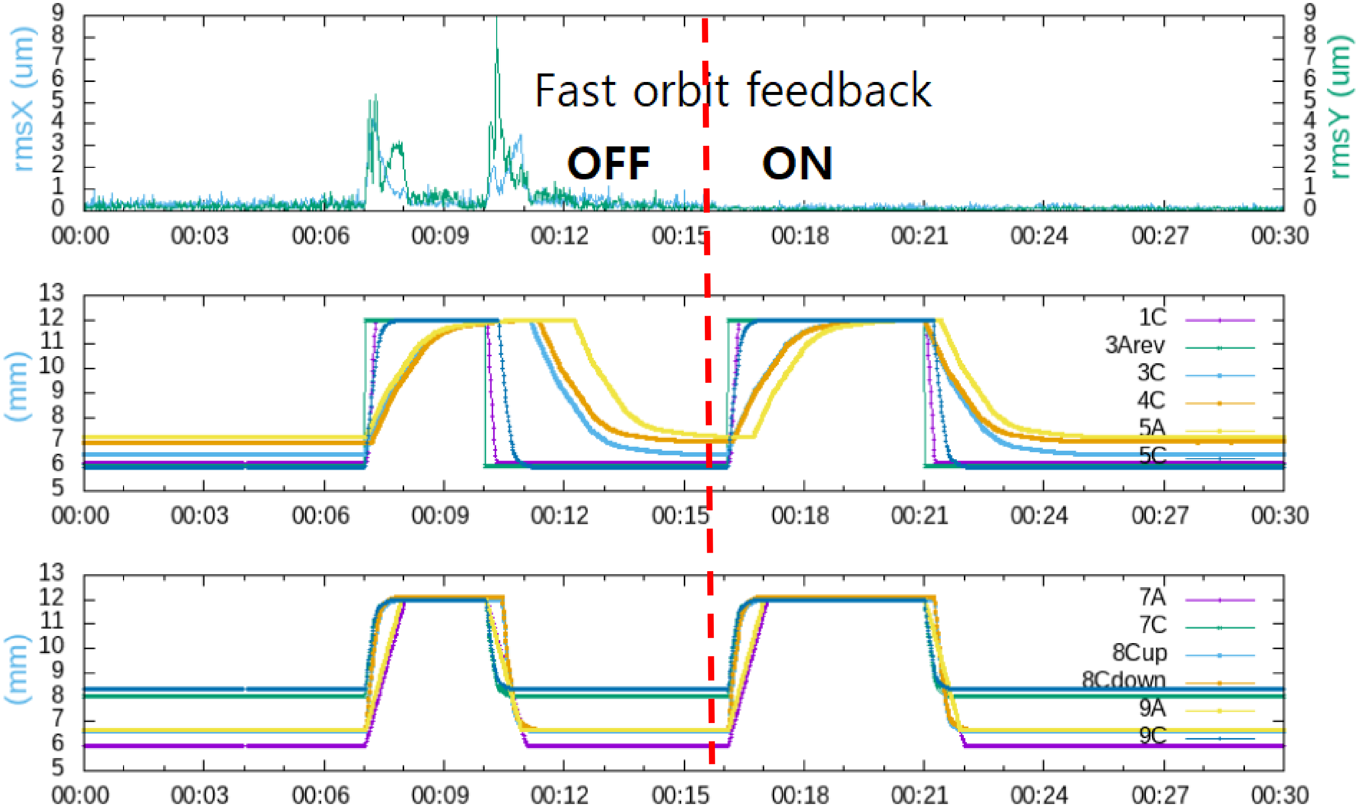
Instrumentations for orbit stability



Electron Beam Stability

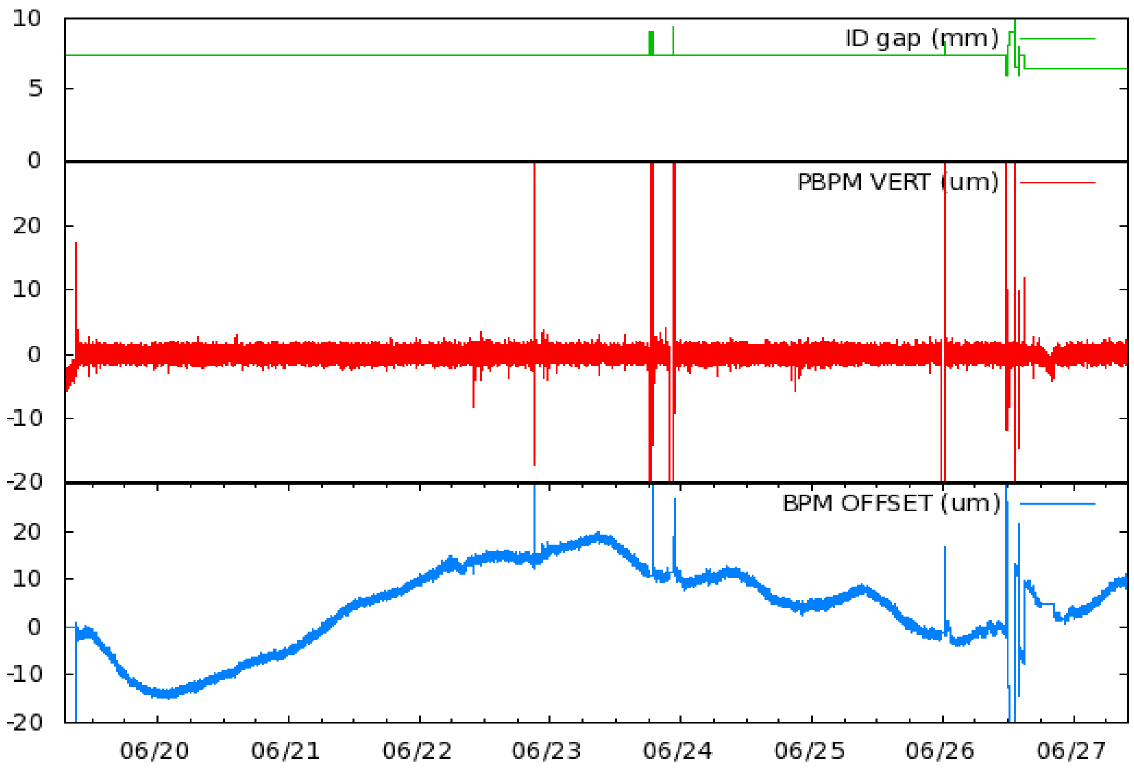
- Orbit change in 10 Hz slow reading: < 1 μm for 10 days
- Orbit change in 10 kHz fast reading: < 5 μm (H), < 3 μm (V)
- Less than 10% of beam size in both directions

