Status of PLS-II and PAL-XFEL

Changbum Kim on behalf of PLS-II and PAL-XFEL



November 13, 2024

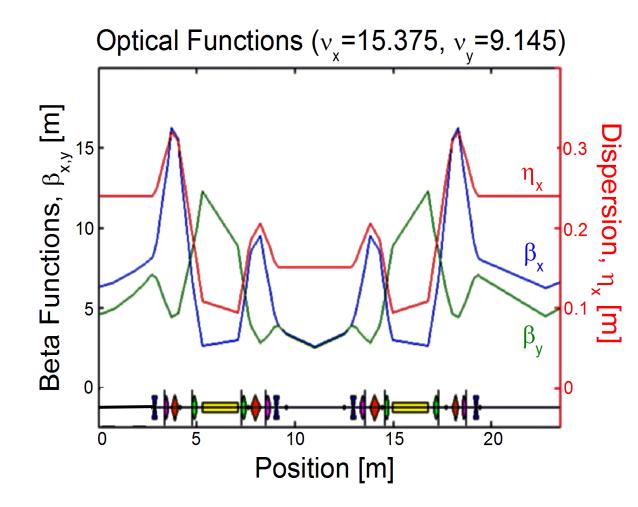
Pohang Accelerator Laboratory





PLS-II Operation Status

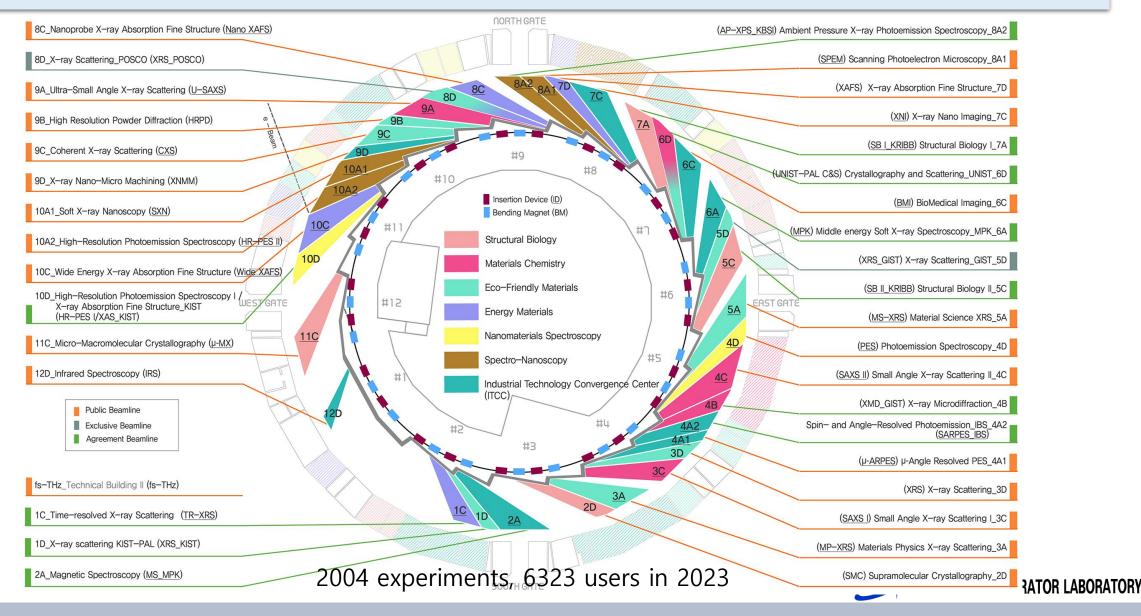




Parameter	Value
Circumference	281.82 m
Super-period	12
Energy	3 GeV
Beam current	250 ~ 400 mA
Emittance	5.8 nm rad
Emittance coupling	< 1 %
Energy spread	0.1 %
Momentum compaction	0.0013
Bunch length	16 ps
Tune (H/V)	15.375 / 9.145
Chromaticity (H/V)	3/3



36 Beamlines of PLS-II



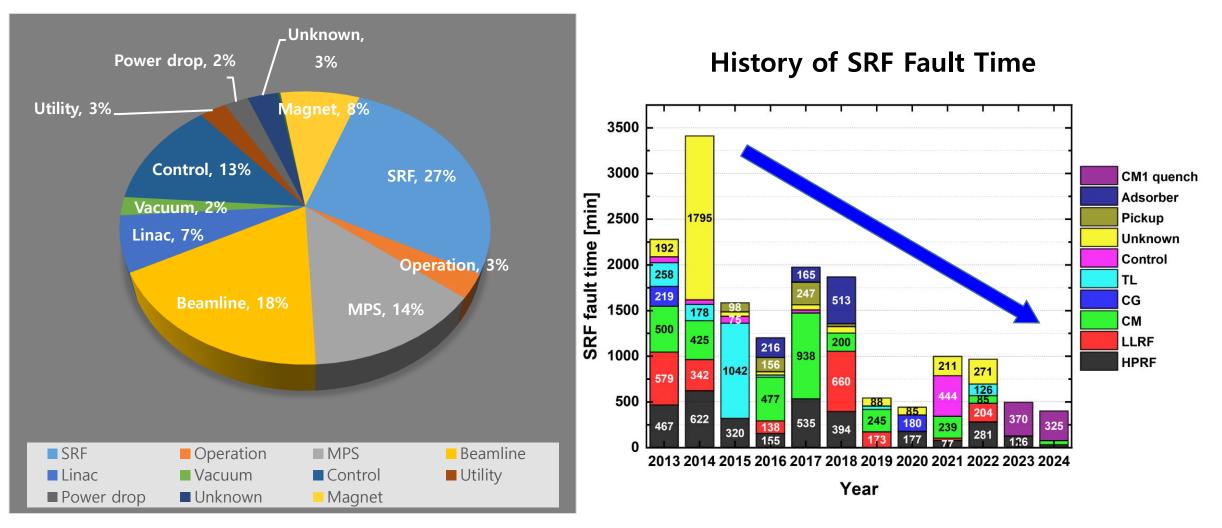
Operation Requirements of PLS-II

- User beamtime: 190 days
- Beam availability: > 97%
- 3 GeV top-up operation
- Beam current: 250~400 mA
- Beam stability < 1 μm rms</p>
- Photon beam stability < 2 μm rms</p>
- Beam stability @ ID gap change < 6 μm rms
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LABORATORY

