Photon Beam Position Monitor for PLS-II Beamline

Song Donghyun*, Kim Changbum, Hwang Ilmoon,
Hahn Garam, Kim Dotae, Lee Eunhee,
Kim Mungyung, Cho Wooseong

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POHANG ACCELERATOR LABORATORY

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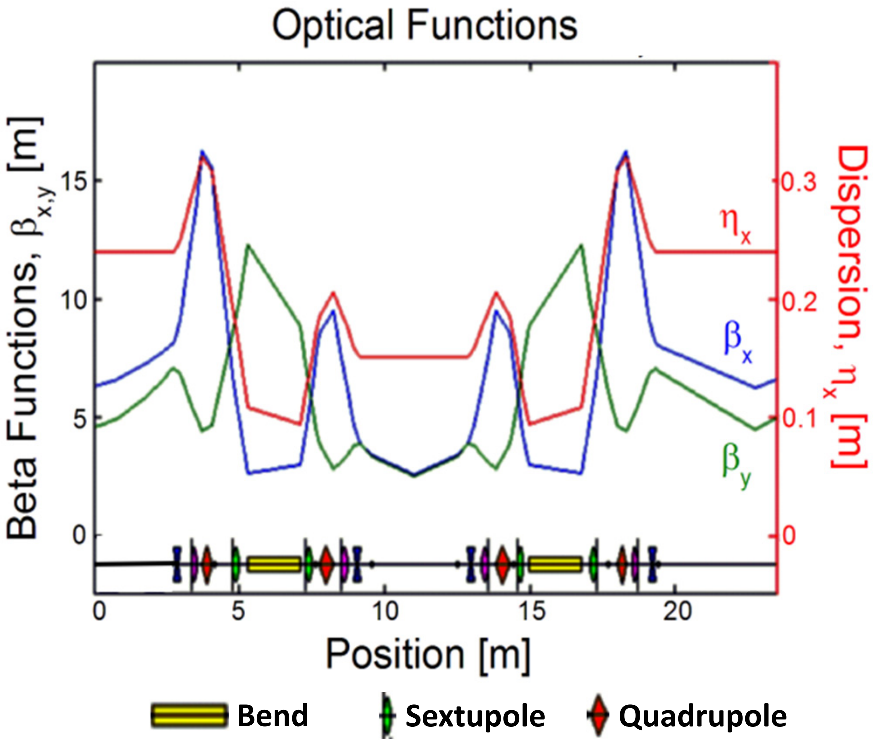

PLS-II Parameter	Value	Unit
Beam Energy	3	GeV
Beam Current	250 ~ 400	mA
Circumference	281.82	m
RF Frequency	499.97	MHz

- The PLS-II storage ring is designed with a Double-Bend Achromat (DBA) lattice structure consisting of 12 super-periods.
- Each of the 12 cells features two bending beamlines and two ID beamlines