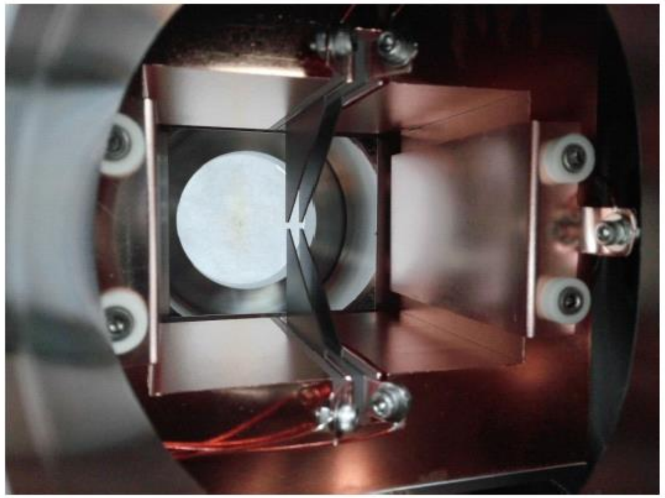




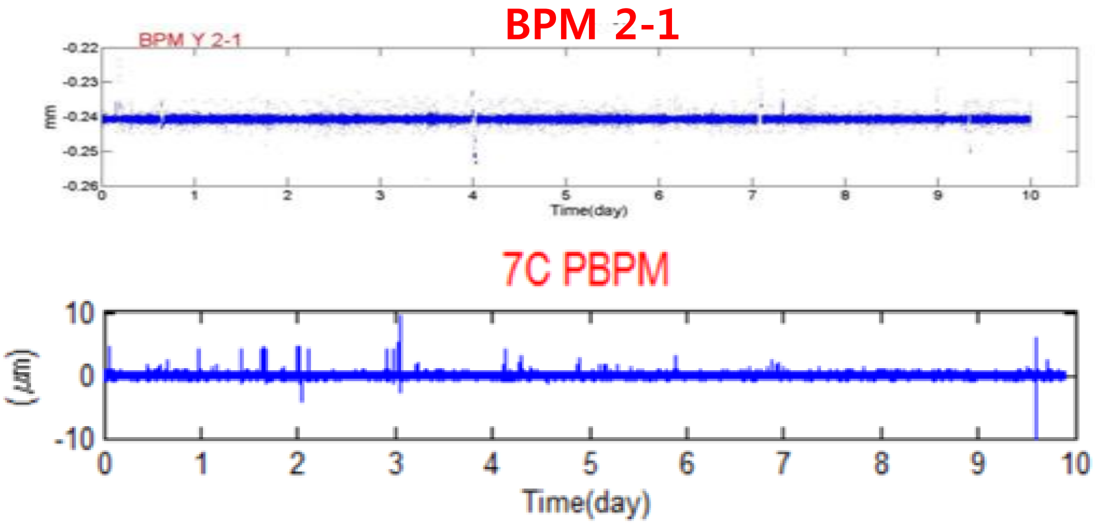
Photon Beam Stability

- Feedback is running in 13 beamlines with PBPMs
- Orbit change in 10 Hz slow reading: < 1 μm for 10 days
- Number of PBPM is increasing



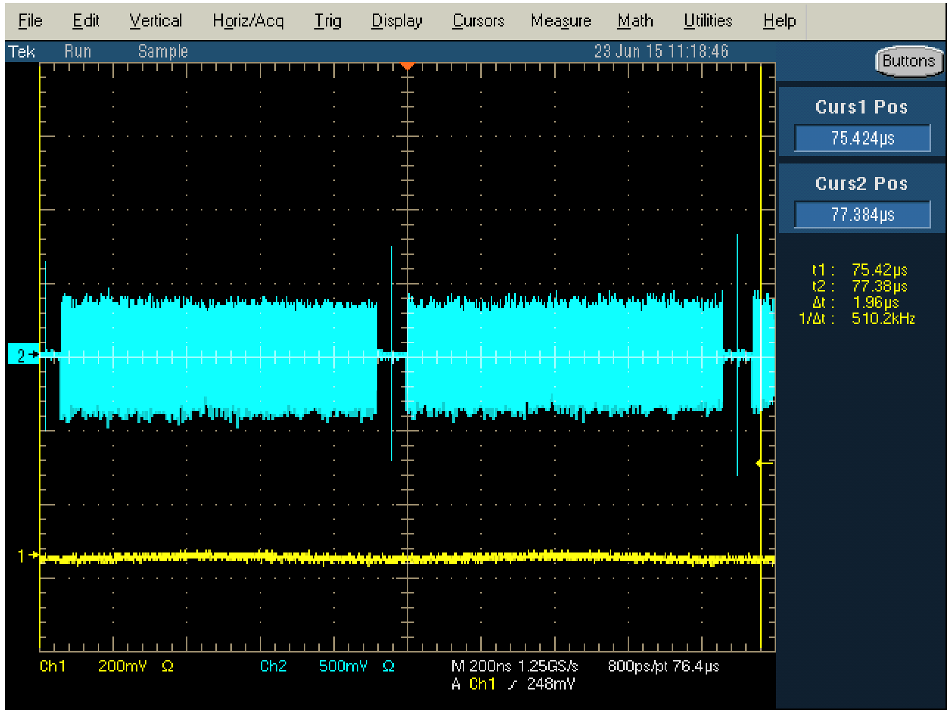


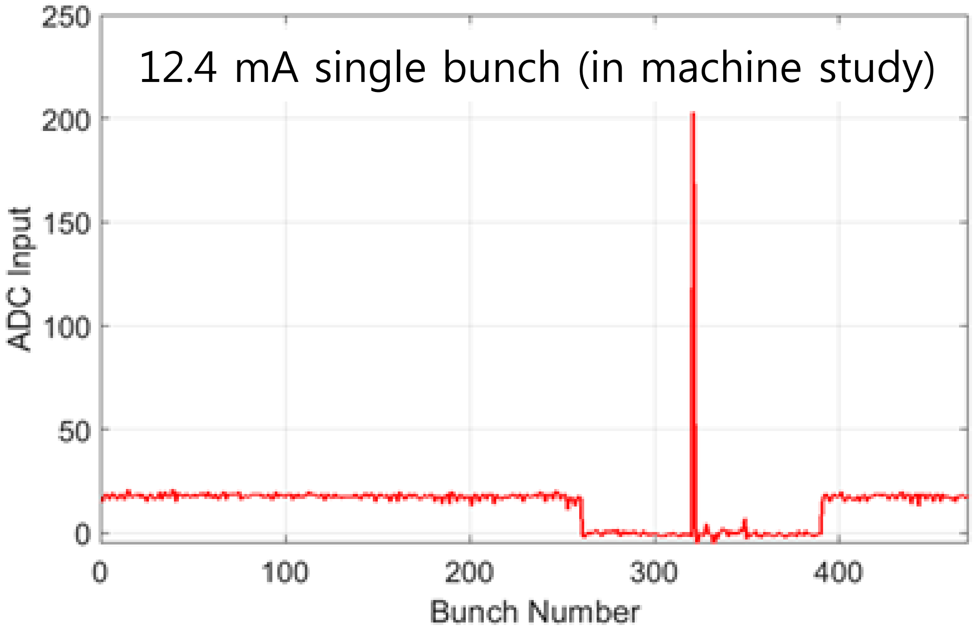
Inside of PBPM



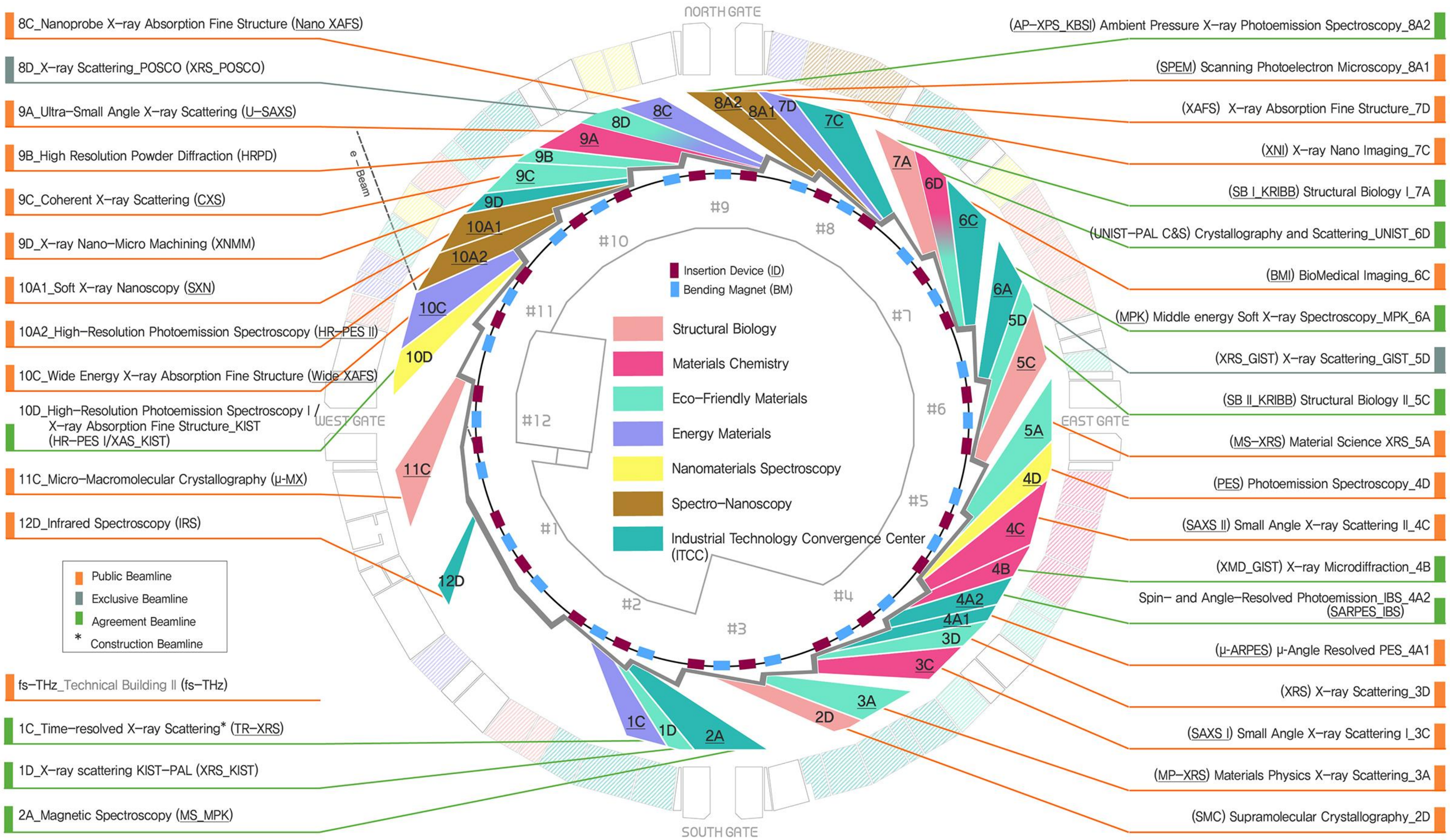
Hybrid Mode for Time Resolved Experiments