Machine Fault of PLS-II

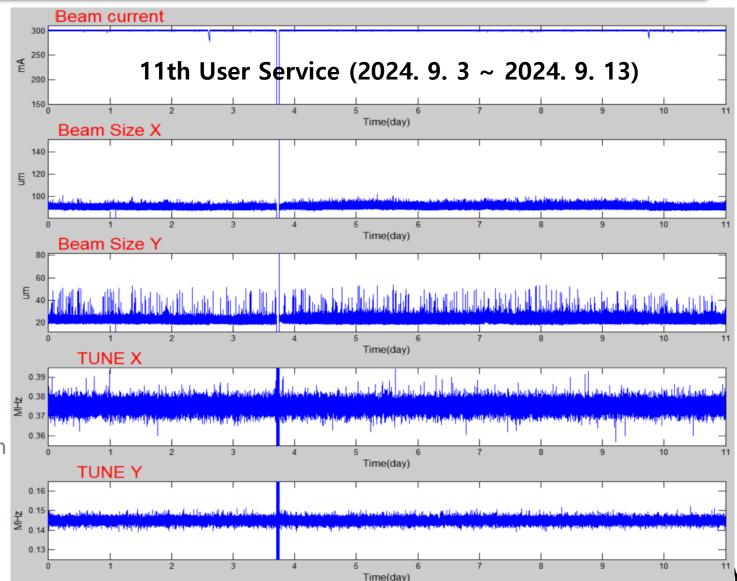


Source of Service Downtime



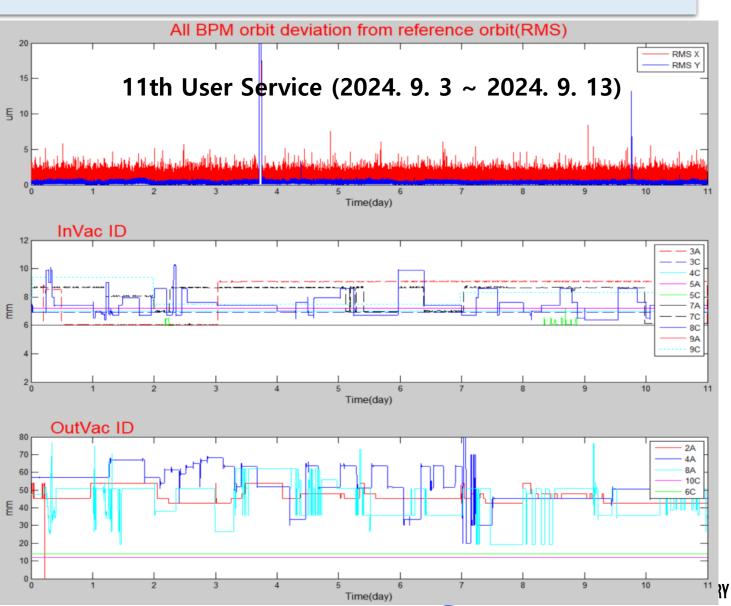
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PLS-II Machine Upgrade



Electron Beam Energy of PLS-II Linac

- Linac energy increasement for uninterrupted Top-up operation
 - 17 klystrons and modulators are used for 3.0 GeV electron beam
 - 3.3 GeV is needed for injection in the case of 1 klystron failure
 - Replacement of old acceleration columns and SLEDs



Replacement of Acceleration Columns (MK02A)

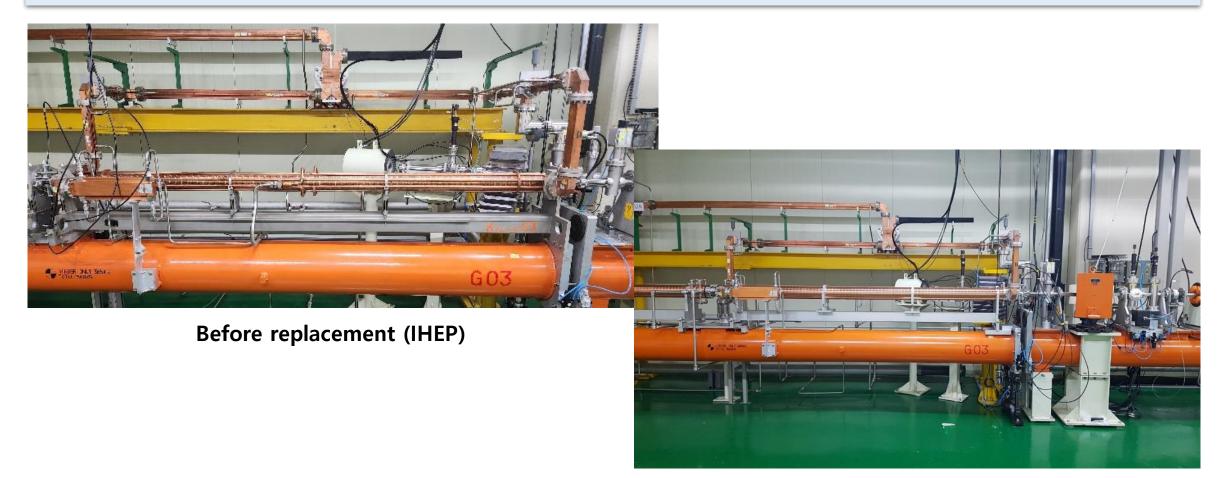
- Frequent tunnel vacuum faults even at lower high voltage (36 kV) than other modules, making it difficult to supply enough RF power
- Frequent vacuum interlock caused by arcing in the acceleration column
- Two acceleration columns of MK02A were replaced with spare parts to increase RF power







Replacement of Acceleration Columns (MK02A)



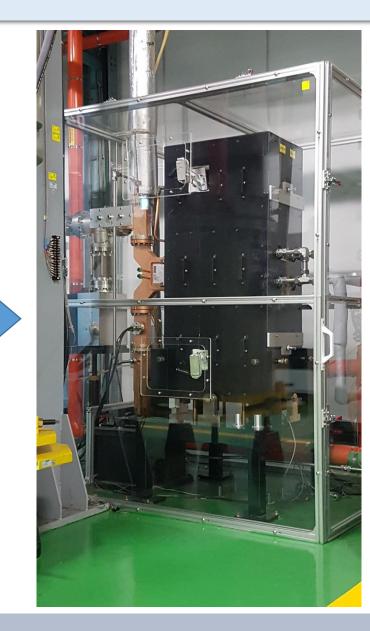
After replacement (Mitsubishi)

Energy gain from MK02A and MK02B: 273.5 -> 332.0 MeV



Replacement of SLED (MK06)