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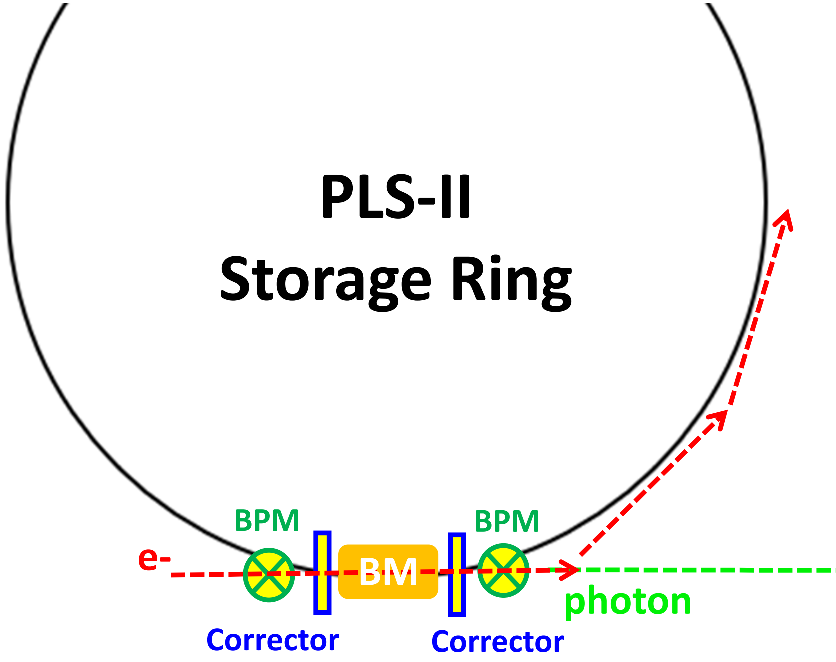
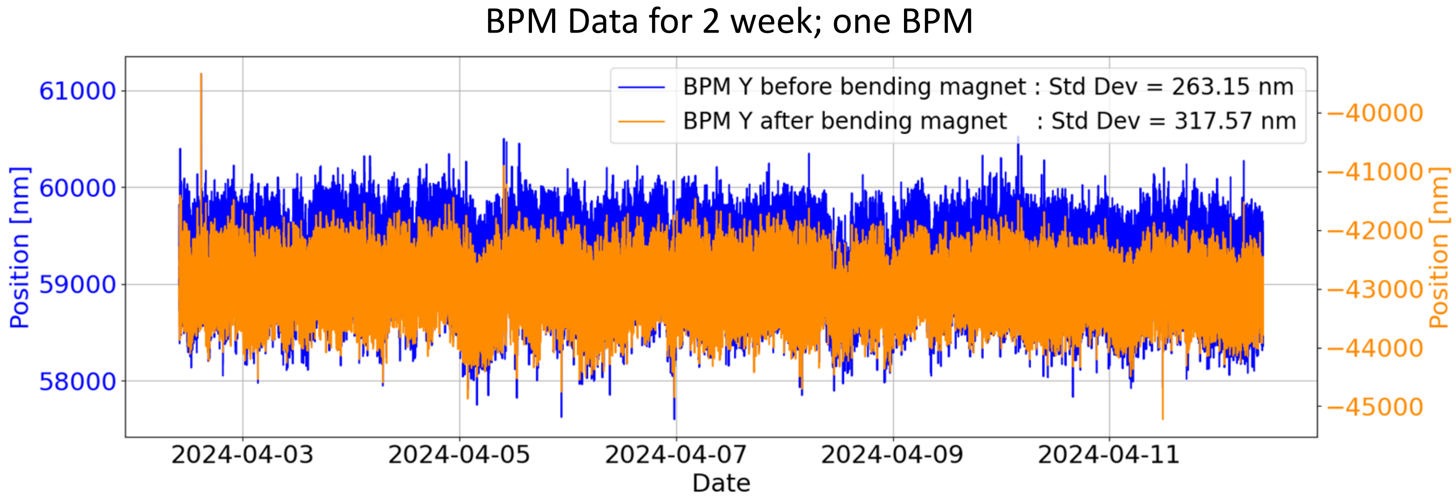
Contents

e-BPM & PBPM in Storage Ring





e-BPM for electron beam

- BPMs are installed before and after each bending magnet or ID
- A total of 96 BPMs are installed, 8 BPMs per cell

PLS-II Orbit Feedback

- Slow Feedback(SOFB) : ~ 2 Hz feedback using 96 BPMs and 96 Horizontal/Vertical slow correctors
- Fast Feedback(FOFB) : ~ 800 Hz feedback using 96 BPMs and 48 Horizontal/Vertical fast correctors
- The standard deviation of the SR orbit is less than 1 μm

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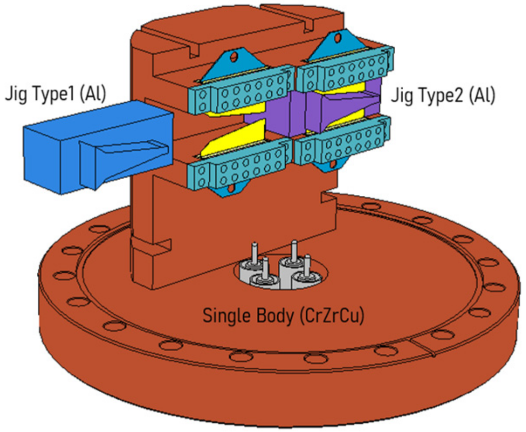
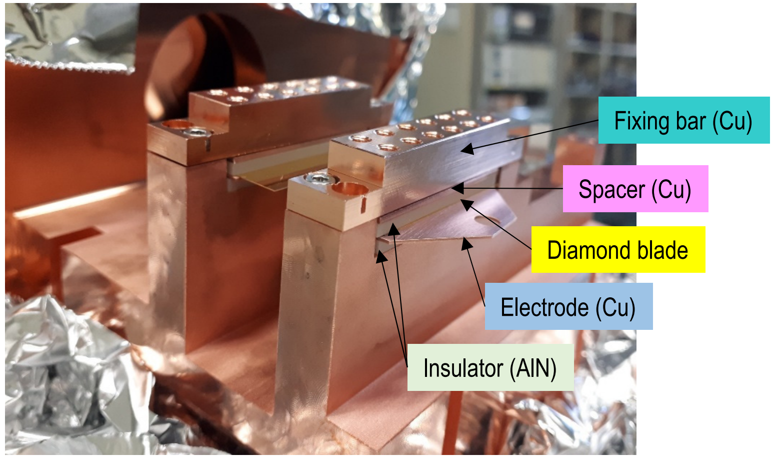
PBPM Material and Structure