- Harmonic number: 470
- Multi-bunch mode: 400 bunches
- Hybrid mode: 300 bunches + Single bunch
- 4 mA single bunch current is available in user operation

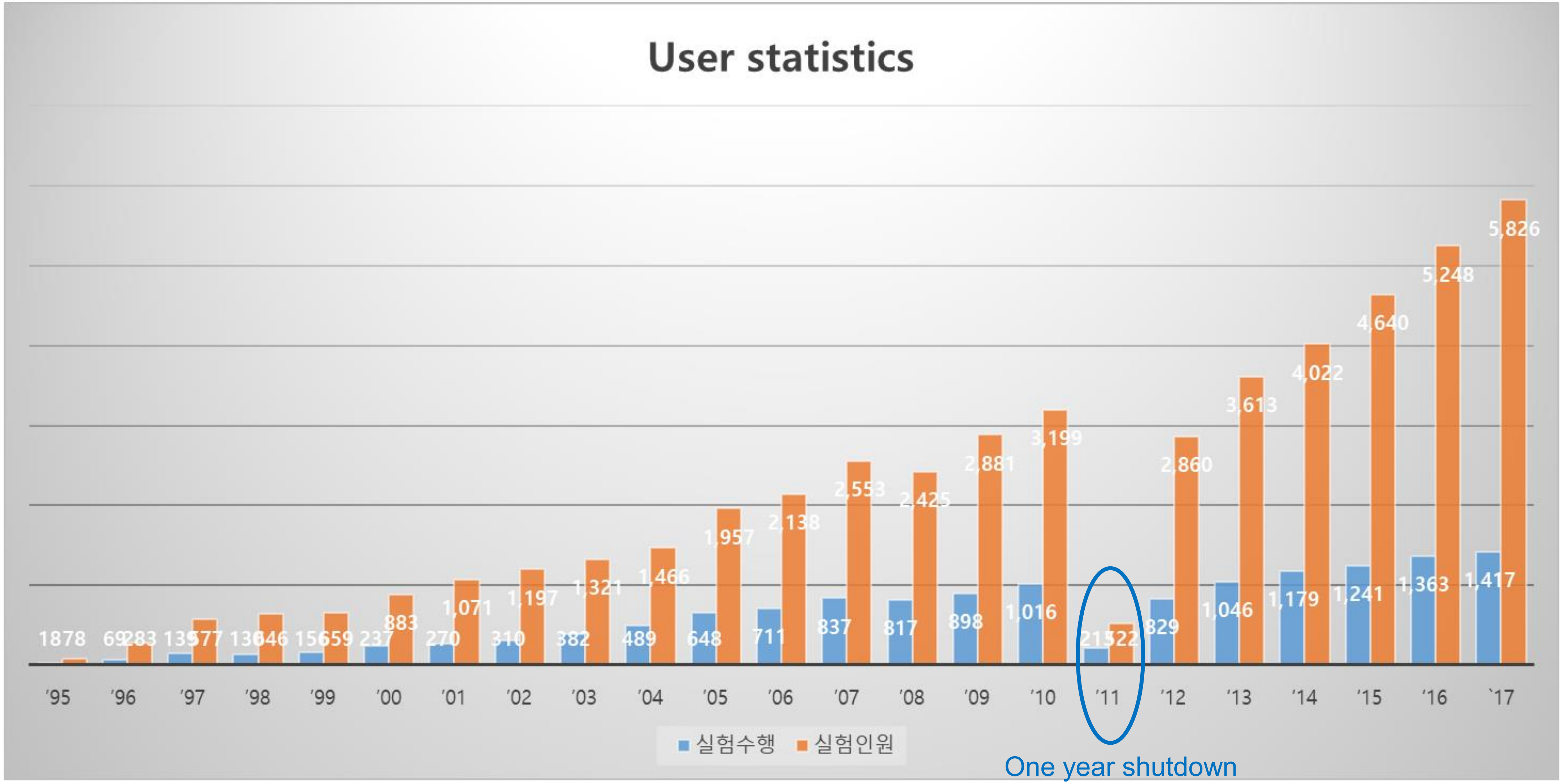




Beamline Map (36 Beamlines)

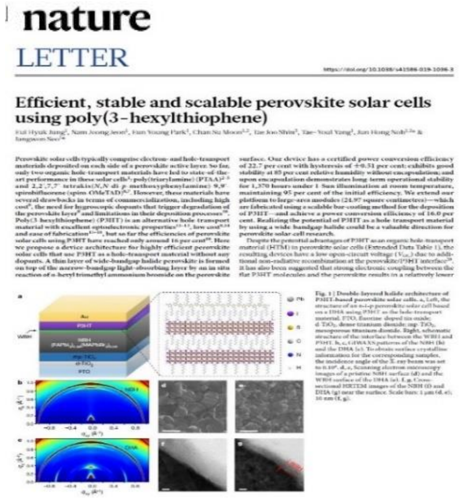


PLS-II User Statistics

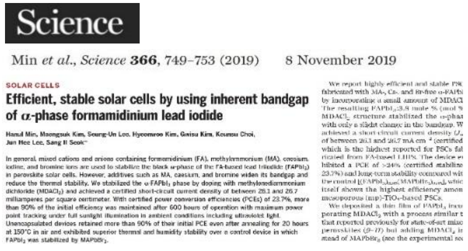


One year shutdown

PLS-II User Achievements (~2020)


nature
LETTER

Efficient, stable and scalable perovskite solar cells using poly(3-hexylthiophene)


