



Magnetic Measurement Activities at Pohang Accelerator Laboratory

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Pohang Accelerator Laboratory



- PLS-II (2009~2011): PLS upgrade, 2.5 GeV \rightarrow 3 GeV, 12 more short straights.
- PAL-XFEL (2011~2015)

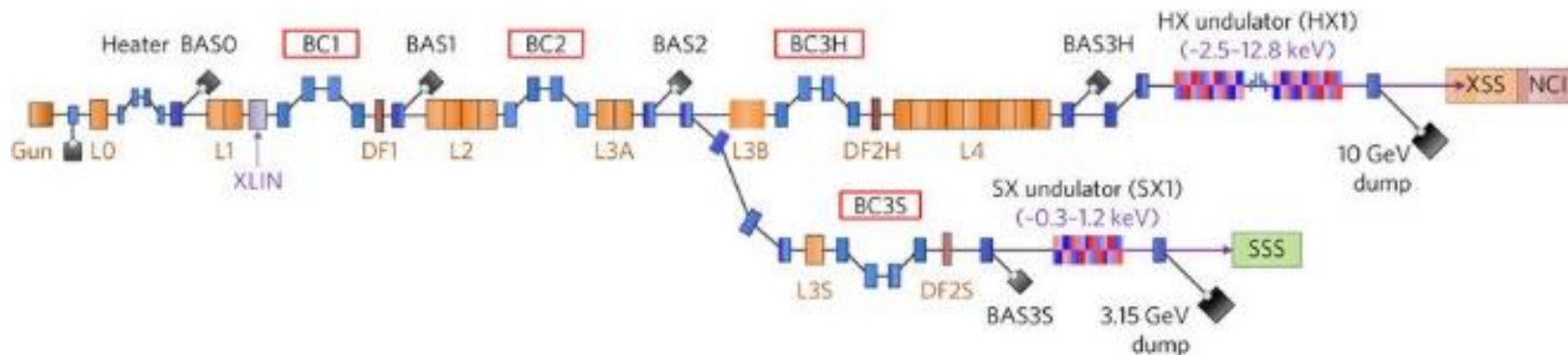
PLS-II Insertion Devices



	Type	Period (mm)	B_{\max} (T)	Qty.	Length (m)
IVU20	In-vacuum undulator, planar	20	0.97	11	1.35 or 1.8
MPW10	Multipole wiggler, planar	100	1.80	1	2.0
MPW14	Multipole wiggler, planar	140	2.02	1	1.12
U68	Out-vacuum undulator, planar	68	0.90	1	3.06
EPU58	APPLE-II undulator, elliptic	58	0.684	1	3.20
EPU72	APPLE-II undulator, elliptic	72	0.79	2	2.58
EPU114	APPLE-II undulator, elliptic	114	0.88	1	3.53
Revolver	In-vacuum undulator, planar	10 (R10) 15 (R15) 20 (R20) 24 (R24)	0.606 (R10) 0.866 (R15) 1.050 (R20) 1.100 (R24)	1	1.02

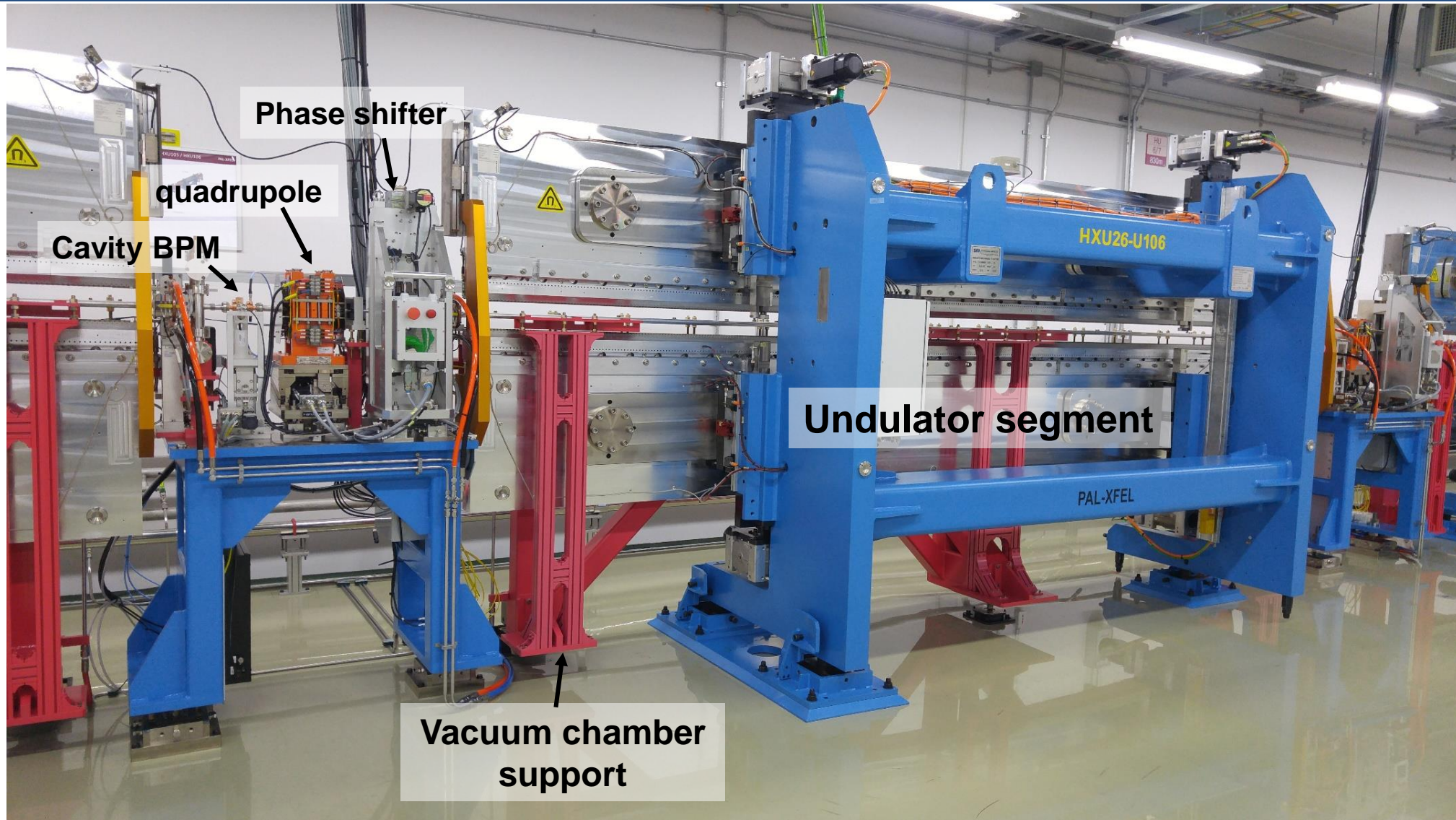
- One IVU20 (1C beamline) re-tuned in January 2019 for reduced phase error.
- One new IVU20 is under production to replace 9A IVU20 in January 2020.
Field measurement and tuning scheduled in late 2019

PAL-XFEL HX1 & SX1 Undulators

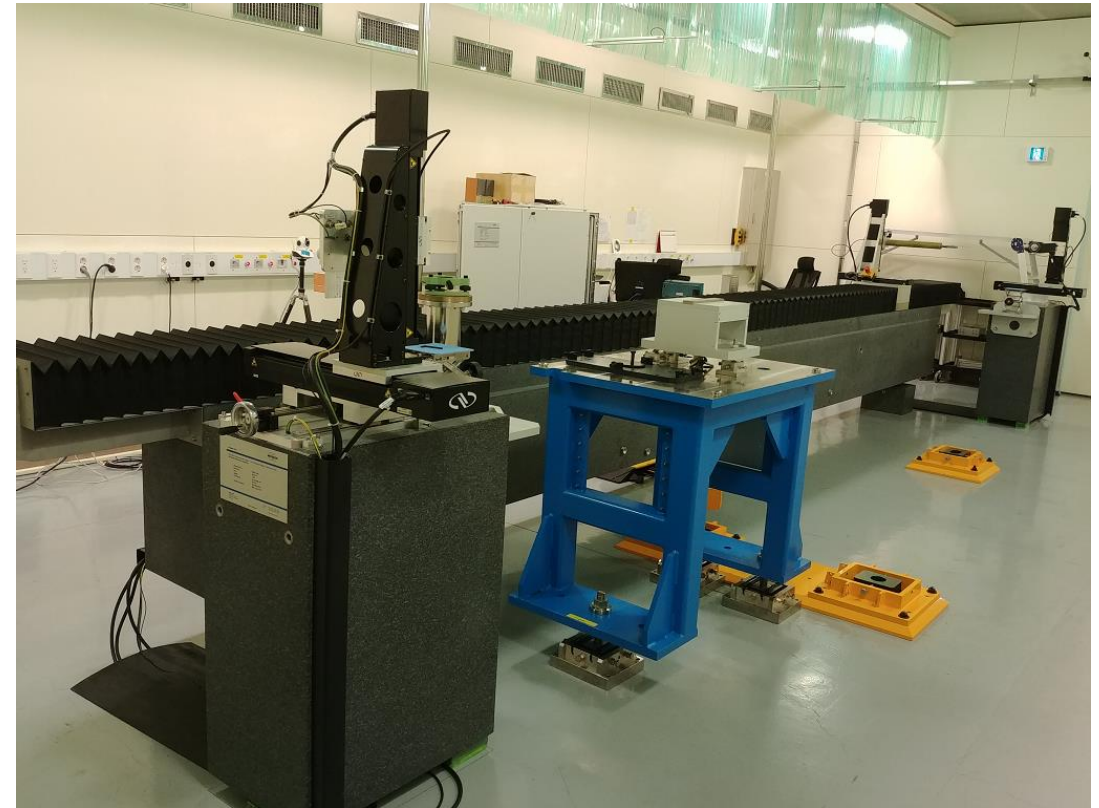


Parameters	Hard X-Ray Beamline	Soft X-Ray Beamline
Type	Hybrid Type Planar Undulator	
Period (mm)	26.0	35.0
Magnet Material	NdFeB magnet and Vanadium Permendur pole (VAC)	
Segment Length (m)	5	5
Minimum Gap (mm)	8.3	9.0
B_{eff} at Minimum Gap (T)	0.812	1.016
K at Minimum Gap	1.973	3.321
RMS Phase Error (deg.)	< 7.0	< 7.0
Number of Installed Segments	20	7