Initial version of PBPM
with tungsten blades





Newer version of PBPM
with gold coated diamond blades

Material of PBPM Component

- Blade : Tungsten or Diamond
- Heat transfer plate : Sapphire or AIN
- Box : Copper

Blade

- The blades in the beamline that can give a high thermal load on the blades are made of diamond
- Other blades are made of tungsten

Horizontal/Vertical Gap

- The gap was fabricated to be about 10% of the maximum value of the photon power density distribution

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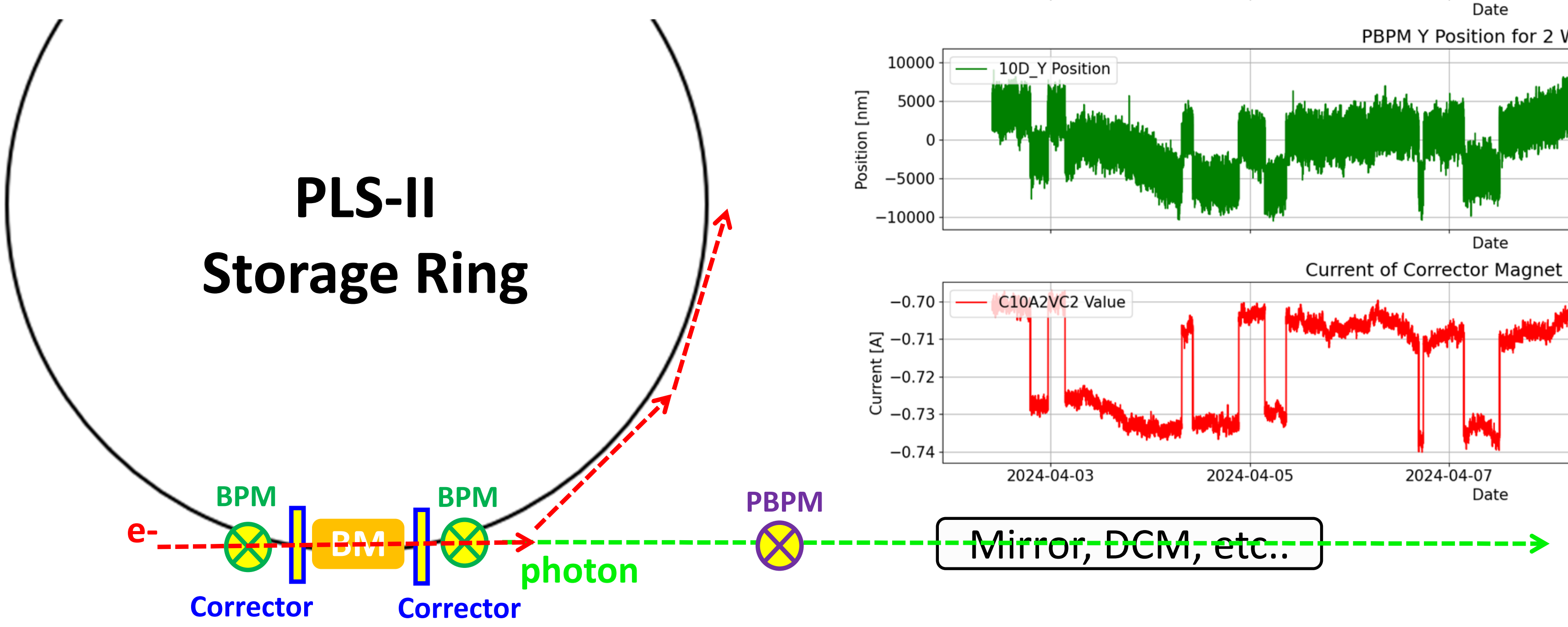
e-BPM & PBPM in Storage Rin



e-BPM for electron beam

- BPMs are installed before and after each bending magnet or ID
- A total of 96 BPMs are installed, 8 BPMs per cell

PBPM for photon beam

- While the electron beam is stable, the photon beam's position is not stable
- This instability is due to a large change in the corrector magnet current