Science

Min et al., Science 366, 749–753 (2019) 8 November 2019

SOLAR CELLS

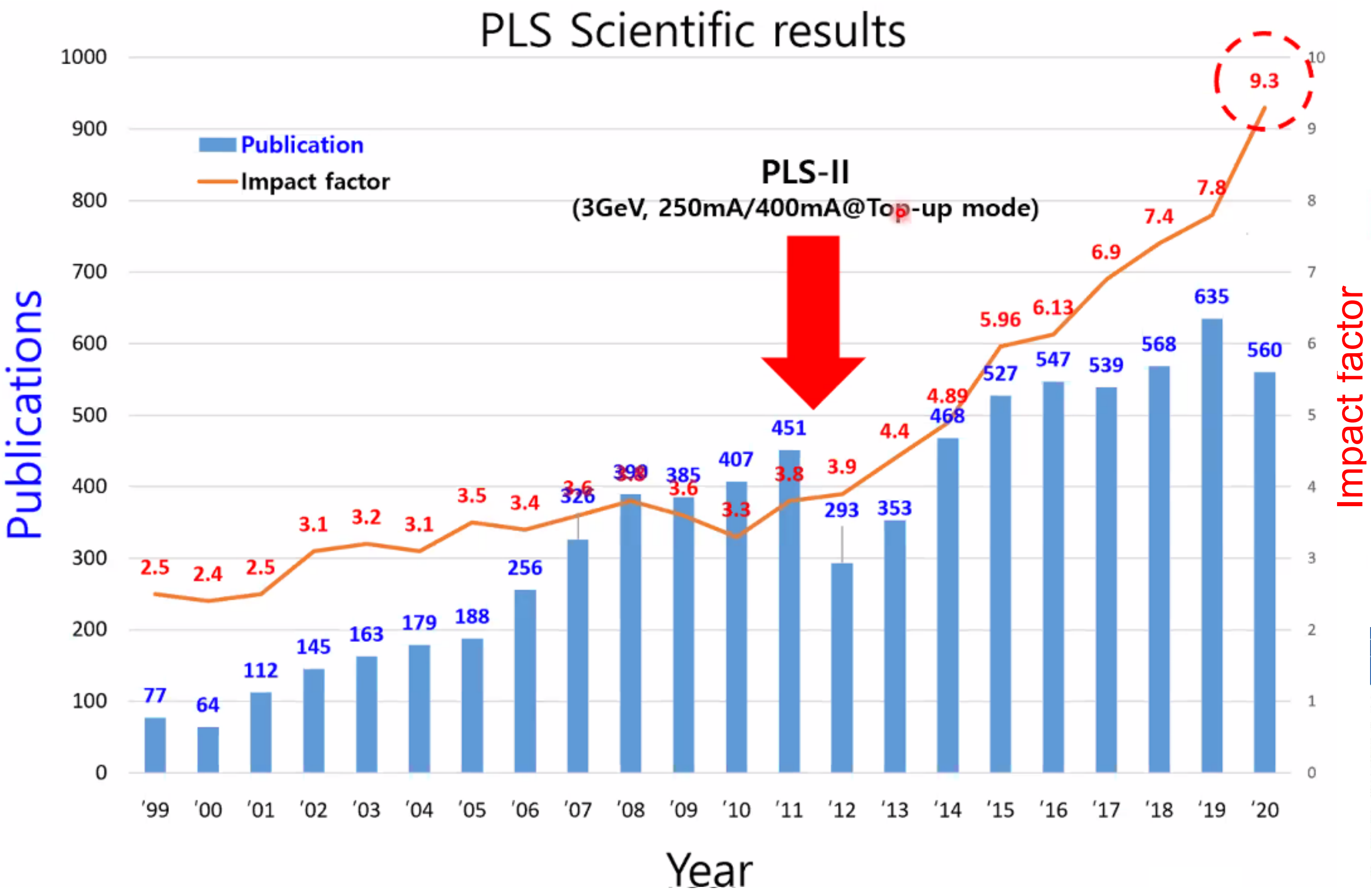
Efficient, stable solar cells by using inherent bandgap of α-phase formamidinium lead iodide

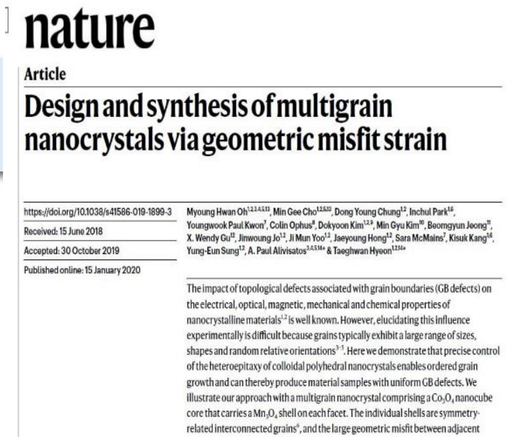

Science

Song et al., Science 367, 777–781 (2020) 14 February 2020

CATALYSIS

Dry reforming of methane by stable Ni–Mo nanocatalysts on single-crystalline MgO




nature

Article

Design and synthesis of multigrain nanocrystals via geometric misfit strain

https://doi.org/10.1038/s41586-019-1899-3

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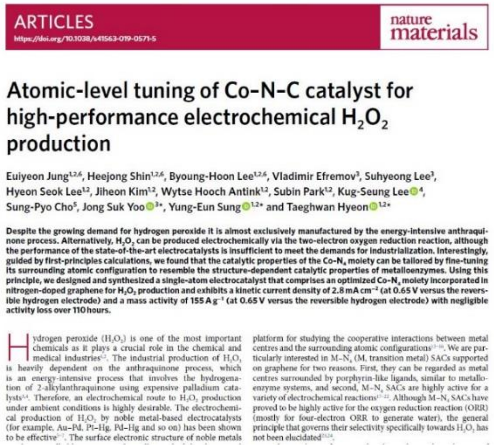
Published online: 15 January 2020

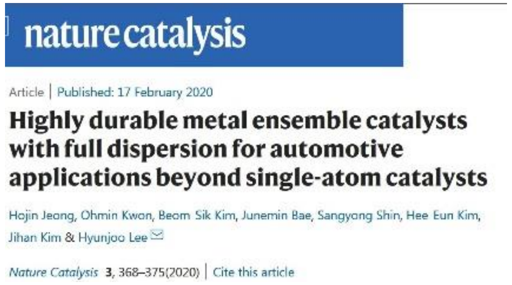
The impact of topological defects associated with grain boundaries (GB defects) on the electrical, optical, magnetic, mechanical and chemical properties of nanocrystalline materials is well known. However, elucidating this influence experimentally is difficult because grains typically exhibit a large range of sizes, shapes and random relative orientations. Here we demonstrate that precise control of the heteroepitaxy of colloidal polyhedral nanocrystals enables ordered grain growth and can thereby produce material samples with uniform GB defects. We illustrate our approach with a multigrain nanocrystal comprising a Co_3O_4 nanocube core that carries a Mn_3O_4 shell on each facet. The individual shells are symmetry-related interconnected grains, and the large geometric misfit between adjacent


ARTICLES

nature materials

Atomic-level tuning of Co–N–C catalyst for high-performance electrochemical H_2O_2 production

Euiyeon Jung, Heejong Shin, Byoung-Hoon Lee, Vladimir Efremov, Suhyeong Lee, Hyeon Seok Lee, Jiheon Kim, Wytse Hooch Antink, Subin Park, Kug-Seung Lee, Sung-Pyo Cho, Jong Suk Yoo, Yung-Eun Sung and Taeghwan Hyeon


nature catalysis

Article | Published: 17 February 2020

Highly durable metal ensemble catalysts with full dispersion for automotive applications beyond single-atom catalysts

Hojin Jeong, Ohmin Kwon, Beom Sik Kim, Junemin Bae, Sangyong Shin, Hee Eun Kim, Jihan Kim & Hyunjoo Lee

Nature Catalysis 3, 368–375(2020) | Cite this article

Korean 4GSR Project

- ❖ 4GSR project was officially approved.
- ❖ CDR was finished.
- ❖ Project will be started from 2022.

Parameter	Units	PLS-II	Korean 4GSR
Electron energy	GeV	3	4
Horiz. Emittance	pm	5800	58 (RB: 39)
Vert. Emittance	pm	~ 58	~ 5.8 (RB: 39)
Bunch length (rms)	ps	20	13 (50 with HC)
Circumference	m	280	800
Harmonic #		470	1332
RF frequency	MHz	500	500
Beam stability @ ID (x/y)	μm	< 4 / 2	< 2.5 / 0.45
Injection mode		Top-up	Top-up

PAL-XFEL

April 2011: PAL-XFEL project started (Total Budget: 400 M$)

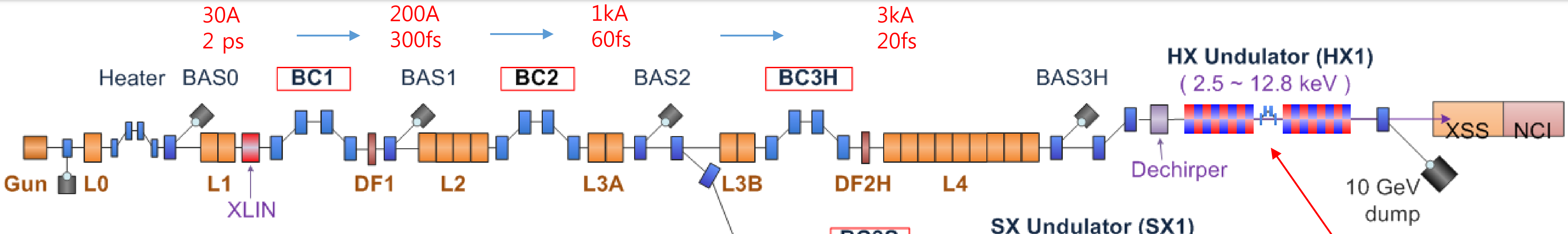
In 2017:
- User service started in June
- 120 days for user service