SLED: SLAC Energy Doubler

Energy gain from MK06: 206.3 -> 251.5 MeV

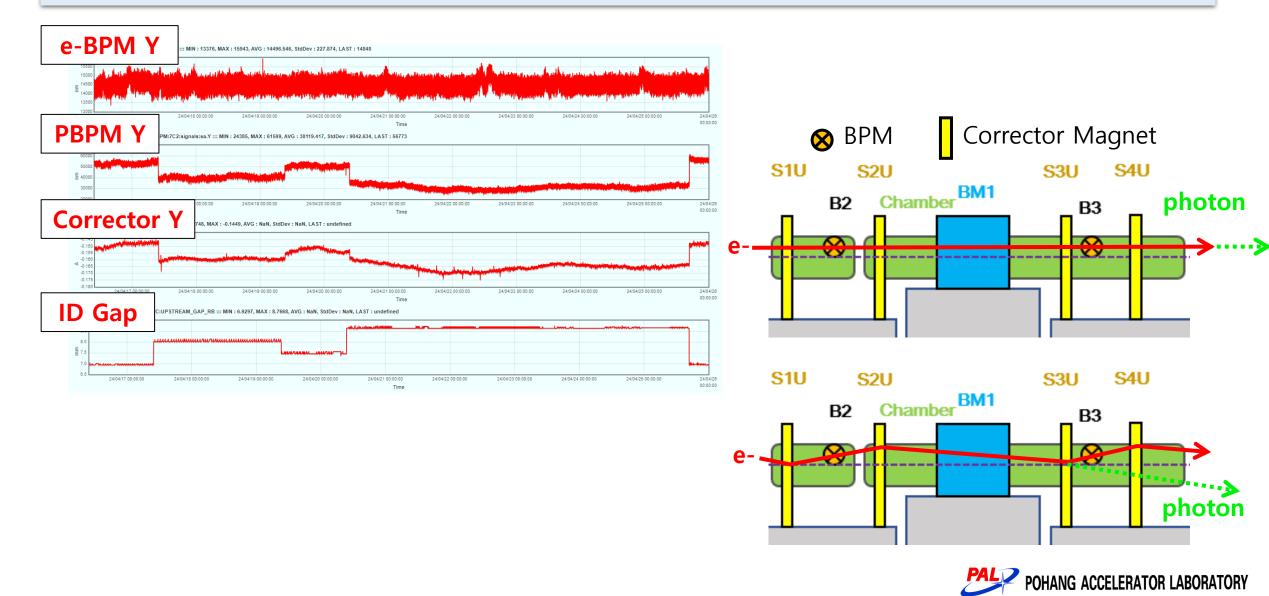


Beam Stability of PLS-II Storage Ring

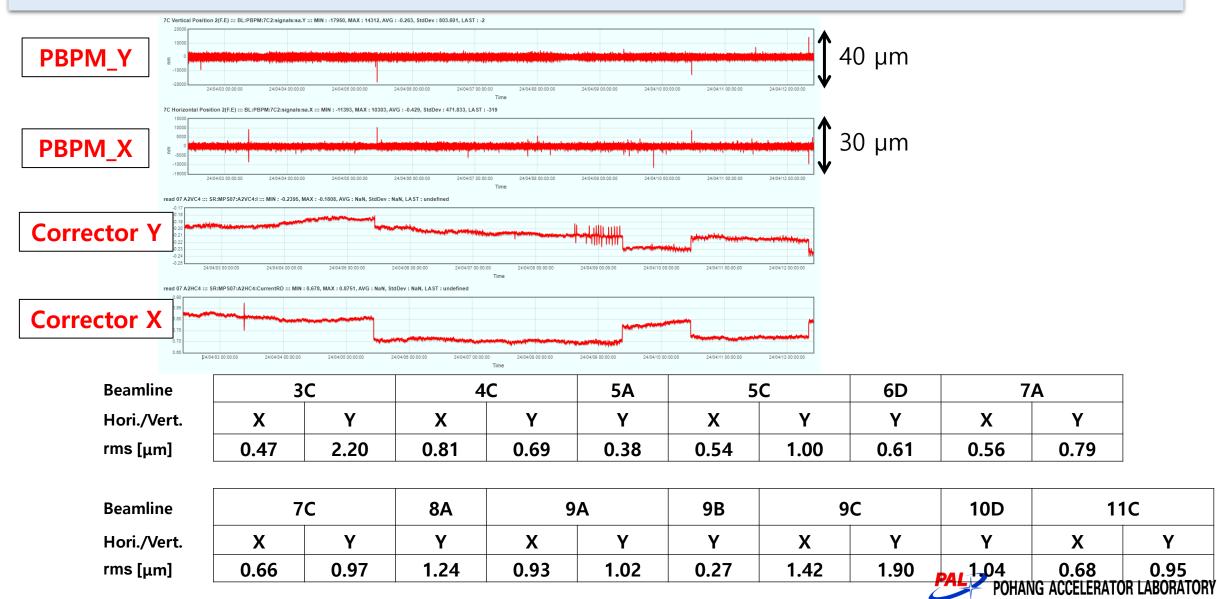
- Increased beam stability
 - Additional application of PBPM feedback in every beamline
- Stable operation of 400 mA & high current of single bunch in hybrid mode
 - Upgrade of bunch-by bunch feedback system (SPring-8 electronics -> Dimtel electronics)



BPM & PBPM



Performance of PBPM Feedback

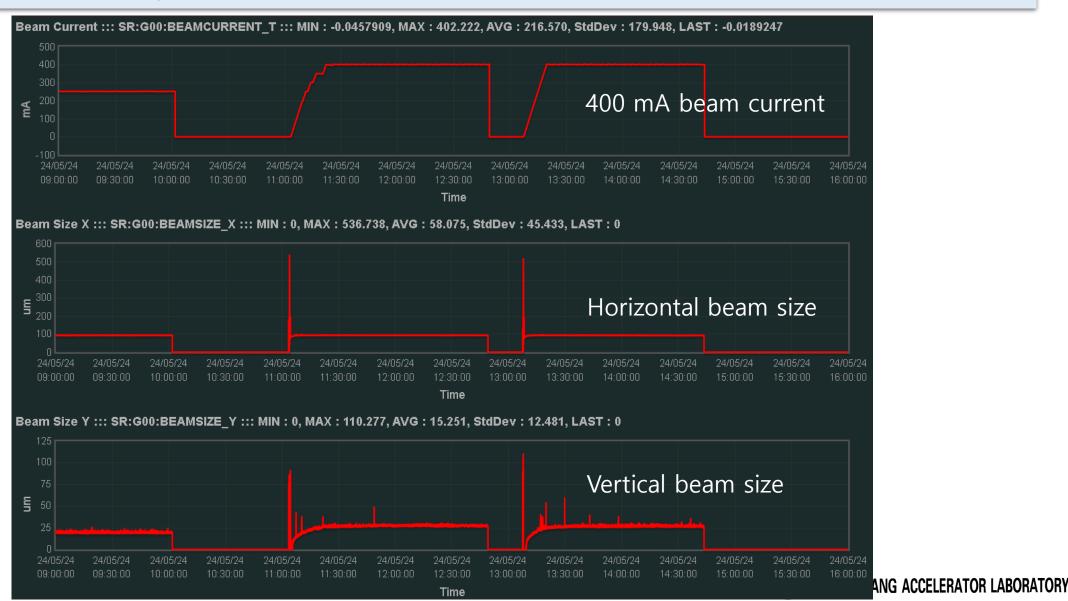


Beam Stability of PLS-II Storage Ring

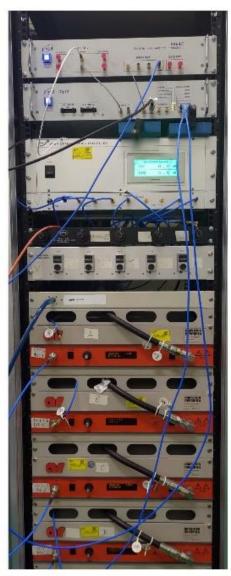
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400 mA Machine Study Result (2024. 5. 24)



Hardware Used (Dimtel Bunch-by-Bunch Feedback Electronics)



Three Dimtel units:

- iGp12 baseband processor;
- FBE-500LT analog front/back-end;
- BPMH-20-2G BPMH hybrid network.
- Used buttons A and C, adjustable delays to compensate for cable length errors;
- Only two amplifiers driven differentially: A and C.

Introduction Coupled-bunch Instabilities

Bunch-by-bunch Feedback Overview Technology

PLS-II Demonstration

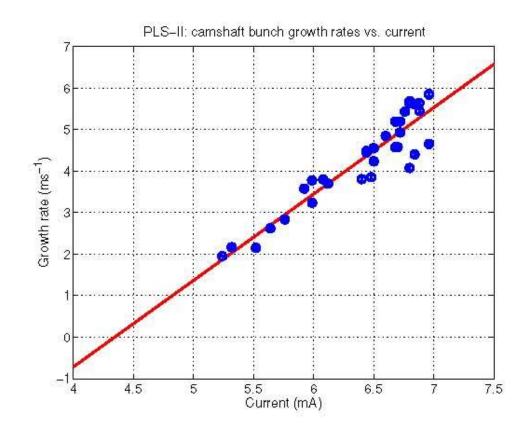
Activities

Comparison With SPring-8 Setup Grow/Damp Measurements <u>Tune M</u>easurements

Bunch Cleaning

Summary

Growth Rate vs. Camshaft Current



- Growth rates vs. camshaft bunch current;
- Current is estimated from the scope peak-to-peak amplitude;
- Steep rise in growth rates, reaching 6 ms⁻¹ at 7 mA — 180 turns;
- Reached 7.6 mA with the demonstration setup;
- With a separate X and Y processors (each driving four amplifiers) one can expect to reach even higher camshaft currents.