PAL-XFEL Undulator Section

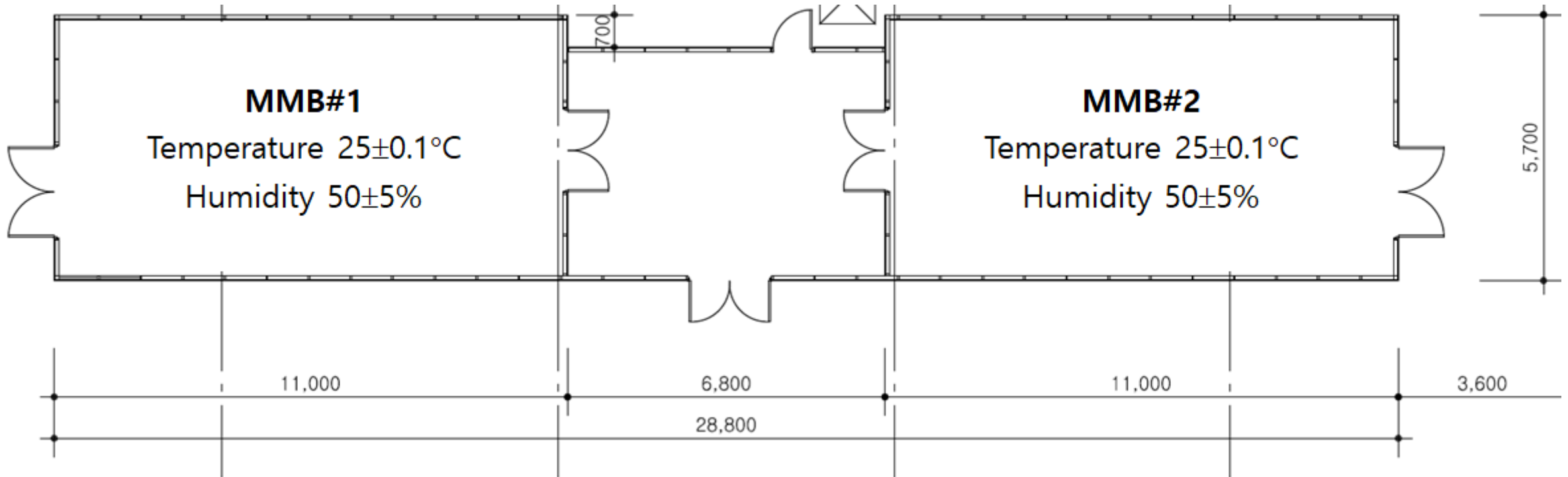


XFEL Undulator Measurement Lab



- **Two 6.5 m long measurement systems, bought from Bruker ASC**
- **FW Bell 3 axes (GH-700) or SENIS 2 axes (YZI10F) Hall probes**
- **Used for 27 undulators of PAL-XFEL, few IVUs of PLS-II**

XFEL Undulator Measurement Lab



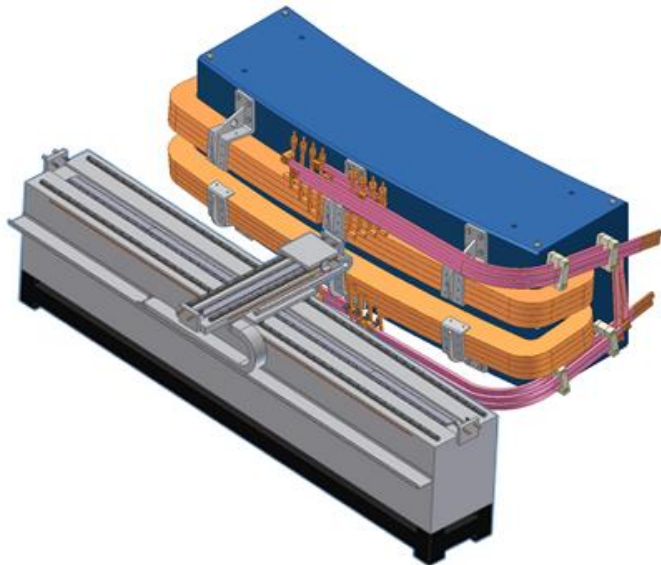
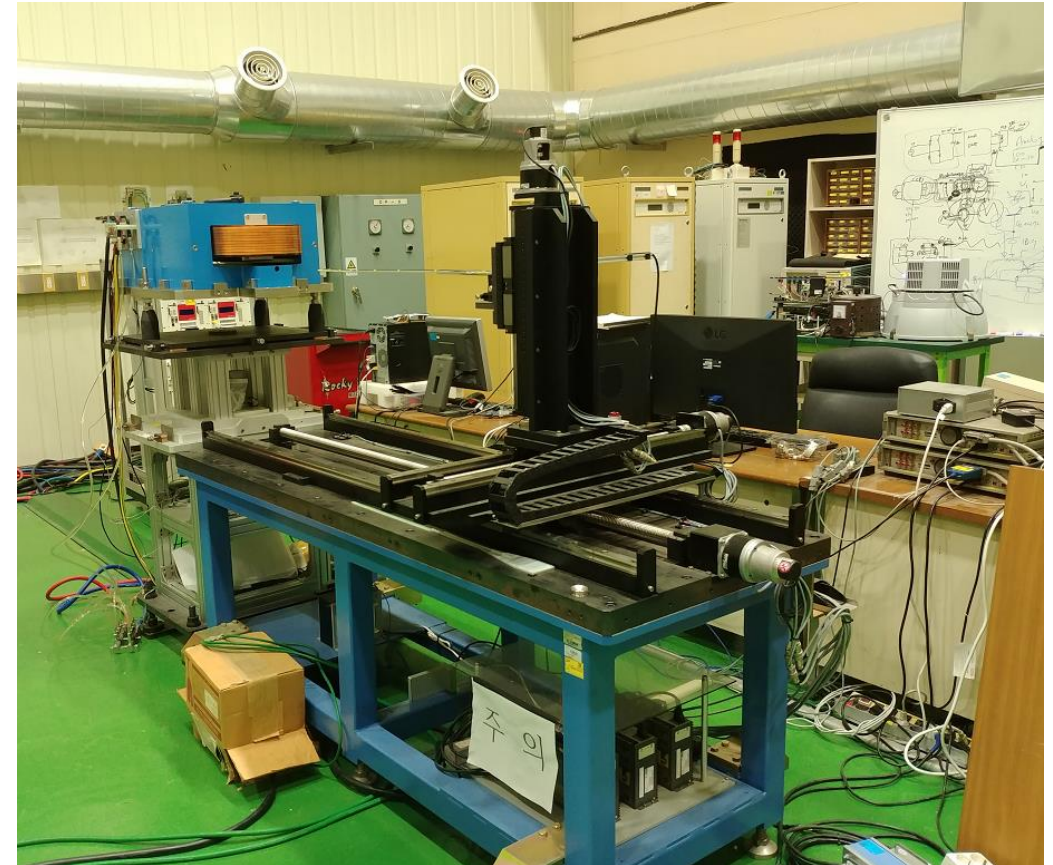
Air temperature and humidity regulated as in PAL-XFEL undulator tunnel

PLS-II In-vacuum Undulator Measurement Lab



- **5 m long measurement system, bought from ADC**
- **FW Bell GH-700 Hall probe (3 axes)**
- **Used for field measurement of 11 IVUs and few more insertion devices in PLS-II**

Magnet Measurement Lab



Teslameter:
Group3 DTN-151

Hall probe:
Group3 MPT-141

Magnet Measurement Lab – Calibration Magnet



Calibration magnet

GMW 2474-140

Pole diameter 250 mm

2.2 T max at 10 mm gap

NMR Precision Teslameter

Metrolab PT2025

NMR Probes

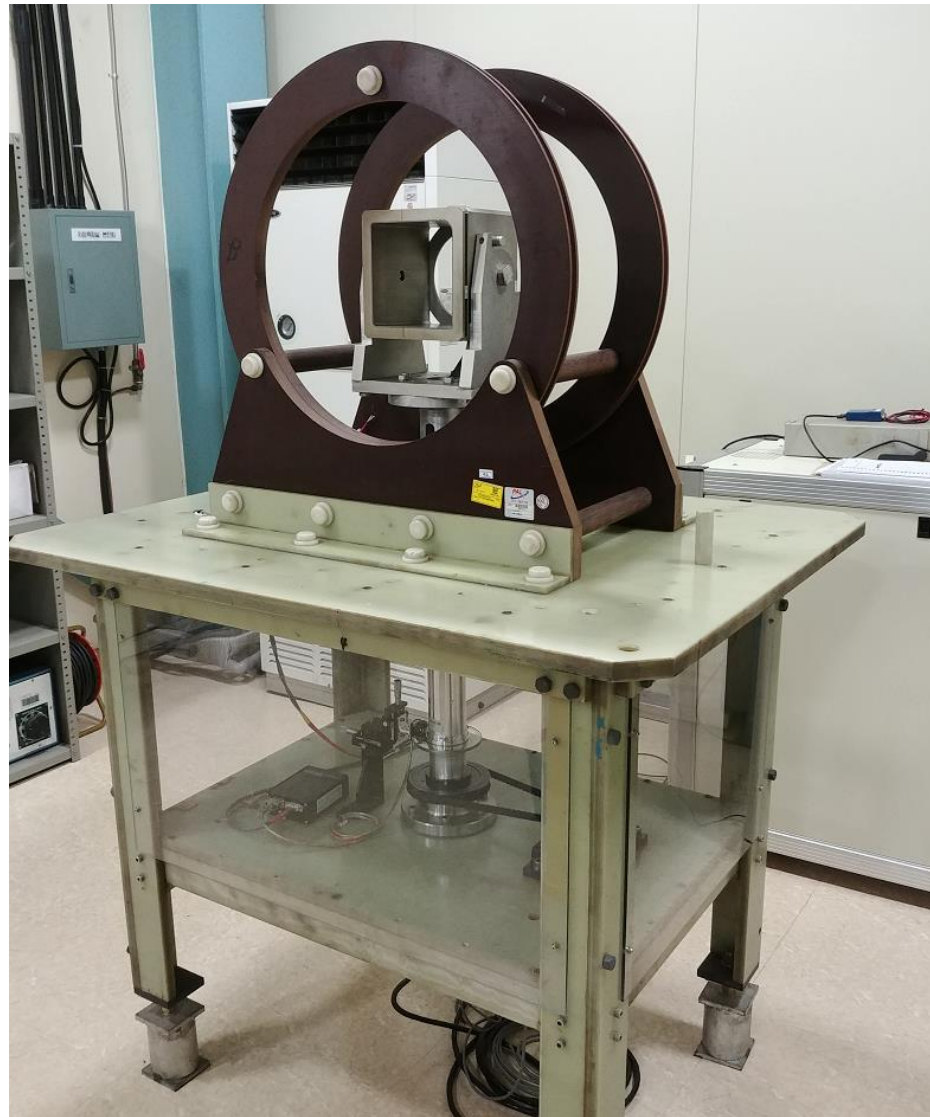
Metrolab 1062-3 (0.17 – 0.52 T)