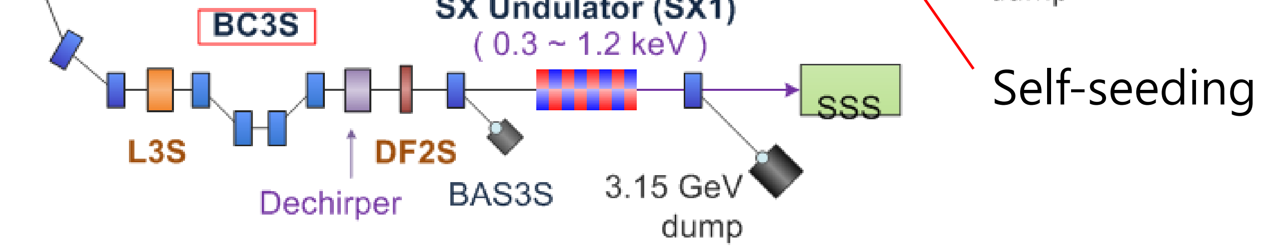
In 2018
- 140 days for user service
- HX self-seeding commissioning

In 2019
- 160 days for user service
- 60 Hz operation started

In 2020
- 170 days for user service
- HX self-seeding user service started

PAL-XFEL Parameters



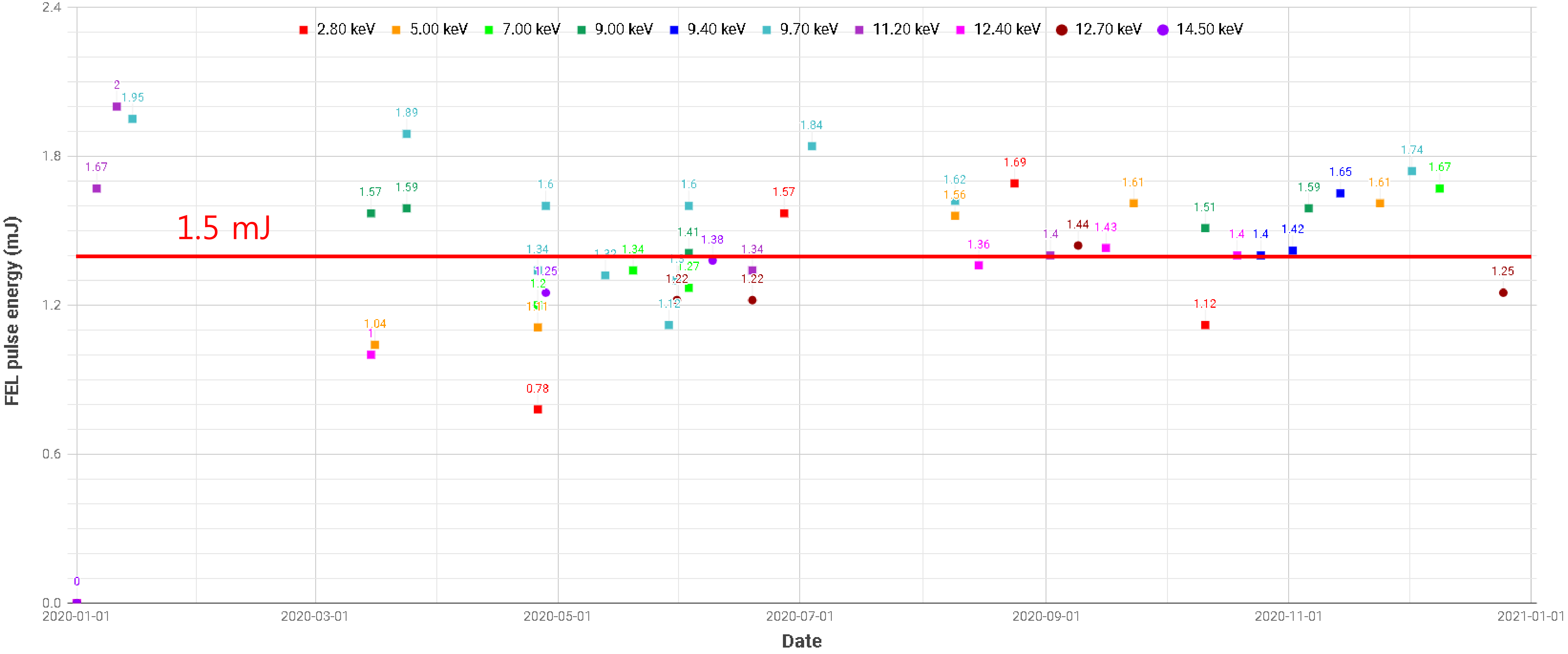


Main parameters

e^- Energy	10 GeV
e^- Bunch charge	20-200 pC
Slice emittance	< 0.4 mm mrad
Repetition rate	60 Hz
Bunch length	5 fs – 50 fs
Peak current	3 kA
SX line switching	Kicker Magnet

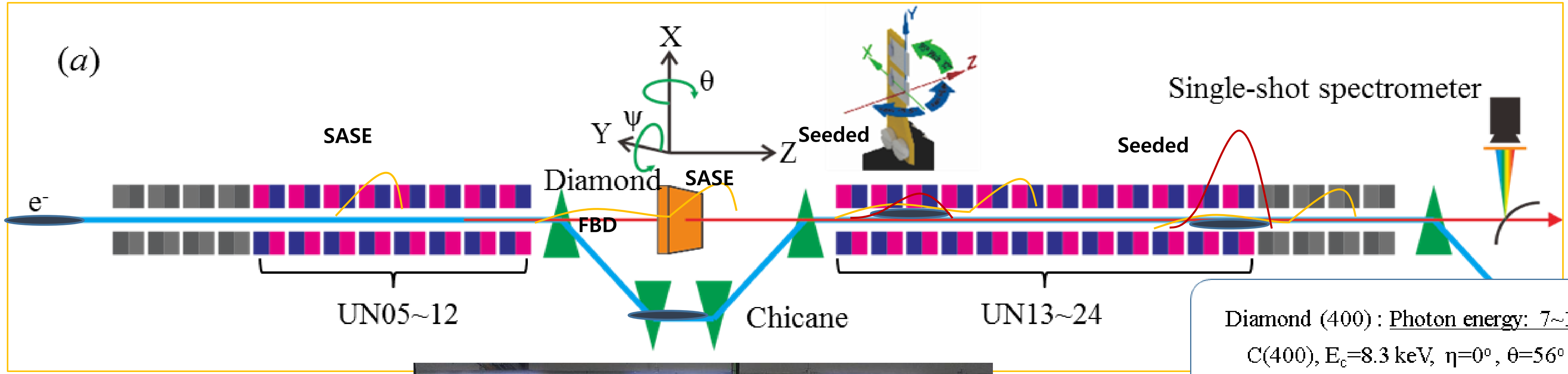
Undulator Line	HX	SX
Photon energy [keV]	2.4 ~ 15	0.28 ~ 1.0
Beam Energy [GeV]	4 ~ 11	3.0
Wavelength Tuning	Energy	Gap
Undulator Type	Planar	Planar
Undulator Period / Gap [mm]	26 / 8.3	35 / 9.0