Feedback

Introduction Coupled-bunch Instabilities

Bunch-by-bunch Feedback ^{Overview} Technology

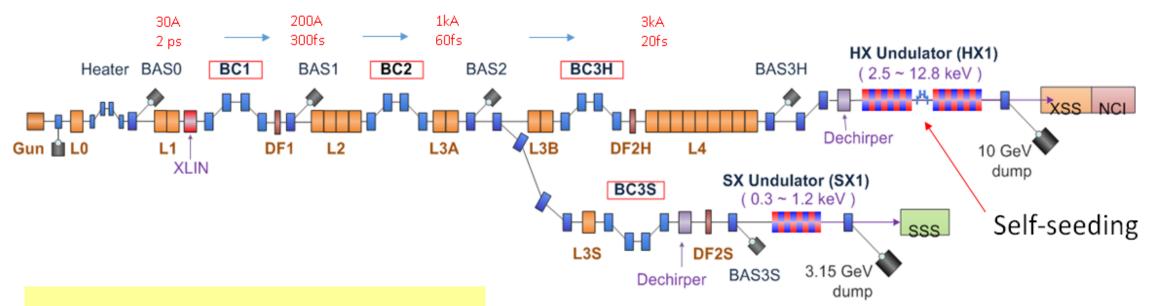
PLS-II Demonstration Activities Comparison With SPring-8 Setup Grow/Damp Measurements Tune Measurements Bunch Cleaning

Summary

PAL-XFEL Operation Status



PAL-XFEL Layout & Parameters



Main parameters

e⁻ Energy e⁻ Bunch charge Slice emittance Repetition rate Bunch length Peak current SX line switching 11 GeV 20-200 pC < 0.4 mm mrad 60 Hz 5 fs – 50 fs 3 kA Kicker Magnet

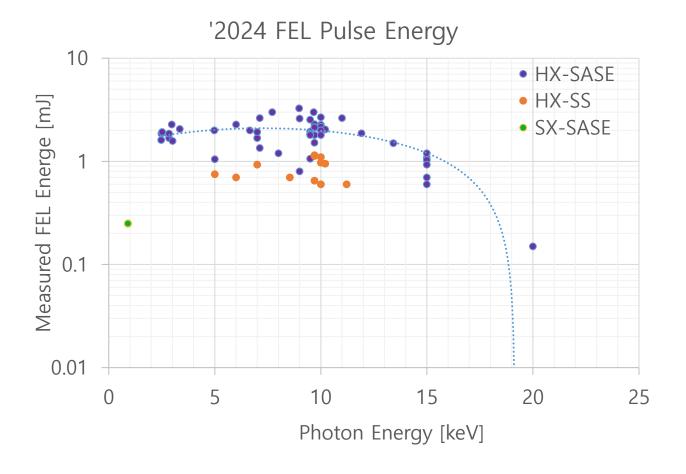
Undulator Line	НХ	SX
Photon energy [keV]	2.0 ~ 15.0	0.25 ~ 1.25
Beam Energy [GeV]	4 ~ 11	3.0
Wavelength Tuning	Energy	Gap
Undulator Type	Planar	Planar
Undulator Period / Gap [mm]	26 / 8.3	35 / 9.0



PAL-XFEL Operation Result (FEL Performance)

- More than 1 mJ SASE HX FEL is serviced in 2.4 keV~15 keV photon range
- Self-seeding HX FEL is available
- SX FEL pulse energy is around 250 μJ
- HX & SX multi-beamline operation was about 15% of beam service time in 2024

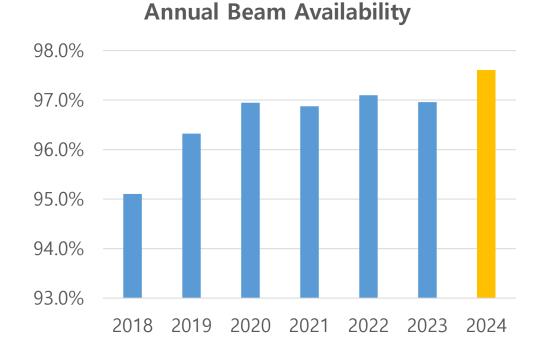


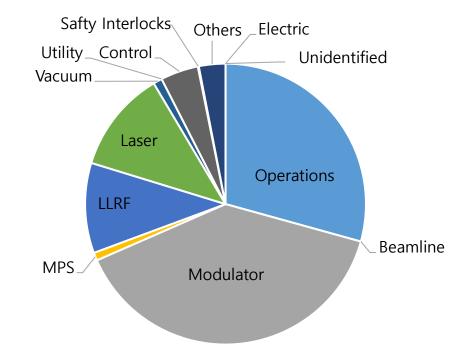




Operation Status (Stability)

- Scheduled beam time : 3489 hour (2024.1.1 ~ 10.31)
- Delivered beam time : 3405 hour (> 97.6%)
- Downtime: 85 hour