Metrolab 1062-4 (0.35 – 1.05 T)

Metrolab 1062-5 (0.7 – 2.1 T)



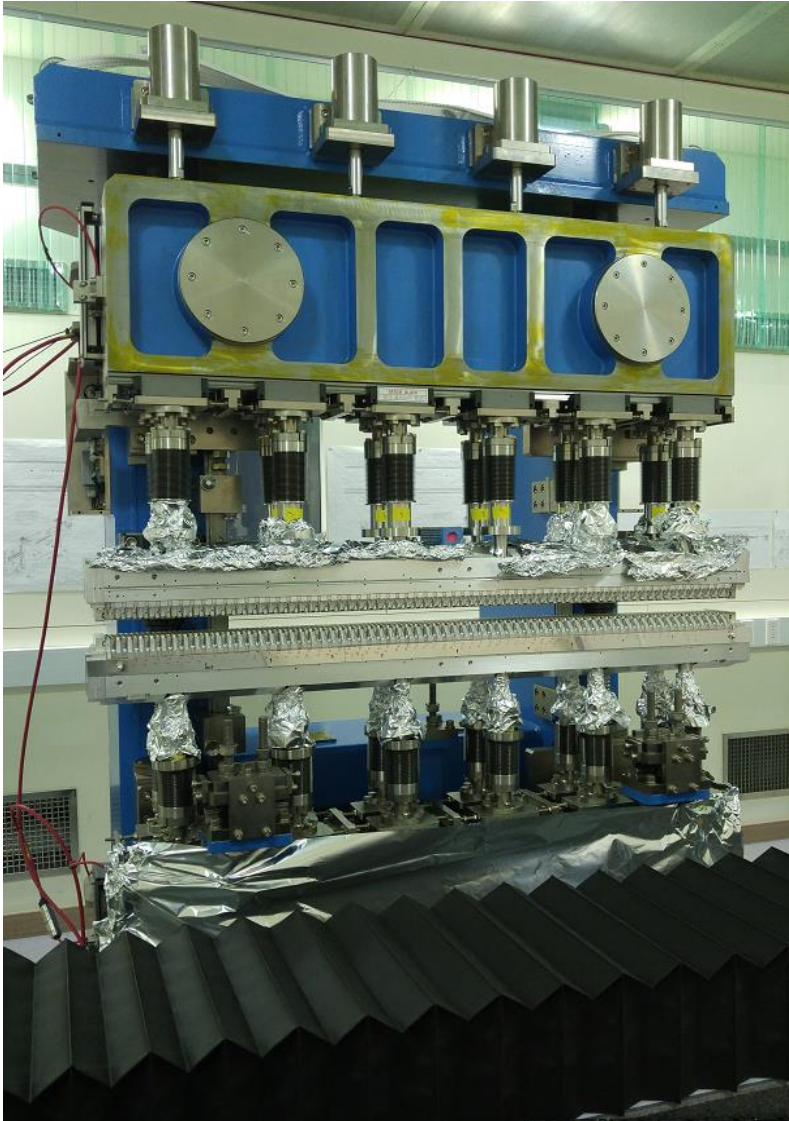
Magnet Measurement Lab – Magnet Block Measure



Helmholtz coil
0.2975 m radius

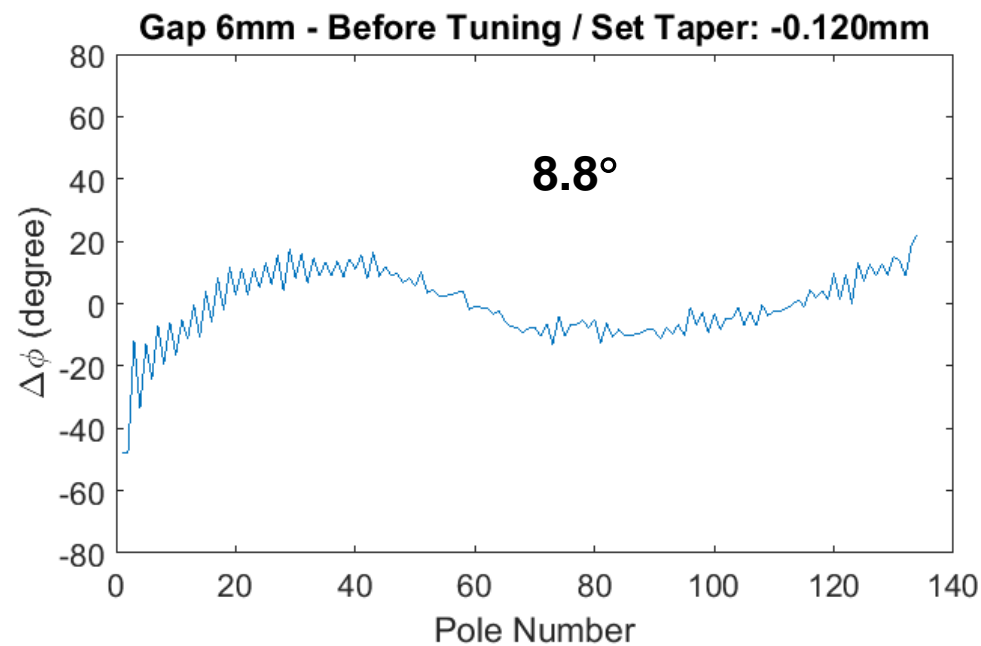
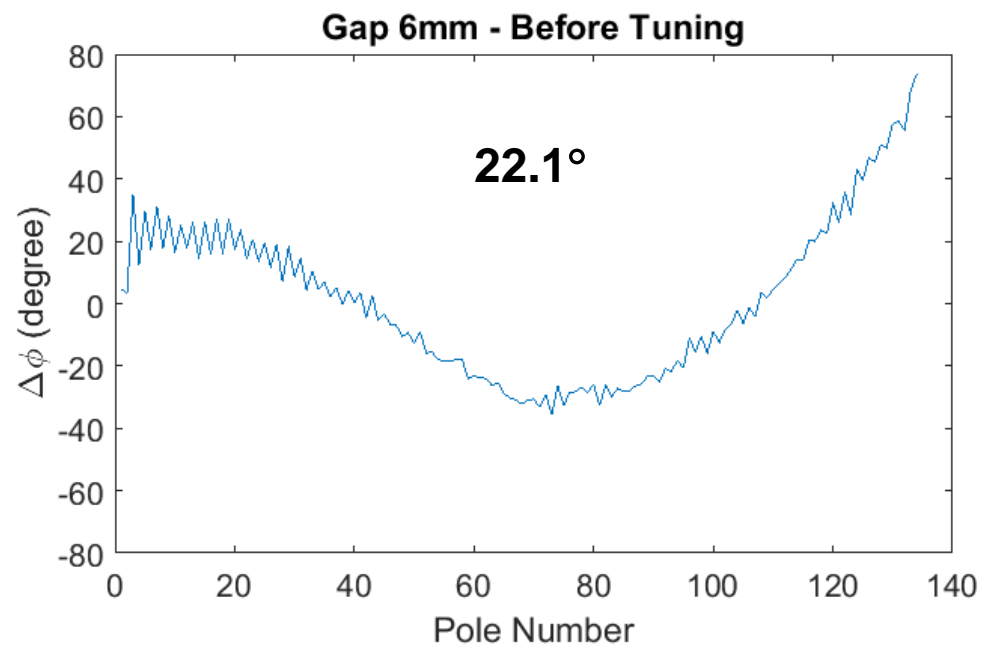
Magnet block holder
Rotatable in 3 angles