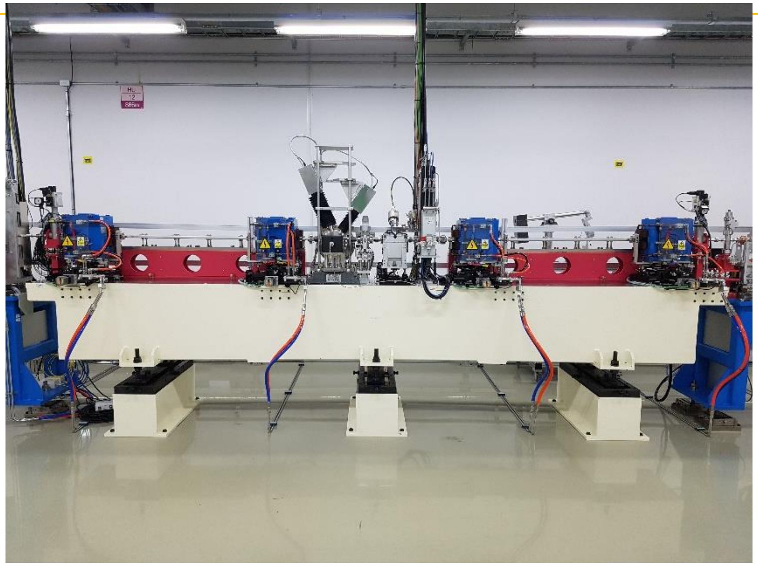
FEL Pulse Energy of User Service (2020)

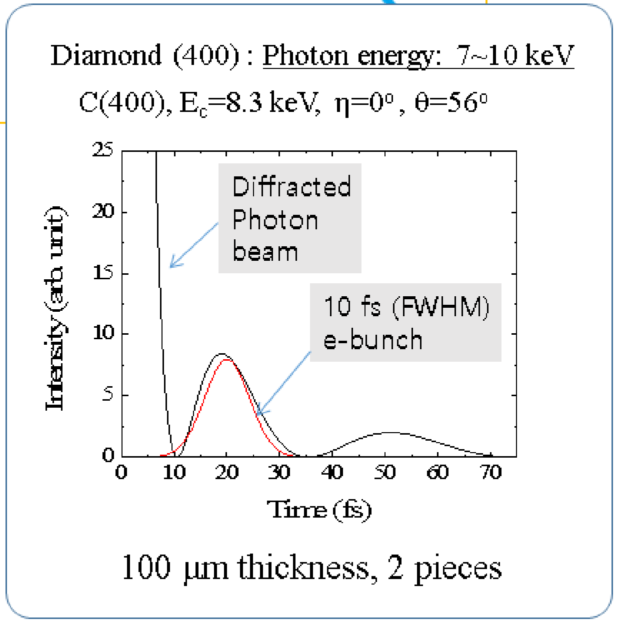


Hard X-ray Self-Seeding

- Schematic of hard x-ray self-seeding with a diamond crystal

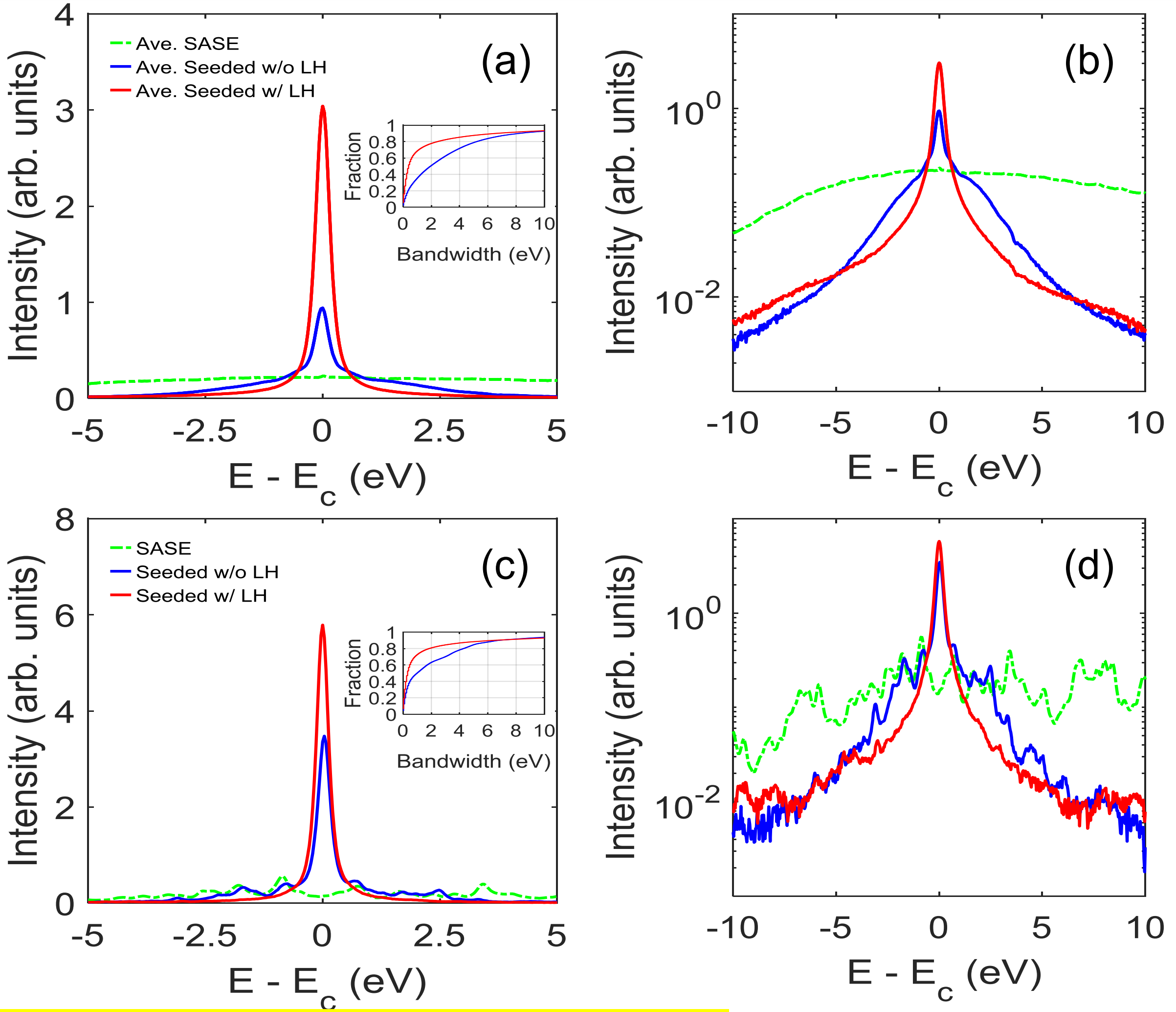






Self-Seeded FEL at 9.7 keV

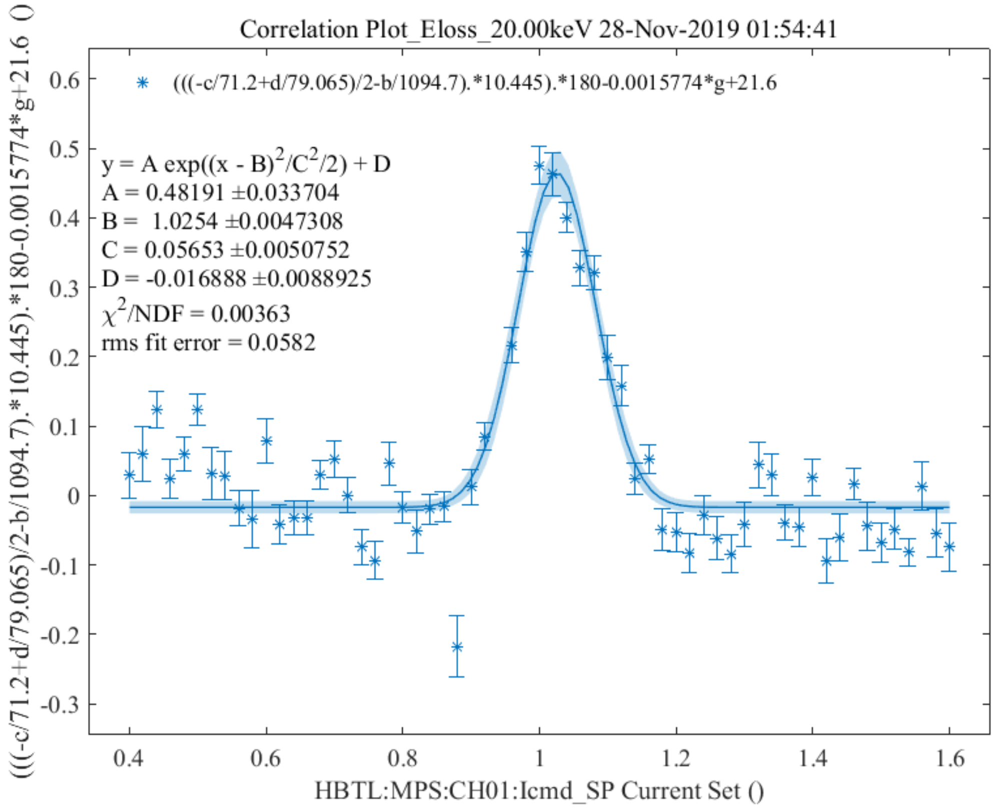
- Photon Energy Ec = 9.7 keV
- Averaged FEL energy: **~850 μJ (~1.5 mJ for single shot)**
- SASE bandwidth (FWHM) = 27 eV
- Measured bandwidth = 0.35 eV (Resolution = 0.26 eV)
- De-convoluted bandwidth (FWHM) = **0.22 eV**
- FEL Pulse duration = ~ 20 fs
- Chicane time delay = 30 fs
- Bragg orientation = [115]
- Diamond thickness = 100 μm (c100)
- Portion of SASE in seeded FEL: ~6 %
- **Fraction of energy enclosed within ±1 eV : ~ 80%**