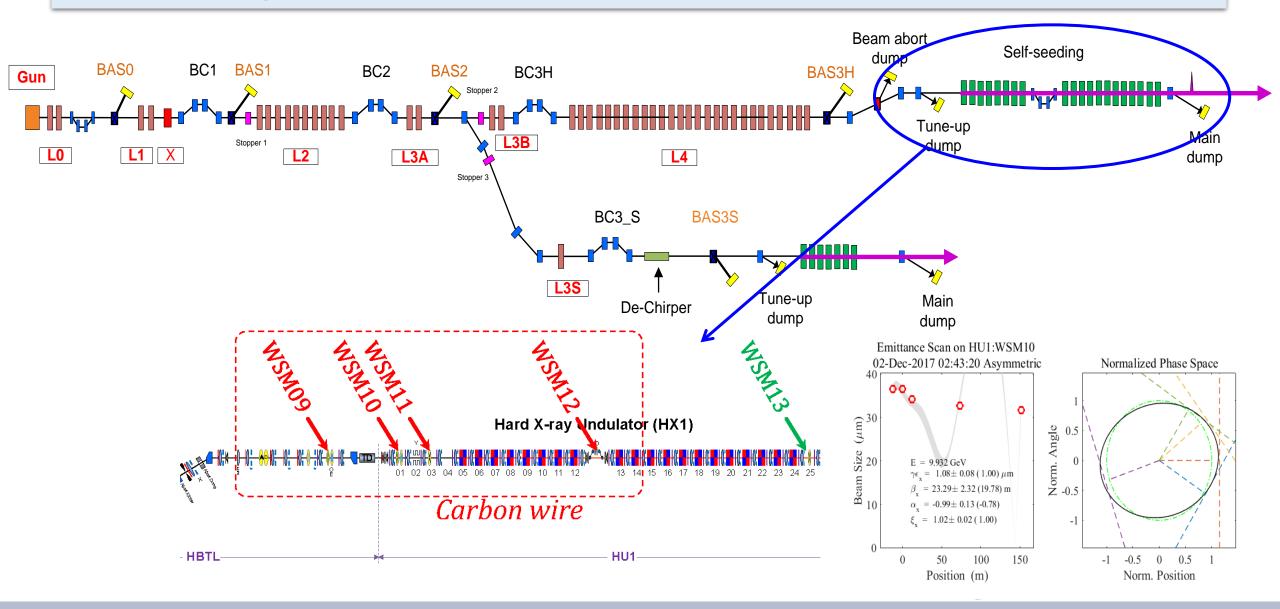
Service Downtime Sources in 2024



PAL-XFEL Machine Upgrade



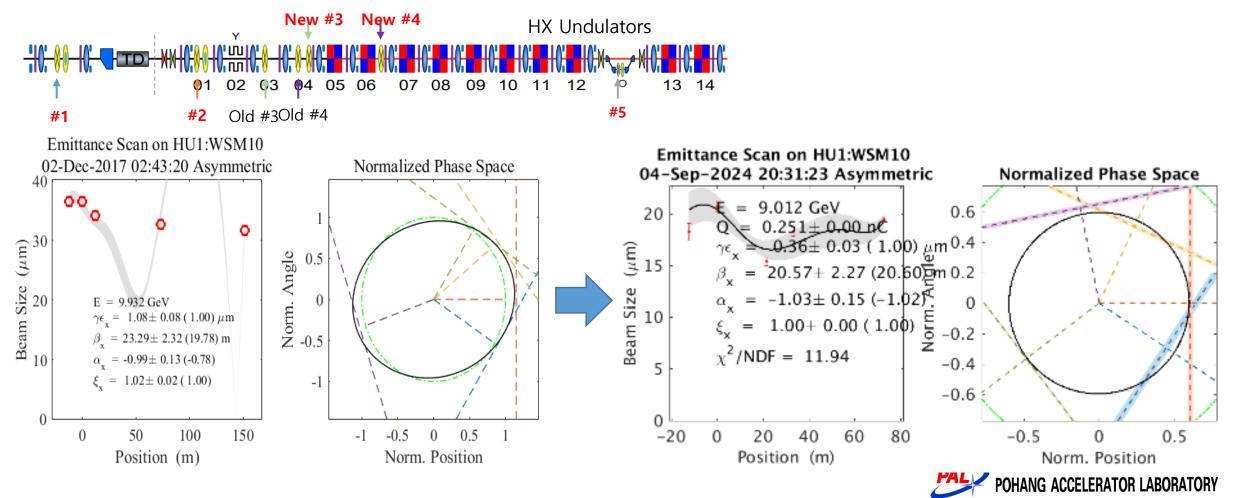
Lattice Matching of PAL-XFEL

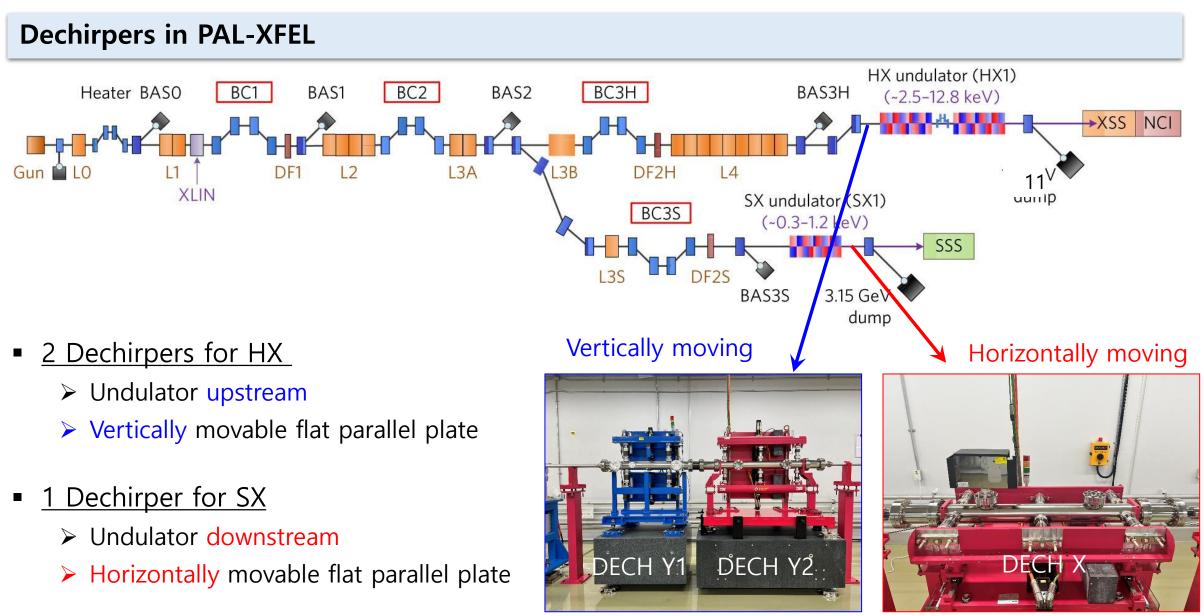


Performance of Moved Wire Scanners

Moved wire scanners for HX undulator matching

Beam matching performance with new wire-scanner positions are better than previous scanning positions.

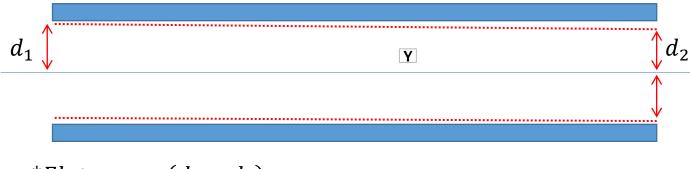


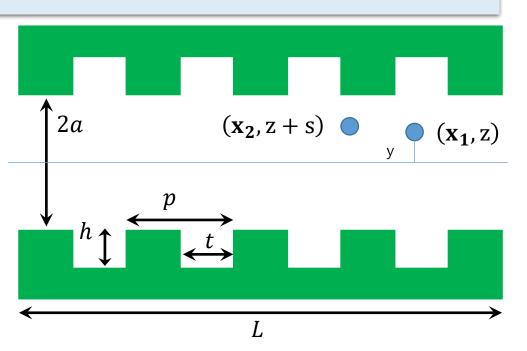


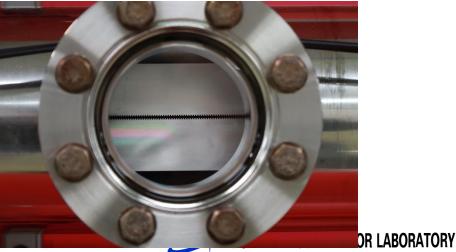


Corrugated Structure of Dechirper

Parameters	DECH Y1 (HX)	DECH Y2 (HX)	DECH X (SX)
L	1 m	1 m	1 m
a _{min}	200 µm	200 µm	200 µm
p	500 µm	1000 µm	1000 µm
h	600 µm	500 µm	500 µm
t	300 µm	500 µm	500 µm
*Flatness	59 µm / 4 µm	23 µm / 23 µm	5 µm / 35 µm