In-Vacuum Undulator Re-tuning

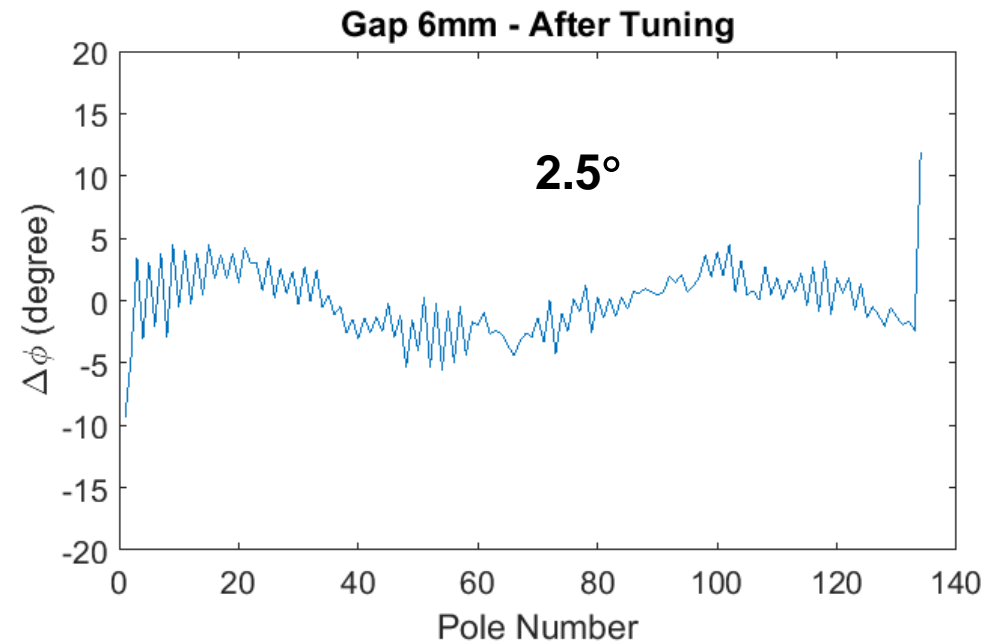
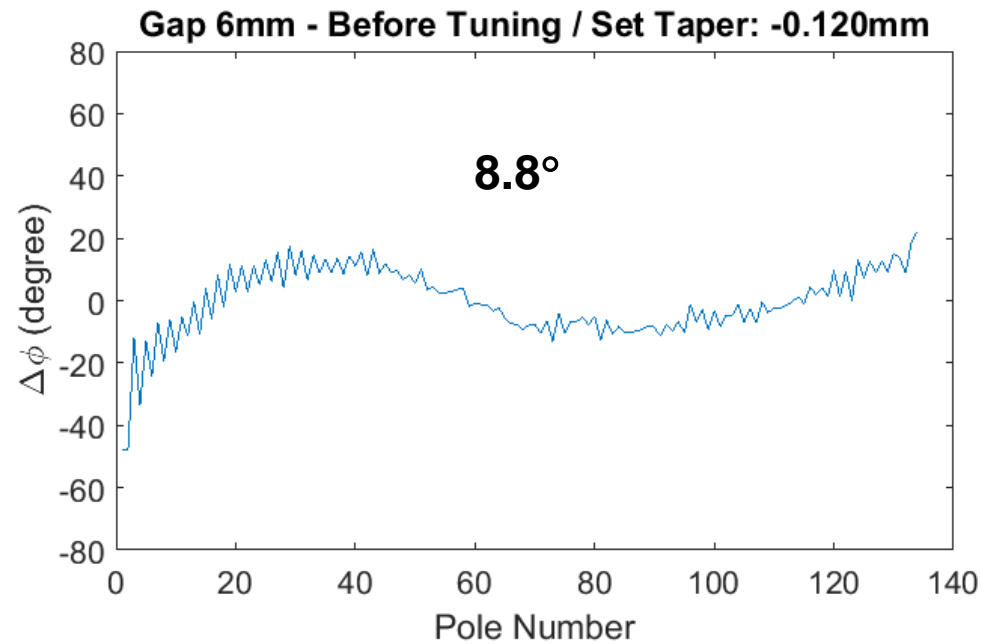


- One 1.35 m long in-vacuum undulator re-tuned after 6 years beam operation
- Measured spectrum differs from calculation by ~ 1 mm gap
- Beamline manager wished higher flux at >11 keV
- Re-tuning during winter maintenance in January 2019

In-Vacuum Undulator Re-tuning - Mechanical Taper



In-Vacuum Undulator Re-tuning - Pole Tuning



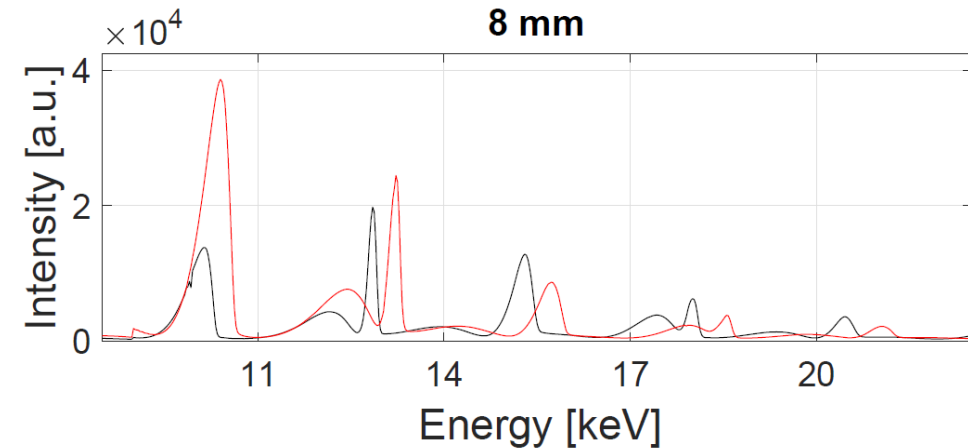
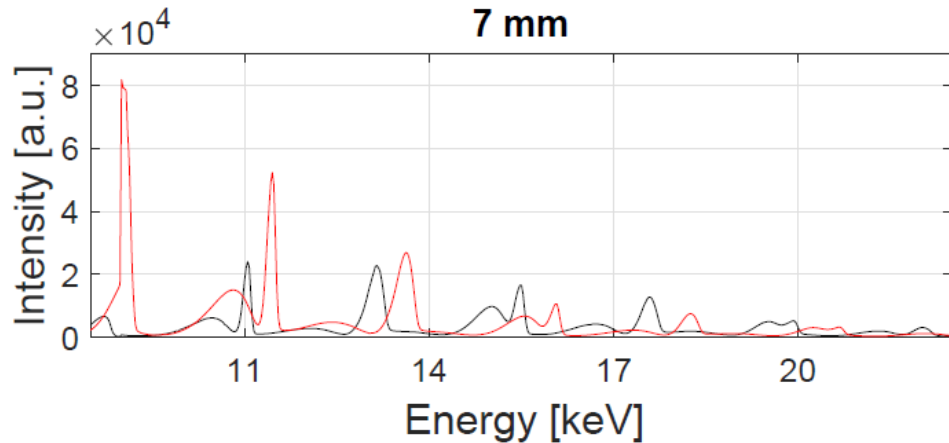
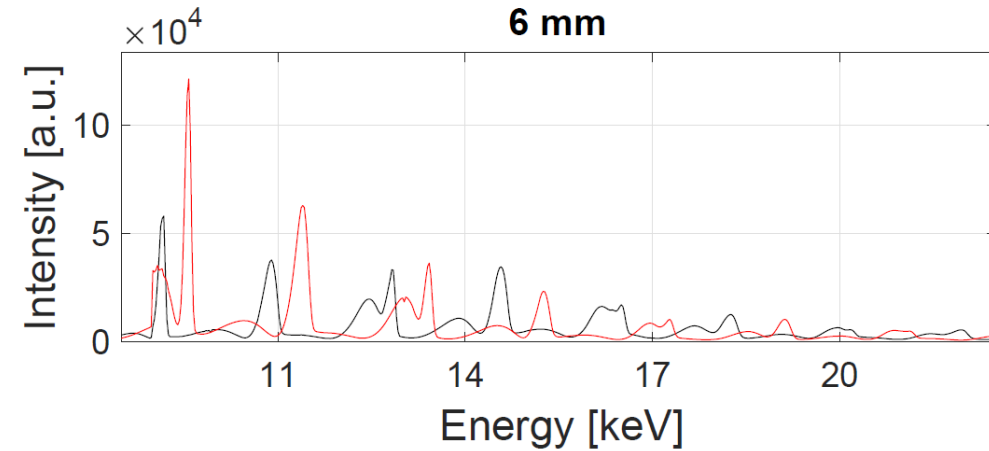
In-Vacuum Undulator Re-tuning