Peak brightness (photons/s/ mm^2 /mrad^2/0.1% BW): 5 x 10^{35}

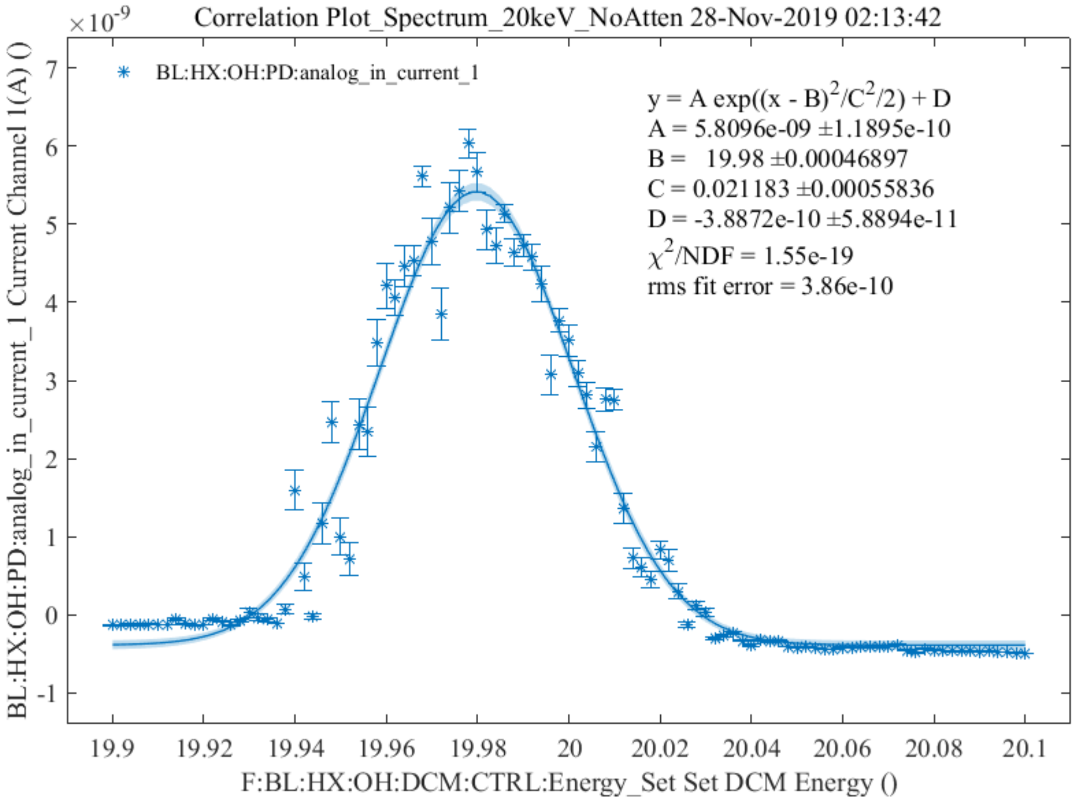
Extending Photon Energy up to 20 keV

Pulse Energy



FEL pulse energy: ~0.48 mJ
Undulator K = 1.409
Electron beam energy: 10.446 GeV

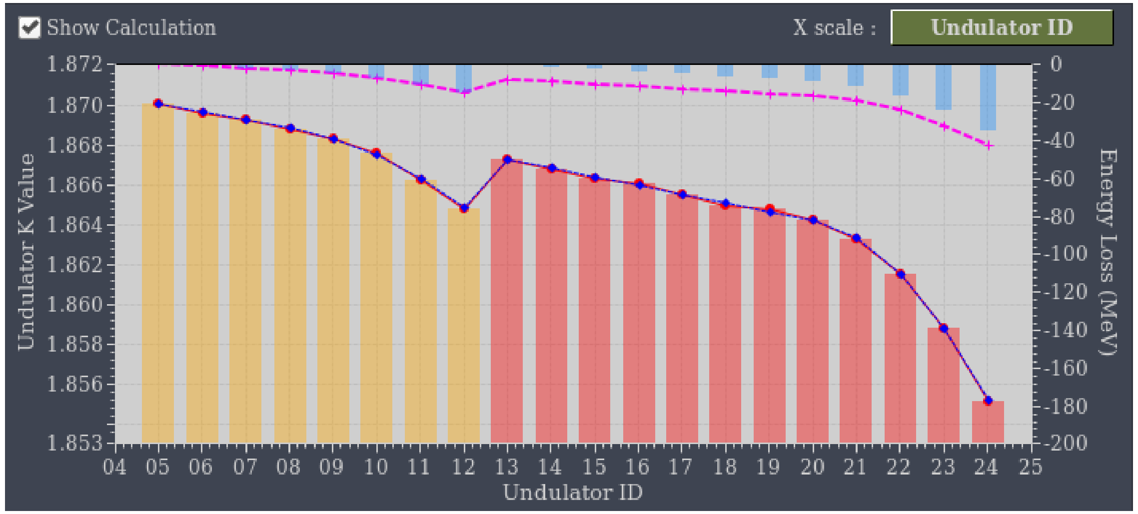
Spectrum



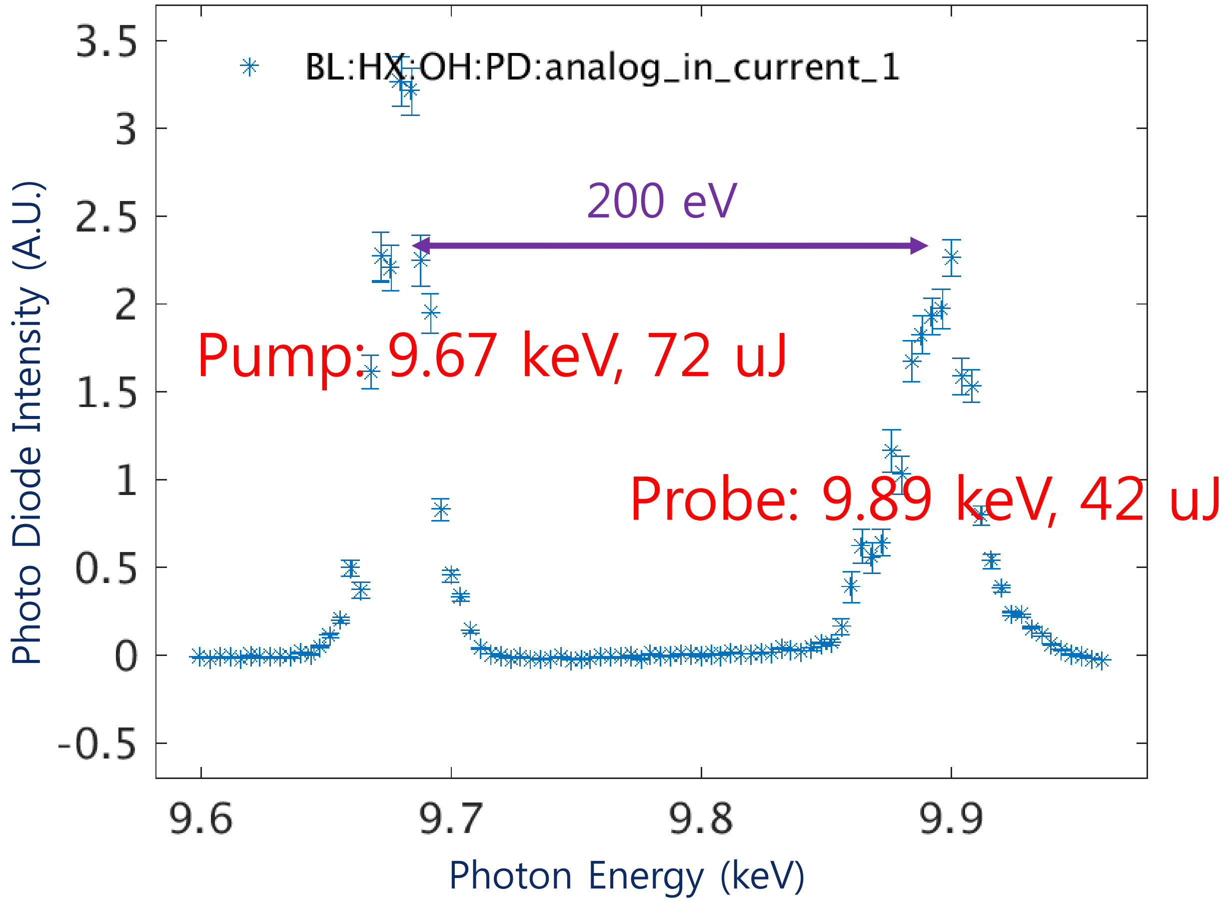
Bandwidth: ~ 21.2 eV (rms)