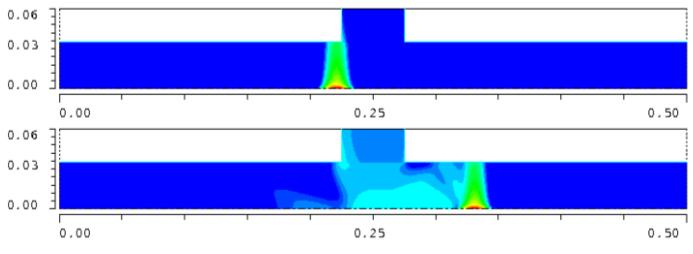


**Flatness* = $(d_1 - d_2)$

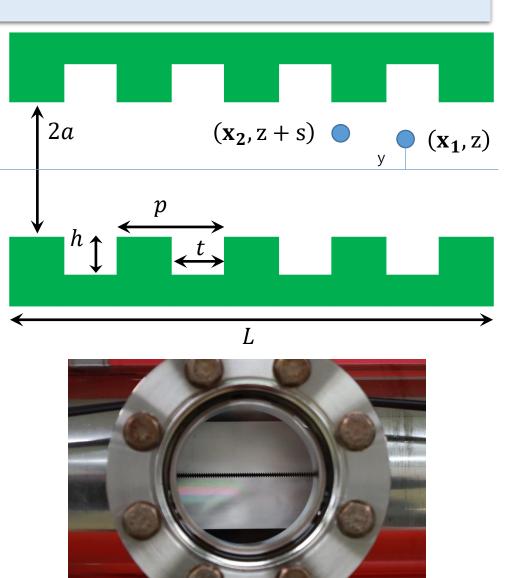
Wakefield from Corrugated Structure

- Wakefield is an electromagnetic field generated when a beam traverses a vacuum chamber with a discontinuity
- **Dechirper** is a well-established **wakefield** structure with a periodic discontinuity in a vacuum chamber

$$\mathbf{w}(\mathbf{x}_1, \mathbf{x}_2, \mathbf{s}) = \frac{1}{q_1} \int_{-\infty}^{\infty} d\mathbf{z} \left[\mathbf{E}(\mathbf{x}_2, \mathbf{z}, \mathbf{t}) + c\mathbf{e}_{\mathbf{z}} \times \mathbf{B}(\mathbf{x}_2, \mathbf{z}, \mathbf{t}) \right]_{\mathbf{t} = (\mathbf{s} + \mathbf{z})/c}$$



Wake fields in a cavity (figure from CERN-2017-006-SP, 2017)



OR LABORATORY

Application of Wakefield

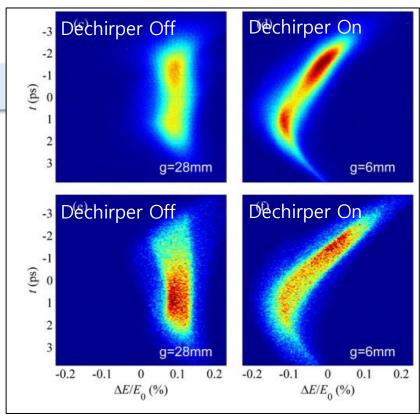
Longitudinal Wakefield

Control of linear energy chirp

- ✓ Experimentally demonstrated at PAL-ITF (2014)
- Transverse Wakefield
 - "Fresh-Slice" technique
 - ✓ Fresh-slice self-seeding
 - ✓ Multi-color FEL pulse generation

✓ Multistage amplification for short pulse high power XFEL generation

- Passive deflector (or streaker)
 - ✓ Longitudinal phase space diagnostics and time-resolved FEL power profile



*Energy chirp-induced by the longitudinal wakefield by corrugated dechirper PRL.***112,** 034801 (2014)

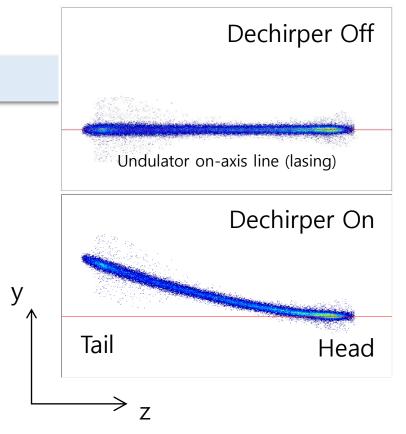
OHANG ACCELERATOR LABORATORY

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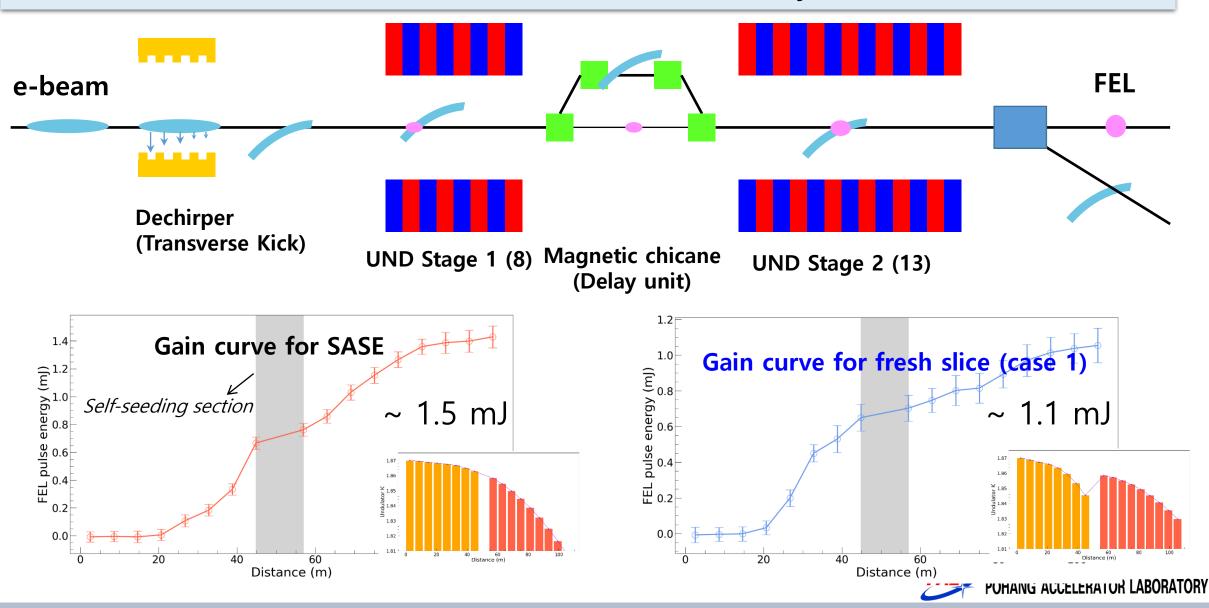
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Particle distribution by simulation (elegant)



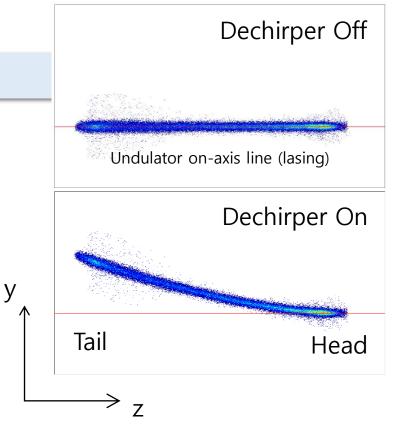
Measurement Result of Fresh Slice FEL Generation (Hard X-ray)