Measurement at 28 m before & after re-tuning

After re-tuning

- Energy shifted upward
- Flux increase up to ~12 keV photon energy

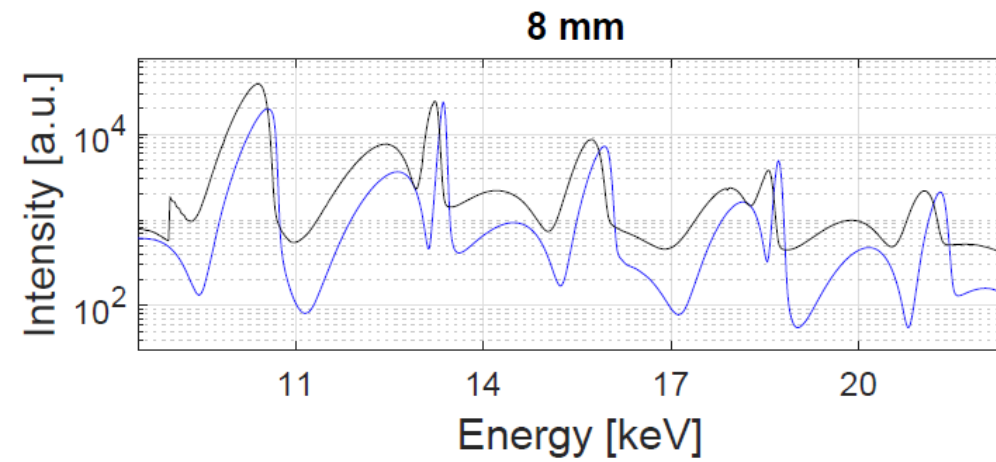
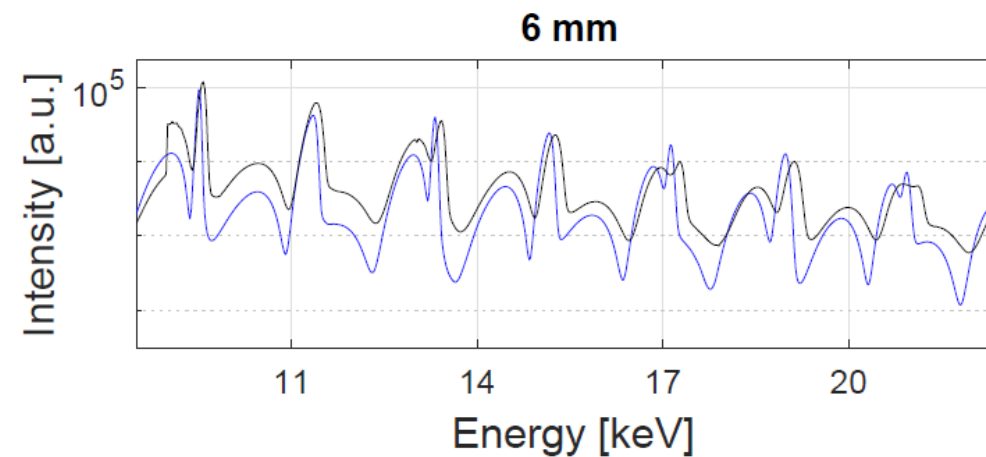
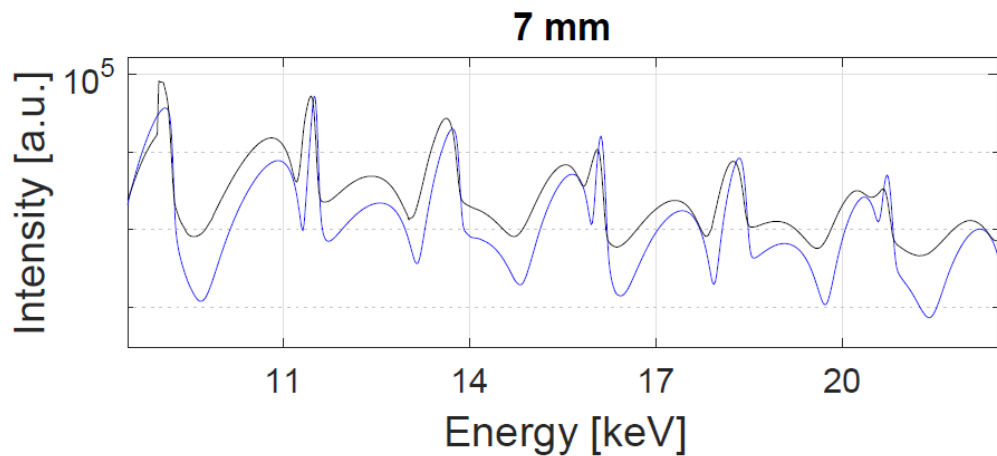


Data provided by Y. S. Kim

In-Vacuum Undulator Re-tuning

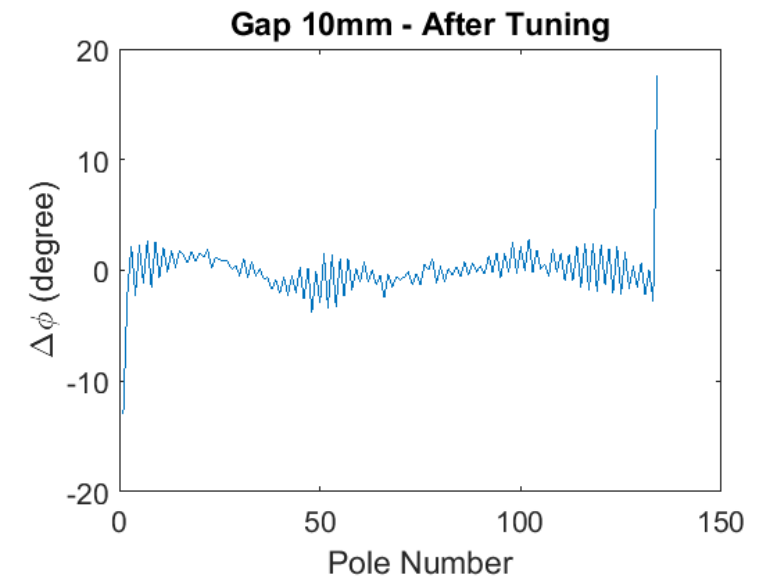
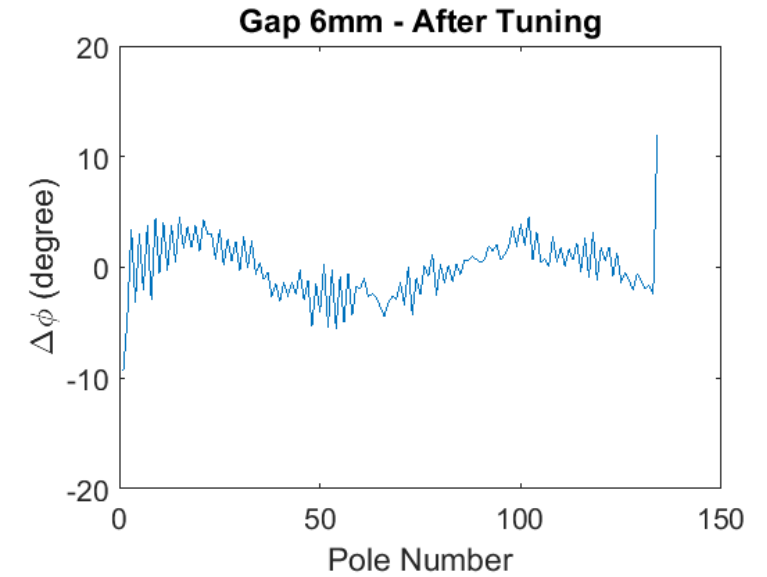
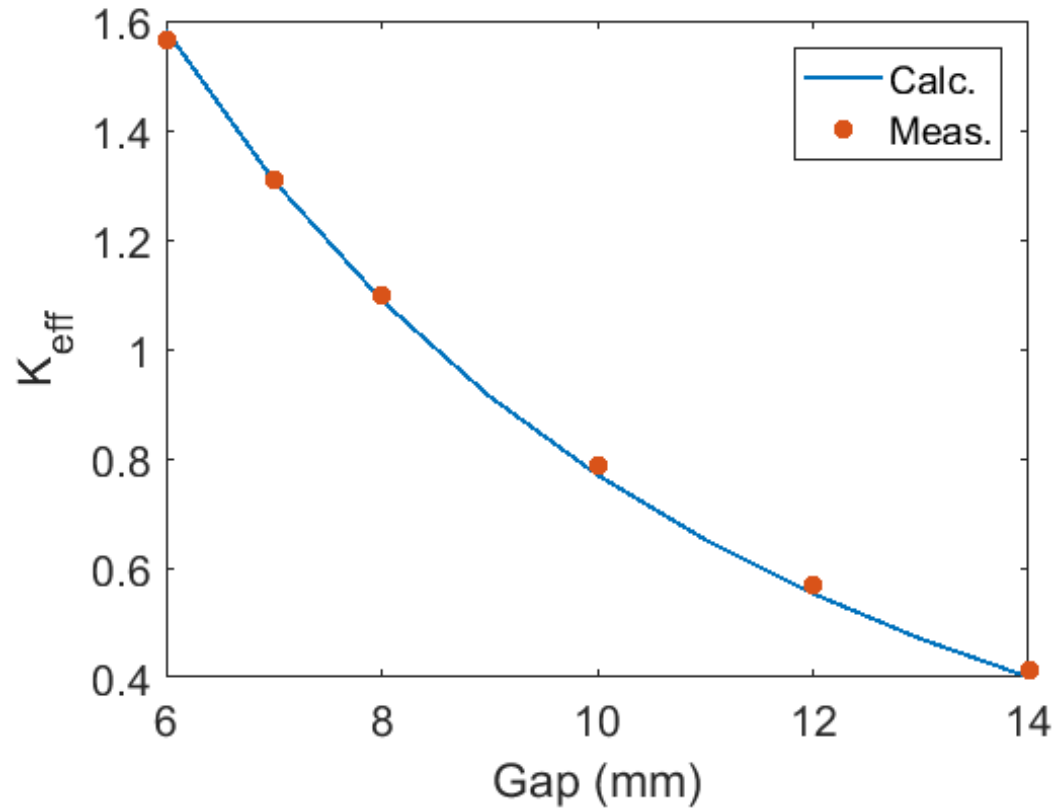