Two-Color FEL Generation

- 8 and 12 undulators were used before and after the self-seeding section.
- Two-color FEL pulses were obtained successfully.



Undulator Gap Setting for Two-Color FEL

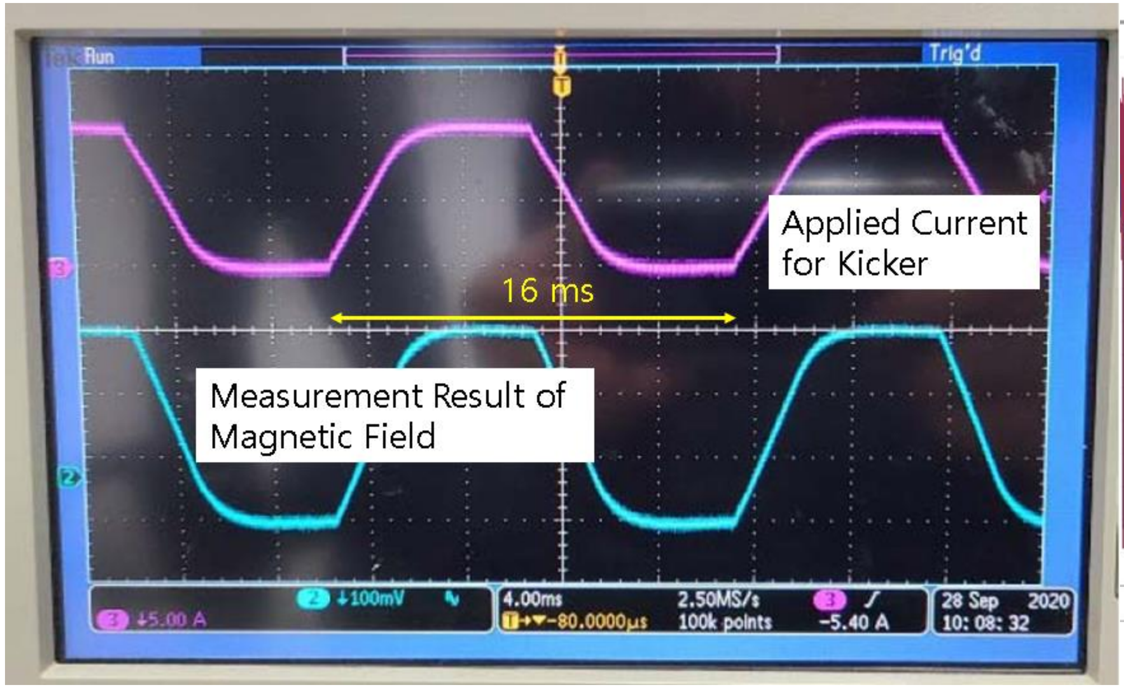


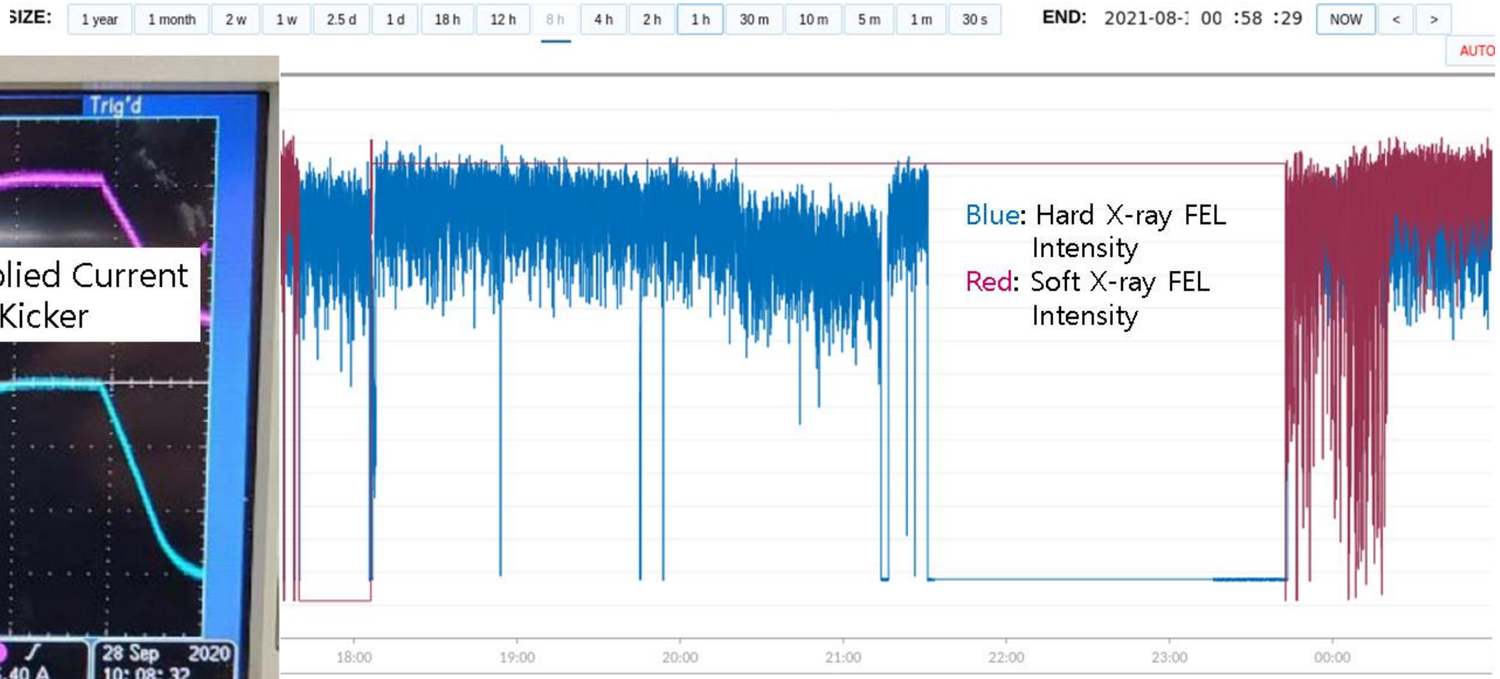
Photon Energy Measurement of Two-Color FEL

Parallel Operation of Hard X-ray (30 Hz) and Soft X-ray (30 Hz)

- Kicker and septum magnets were installed in soft X-ray branch line
- Machine studies are ongoing for parallel operation

Name	DBRType	Units	Processing	Scale	Time (local)	Value	Notes
BL:HX:OH:QBPM1:analog_in_totsum	DBR_SCALAR_DOUBLE		raw	linear	2021-08-13 **21:33:19**	7.001874018417634e-11	
SU1E:SCM10:Stats1:MaxValue_RBV	DBR_SCALAR_DOUBLE		raw	linear	2021-08-13 **18:06:31**	3344	





Thank you for your attention!