Application of Wakefields

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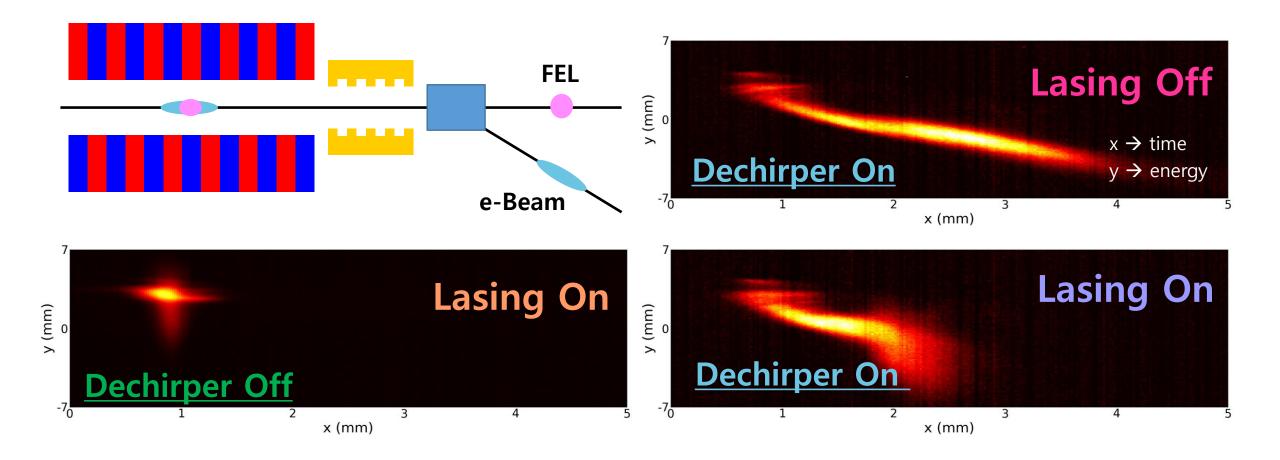
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Particle distribution by simulation (elegant)



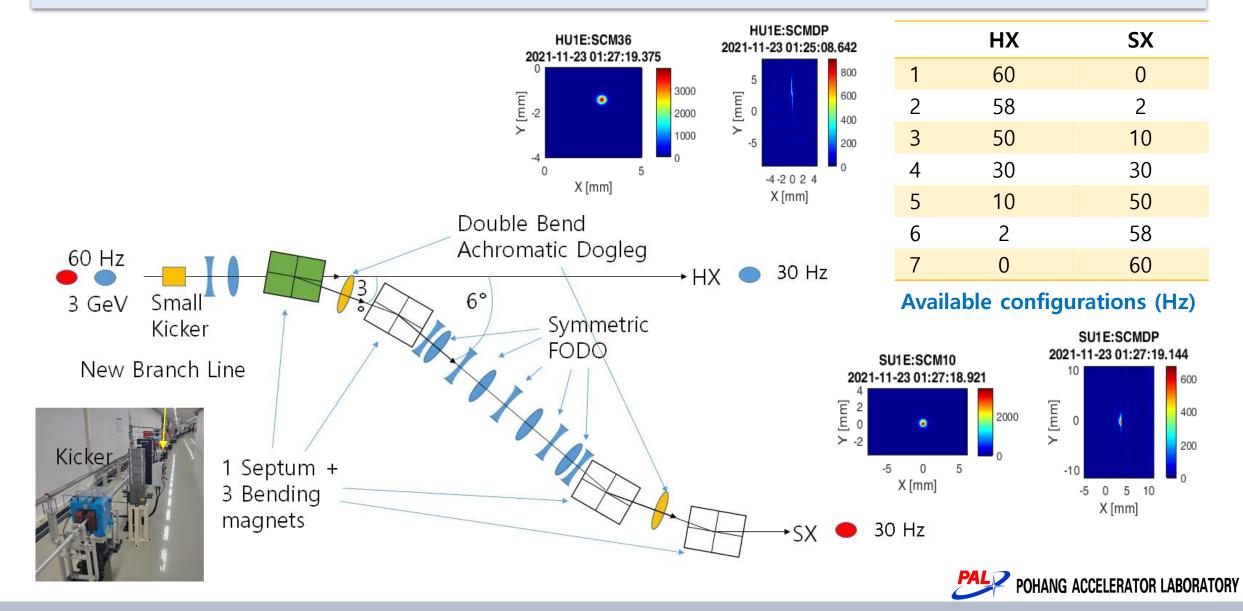
Measurement Result of Passive Deflector (Soft X-ray)



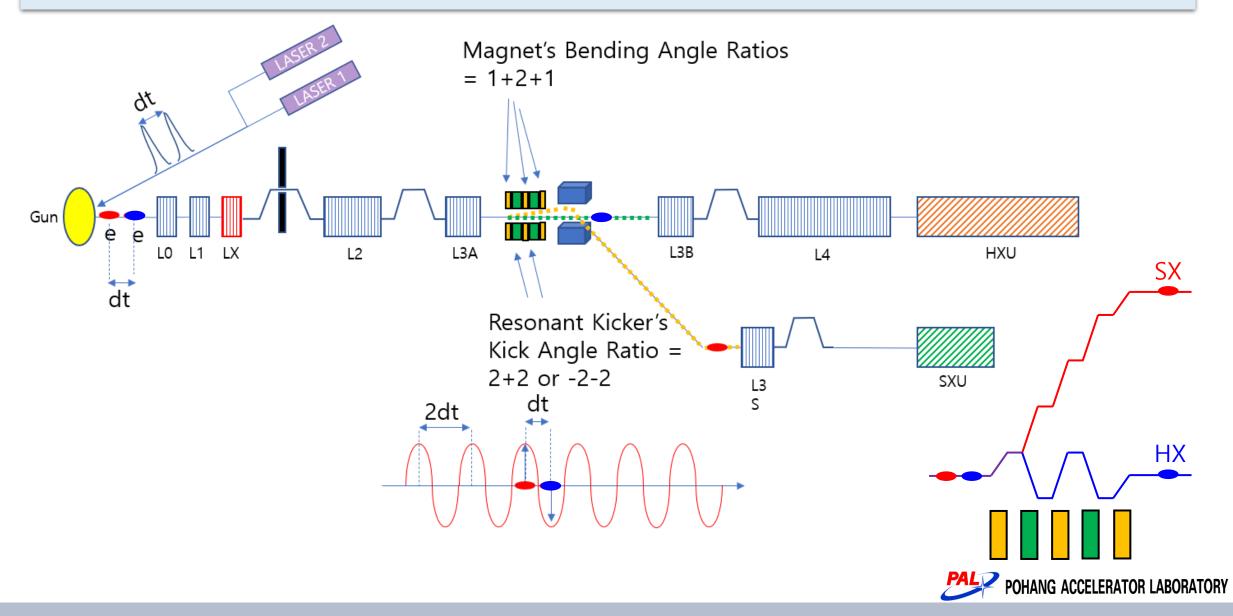
> Diagnostics for longitudinal phase space of 2.8 GeV e- beam after lasing on/off



Result of Multi-Beamline Operation (HX and SX)