Measurement & calculation
at 28 m after re-tuning



Data provided by Y. S. Kim

In-Vacuum Undulator K vs Gap



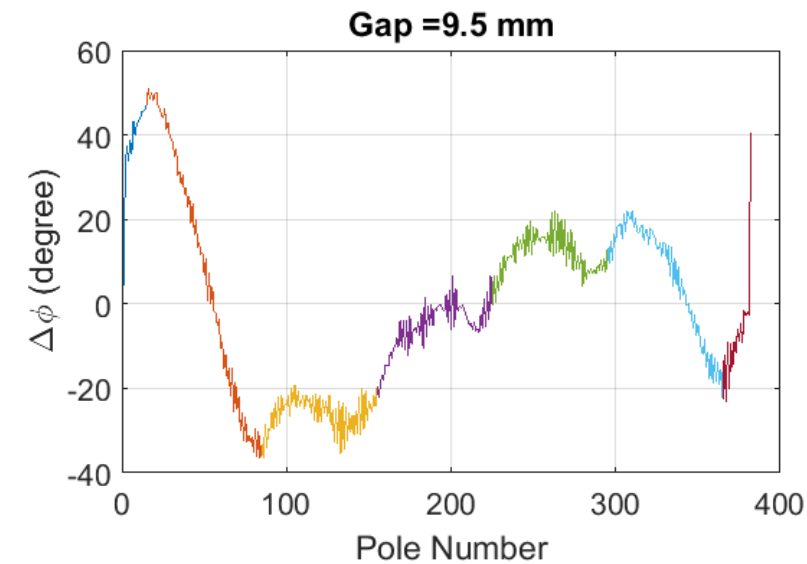
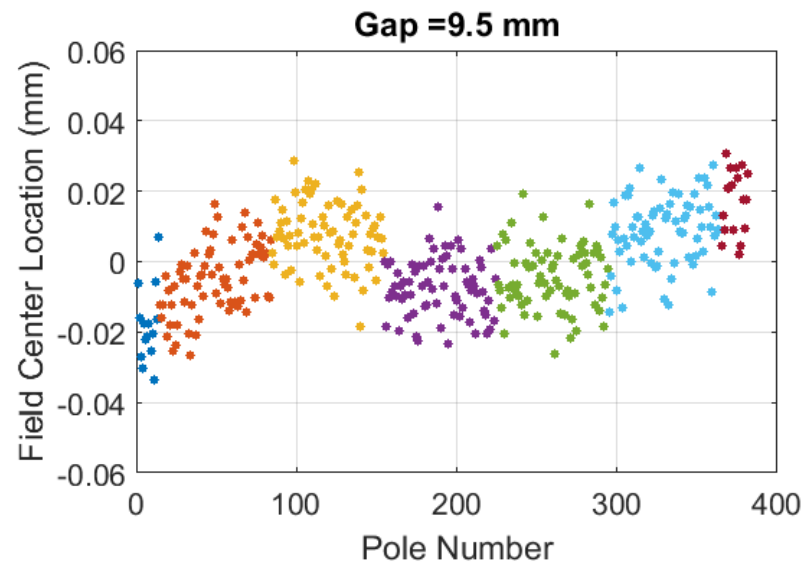
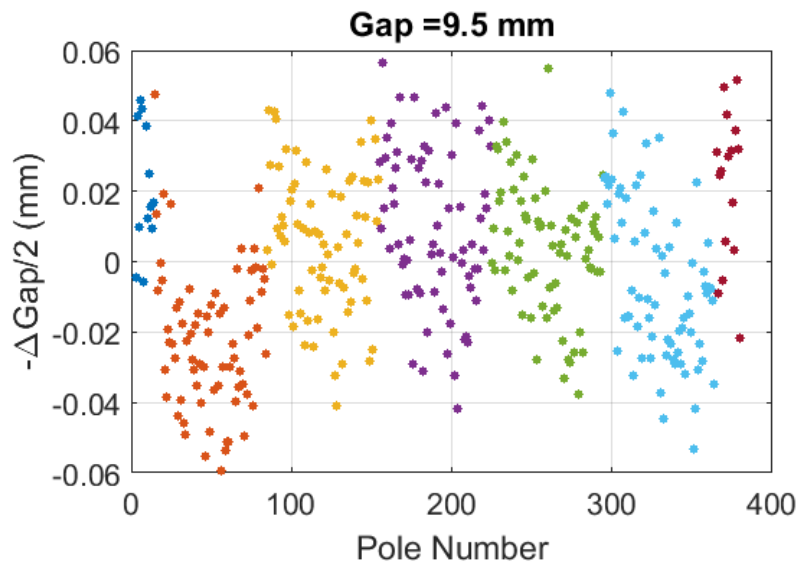
PAL-XFEL HX Spare Undulator



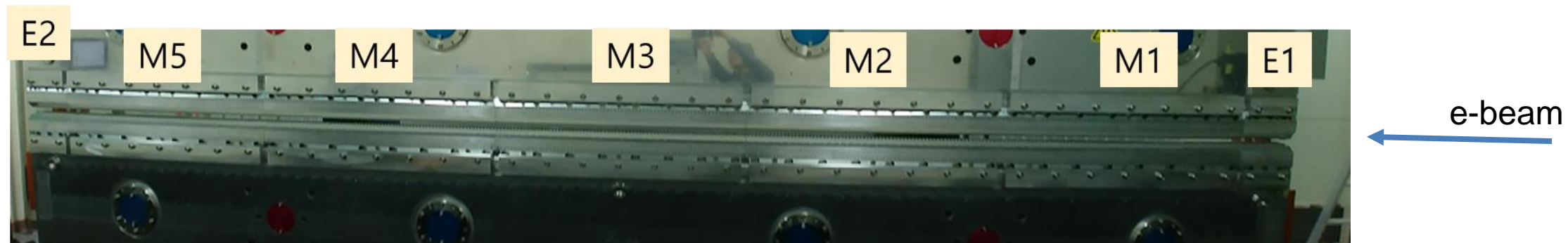
- Prototype undulator manufactured at the early stage of the PAL-XFEL project was refurbished in 2018.
- This undulator was originally prepared as spare, but it will be installed at the HX1 beamline in summer 2020.
- Field measurement and tuning was carried out in spring 2019.



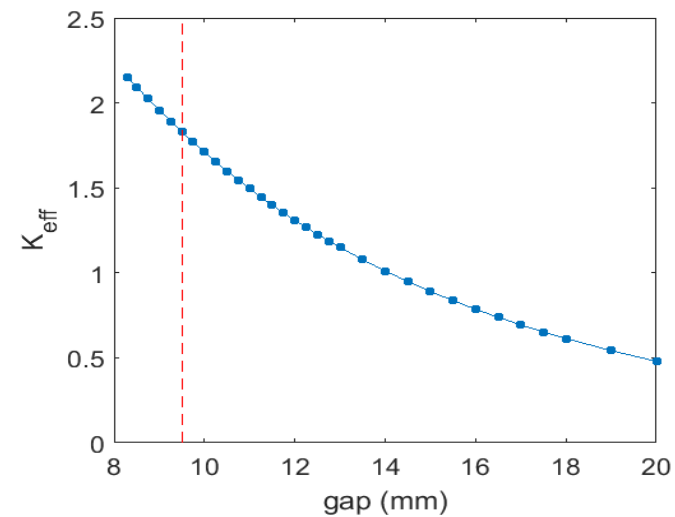
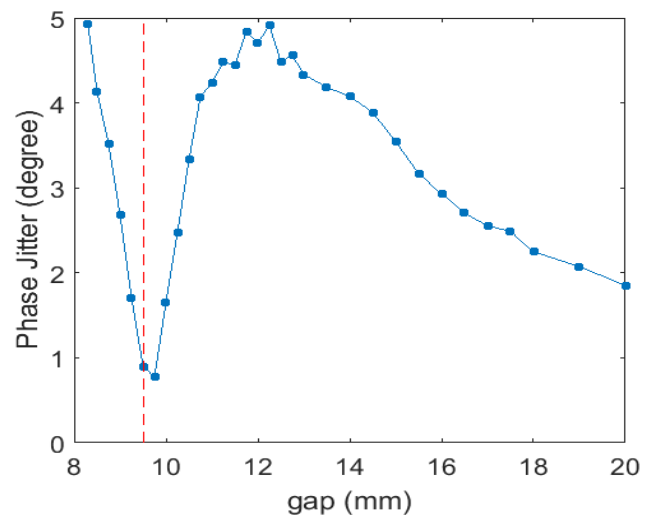
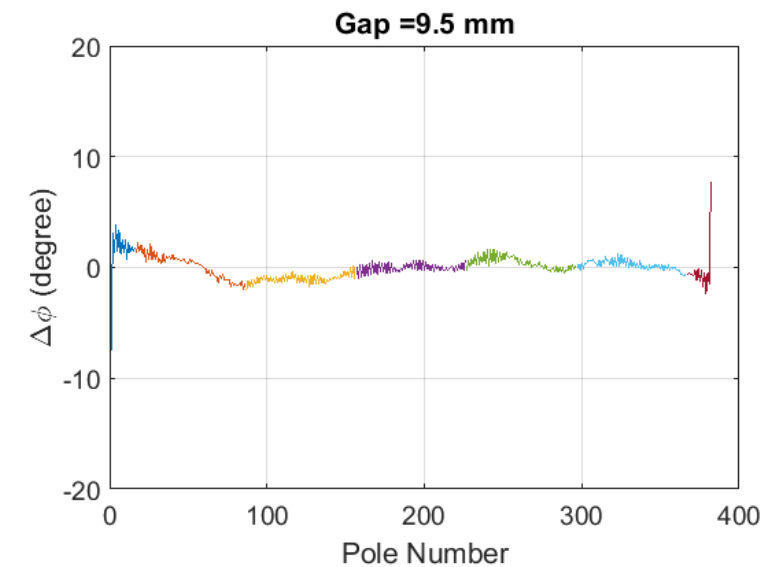
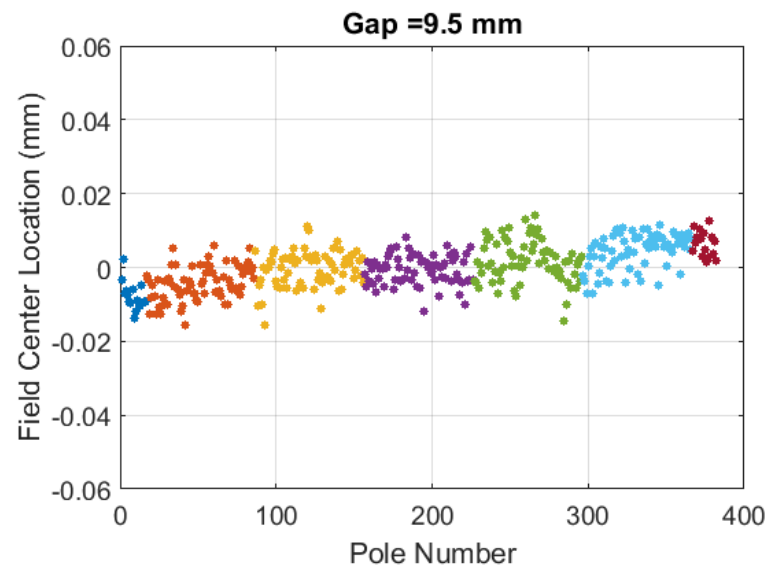
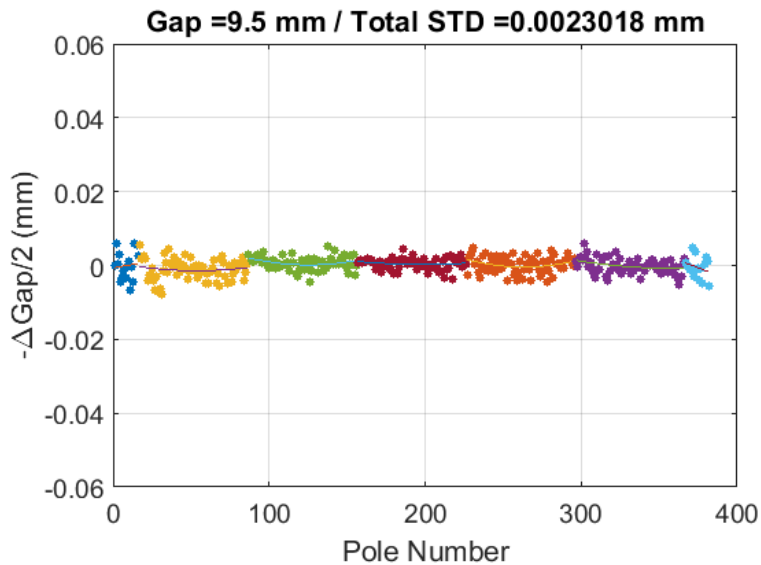
PAL-XFEL HX Spare Undulator - First Measurement



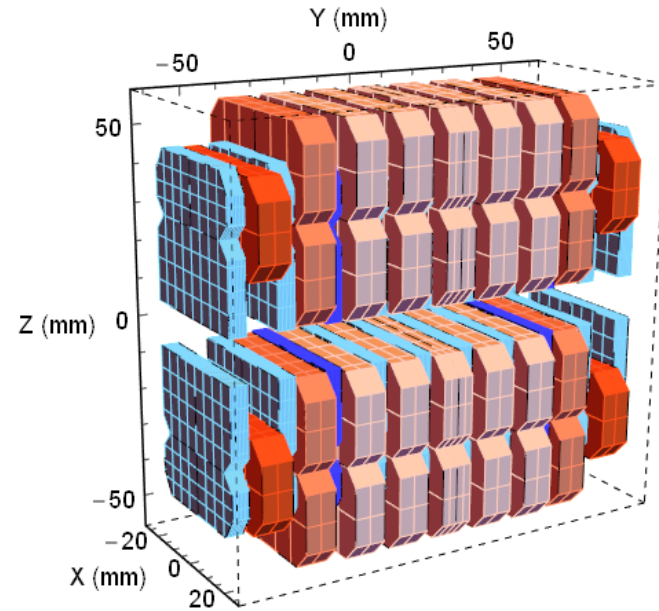
E1 M1 M2 M3 M4 M5 E2



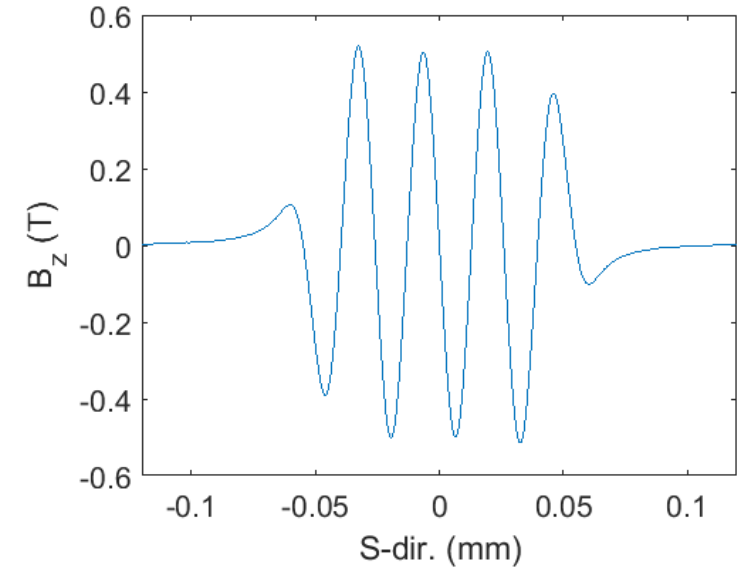
PAL-XFEL HX Spare Undulator - Tuning



Radiation Test Undulator



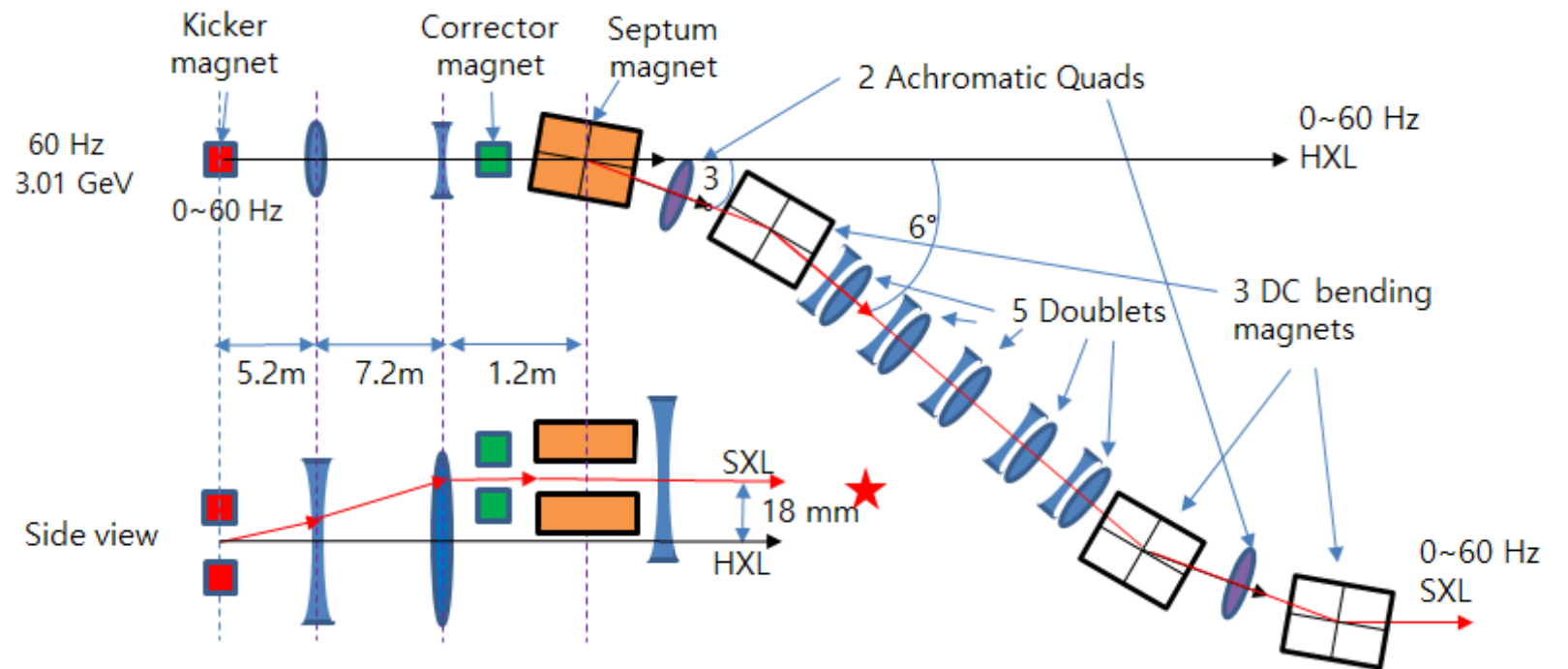
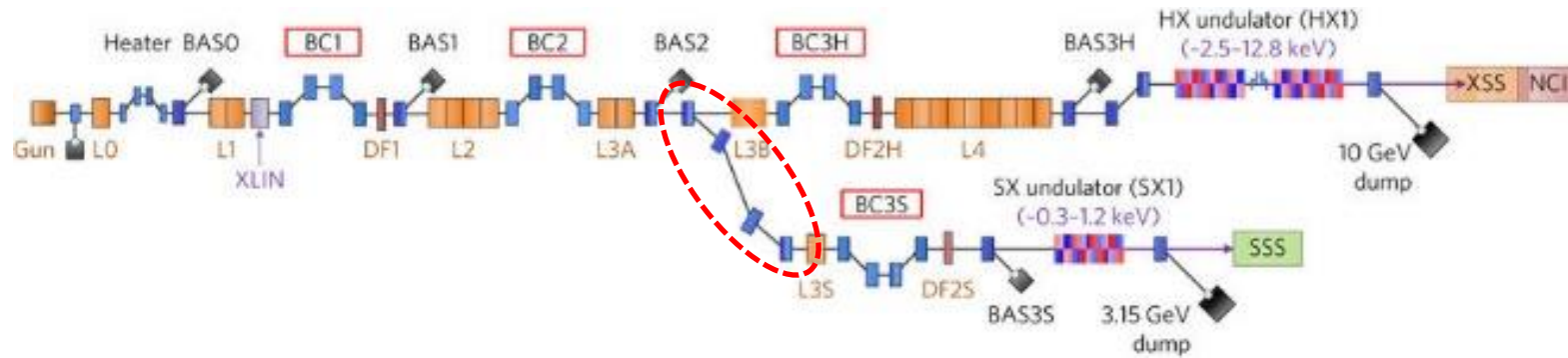
Magnet structure model