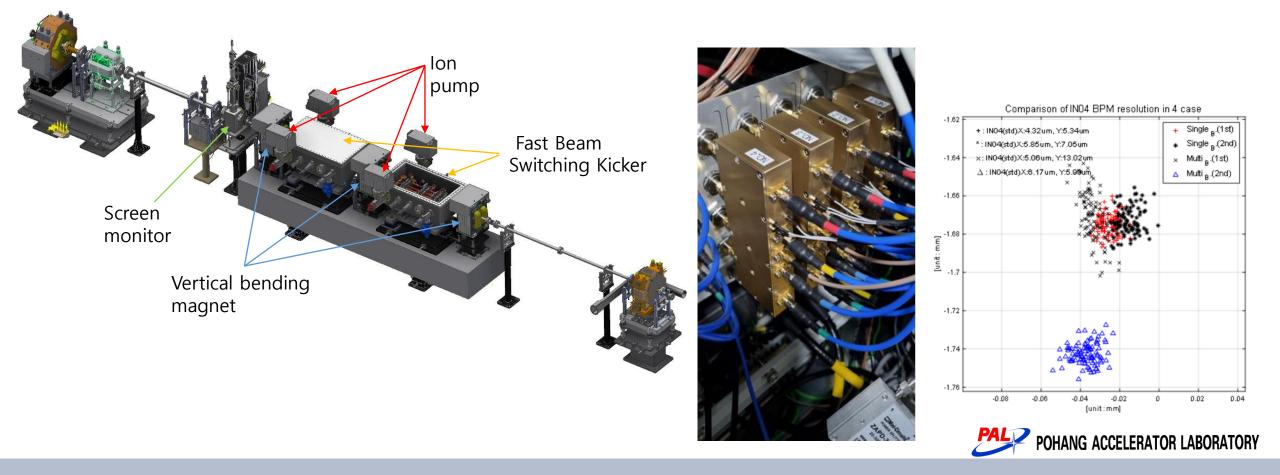


Fast Resonant Kicker



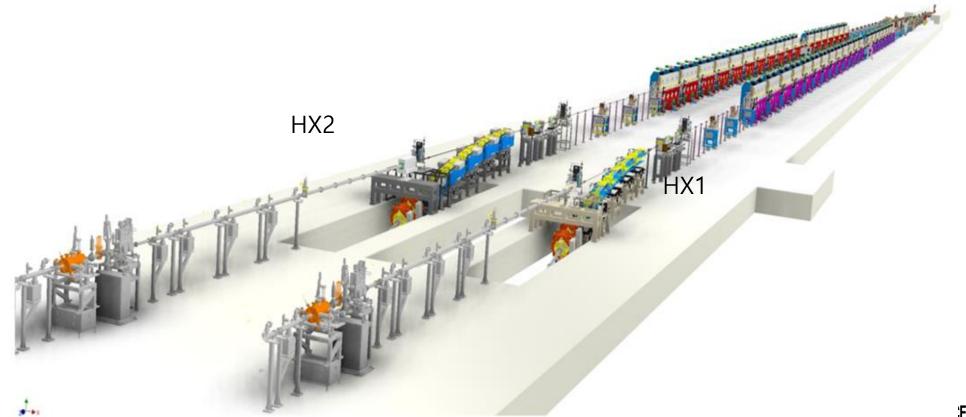
Status of 60 Hz Multi-Beamline Operation

- Physics design of fast resonant kicker has been finished
- Preliminary tests with BPM electronics for double bunch have been finished

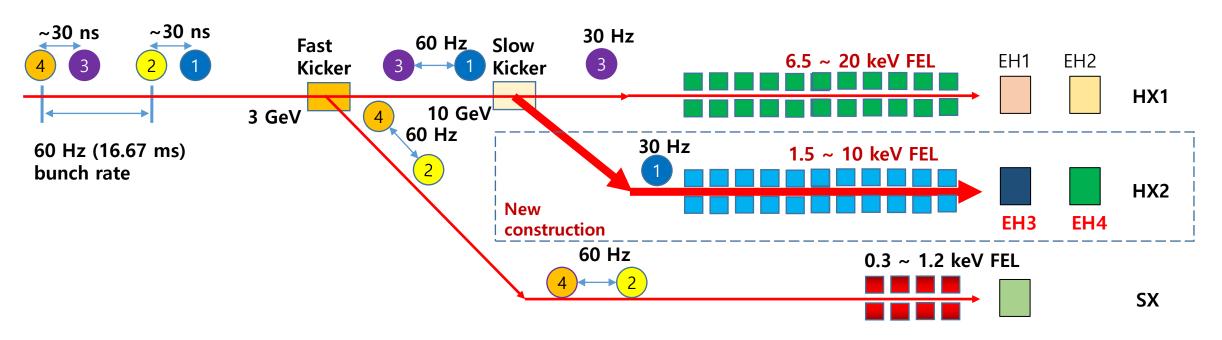


2nd Hard X-ray Undulator Line in PAL-XFEL

- Continuously discussing with the government to realize 2nd Hard X-ray undulator line project
- Also PAL-XFEL's SX undulator line upgrade is planning, considering HX2 project



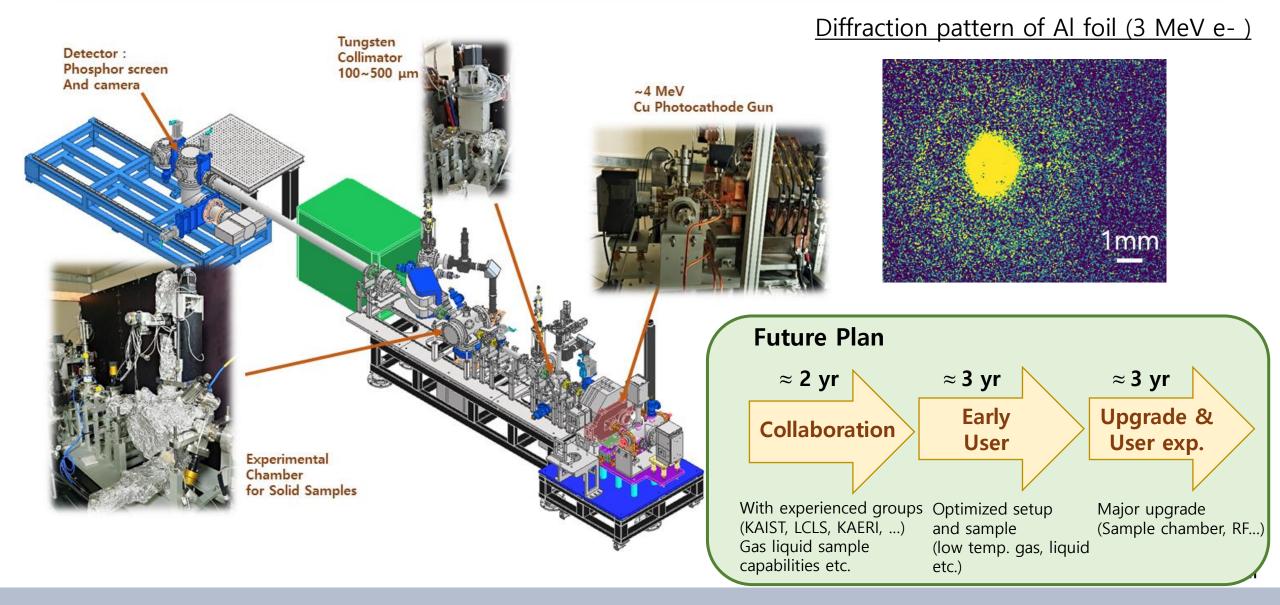
Multi-Beamline Operation of HX1, HX2, and SX



➤ HX2 allows...

- An increased acceptance rate of HX user experiments with higher user demand. (Broaden XFEL user base and Attracting new users)
- Dedicated and specialized science programs of the PAL-XFEL.
- To operate 3 independent FEL lines (HX1, HX2 & SX) through the multi-beamline operation mode. (Increased user beamtimes of all FEL lines as a result)

Status of MeV Ultrafast Electron Diffraction



Thanks to:

All members of PLS-II and PAL-XFEL