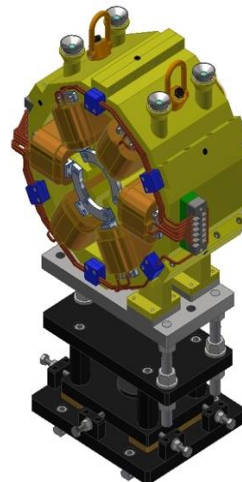
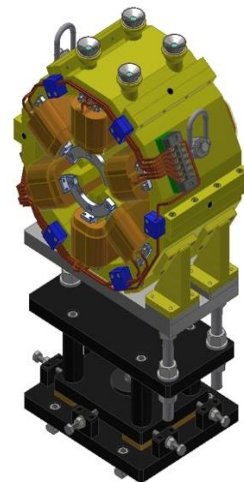
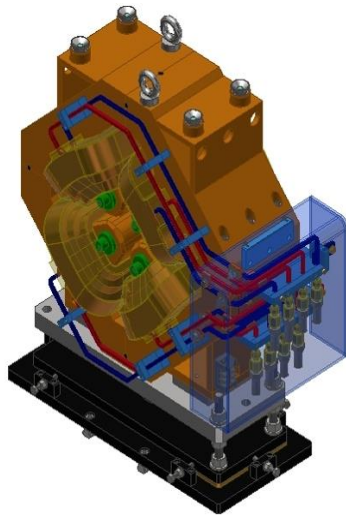
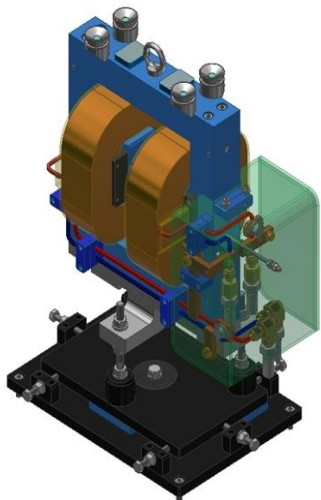
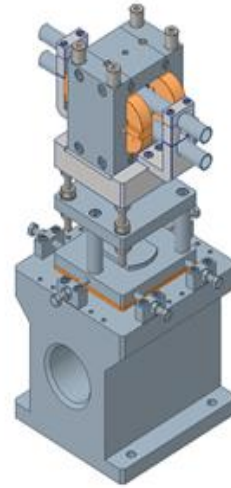
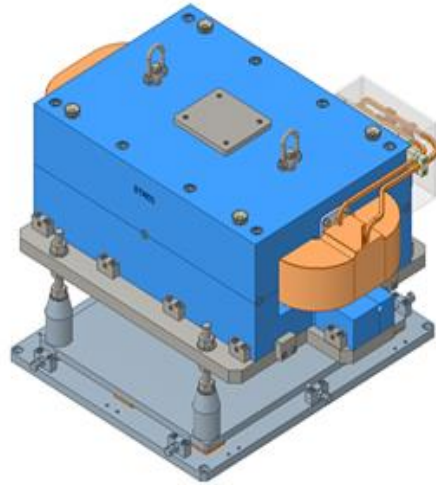
Field profile model

Installed upstream of 1st undulator segment in December 2018
Exposed to about 80 Gy
Field measurement after use to be done in July 2019

PAL-XFEL HX1-SX1 Parallel Operation



PAL-XFEL HX1-SX1 Parallel Operation

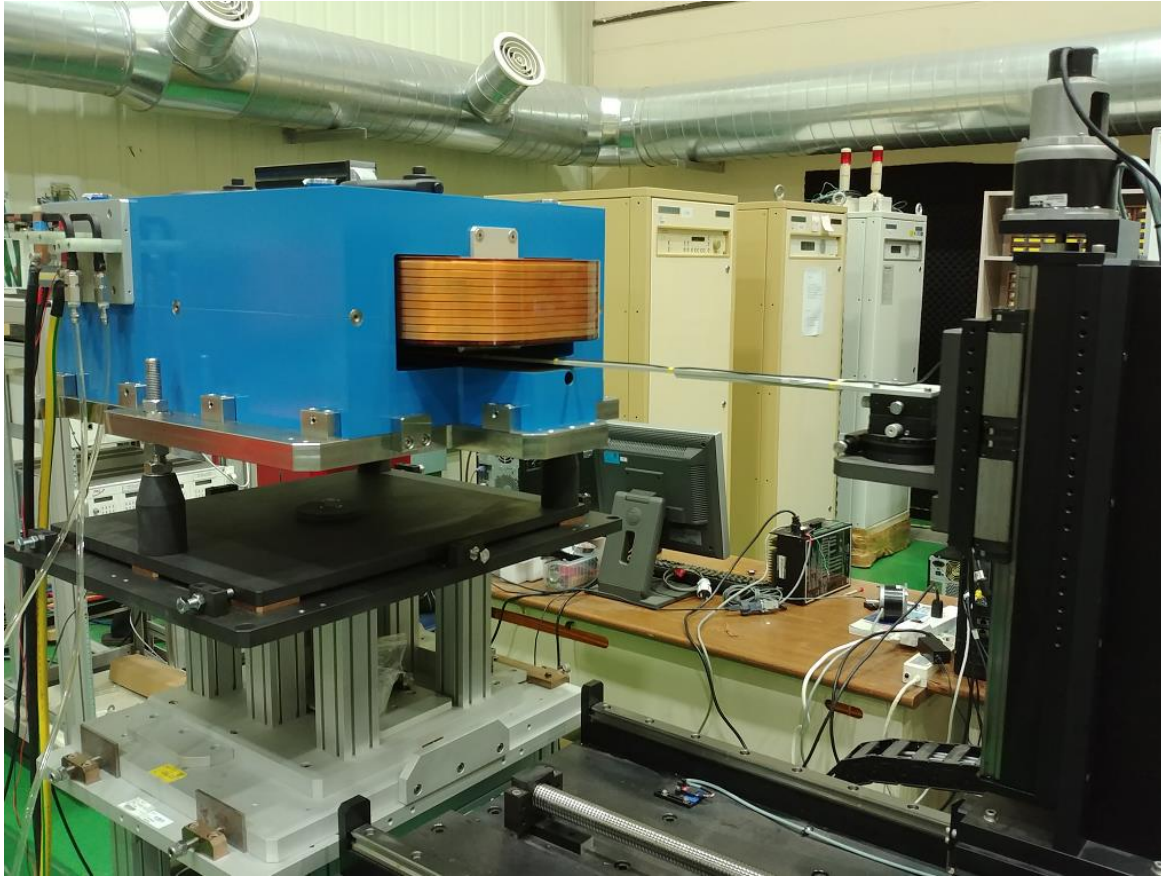


New magnets:

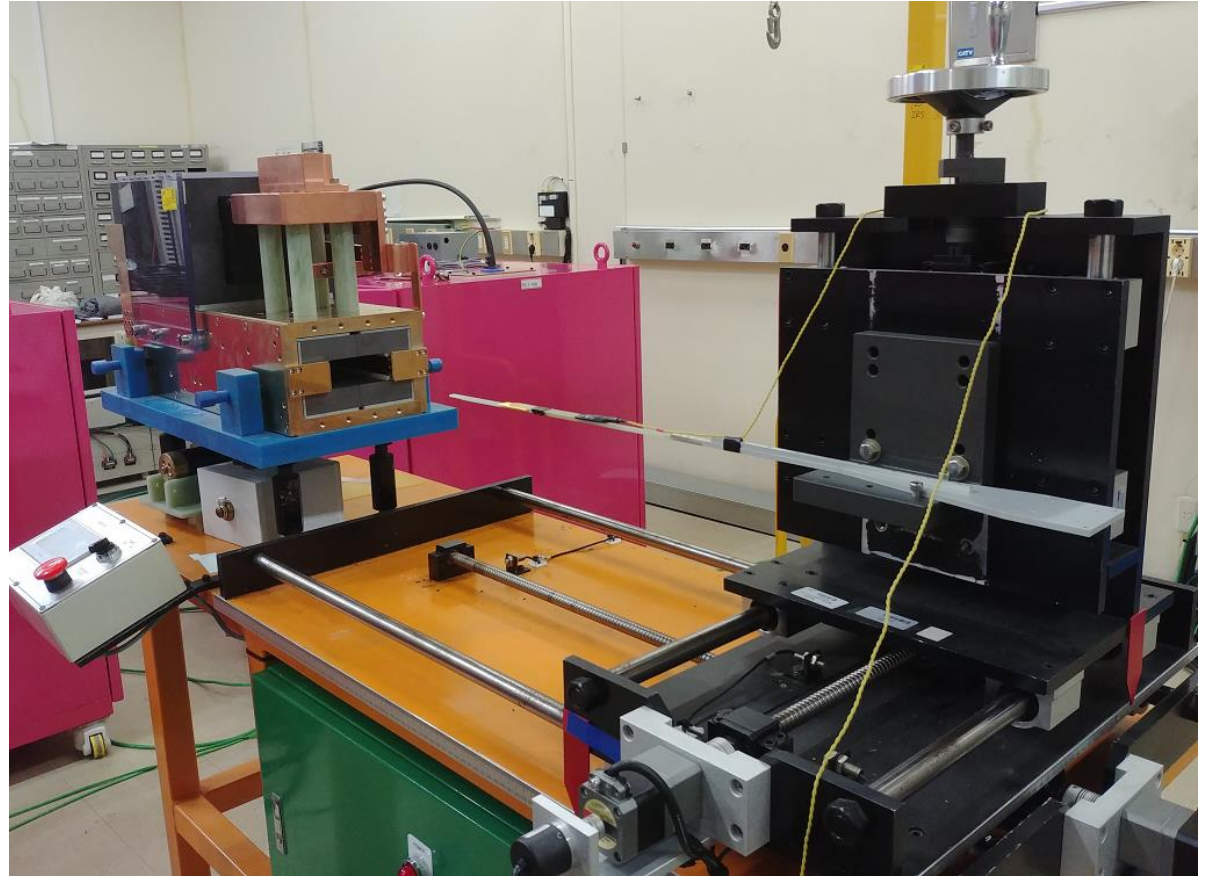
- 1 kicker with 60 Hz
- 1 septum
- 1 vertical corrector septum
- 8 dipoles
- 2 quadrupoles
- 4 sextupoles

Septa were delivered two weeks ago.
Other magnets are to be delivered this week.

Ongoing Electromagnet Measurements



PAL-XFEL septum magnet



New PLS-II injection kicker magnet

- During the major projects, PLS-II and PAL-XFEL, >40 insertion devices and >400 magnets were measured in 3 insertion device measurement labs and one magnet measurement lab.
- In early 2019, one used PLS-II IVU was re-tuned and one new PAL-XFEL HX undulator was measured and tuned.
- One new PLS-II IVU being manufactured. Magnetic measurement to be done in late 2019.
- A bunch of magnets for HX-SX parallel operation of PAL-XFEL to be measured soon.
- New injection kicker magnets for PLS-II being measured.