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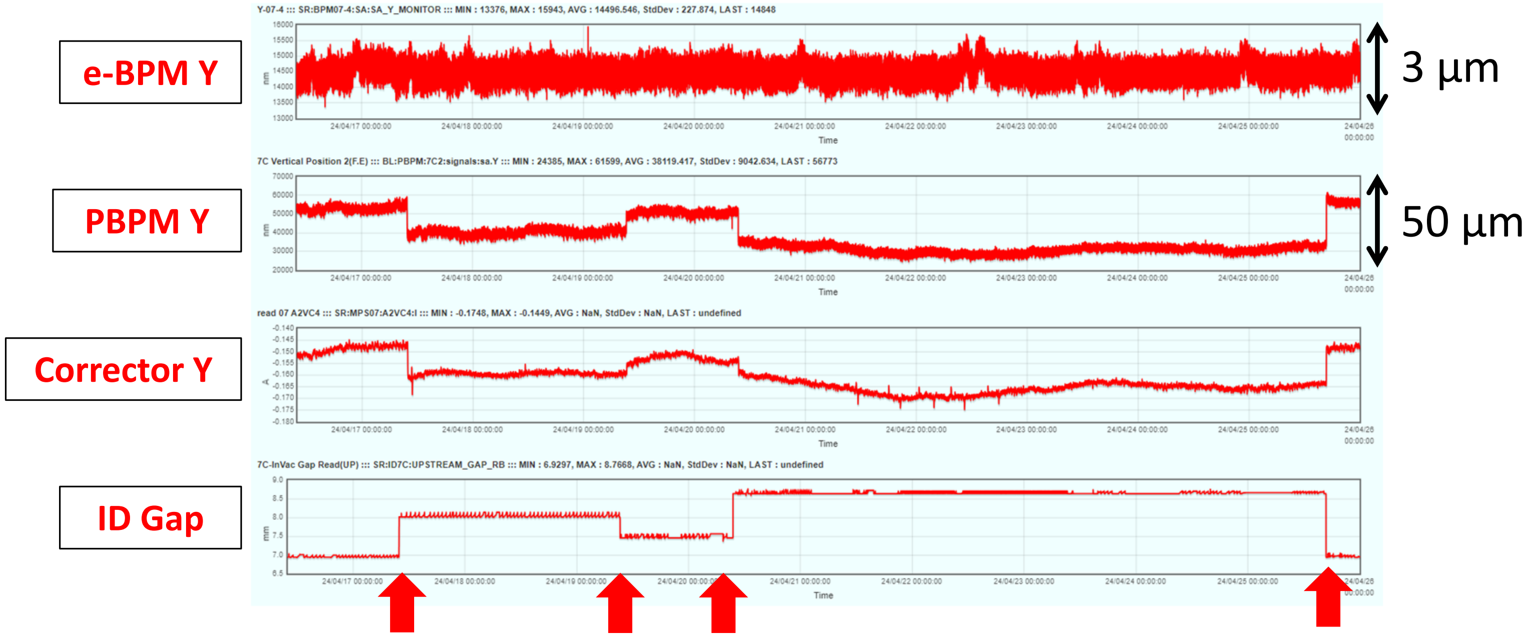
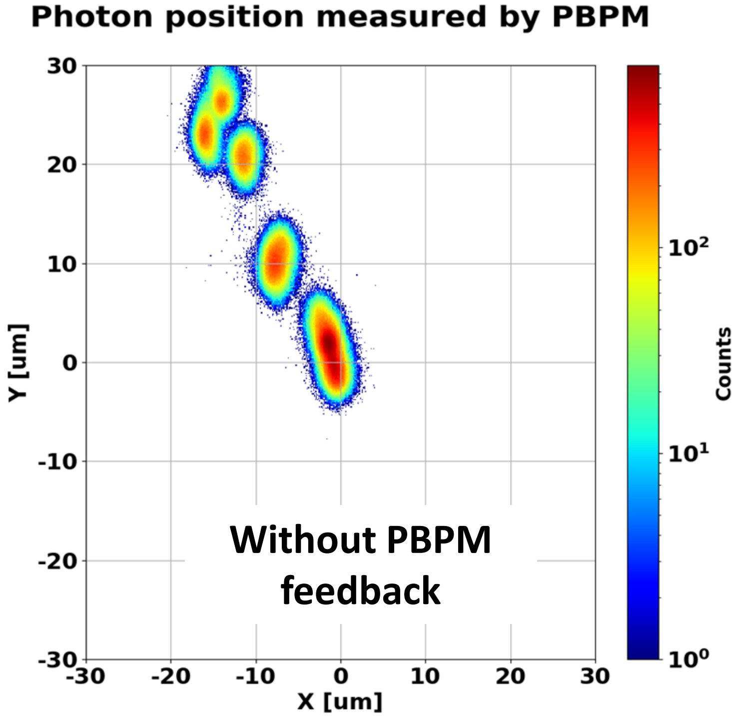
Photon position without PBPM feedback





Data on the vertical positions, corrector magnet and ID gap over two weeks (left)

- The orbit feedback at PLS-II adjusts the electron orbit by changing the corrector magnet current
- As the electron orbit is changed by orbit feedback, the central position of the photon beam is also changed

Change in the central position of the photon beam over two weeks (right)

- The center position changes in response to adjustments in magnet current made by the orbit feedback

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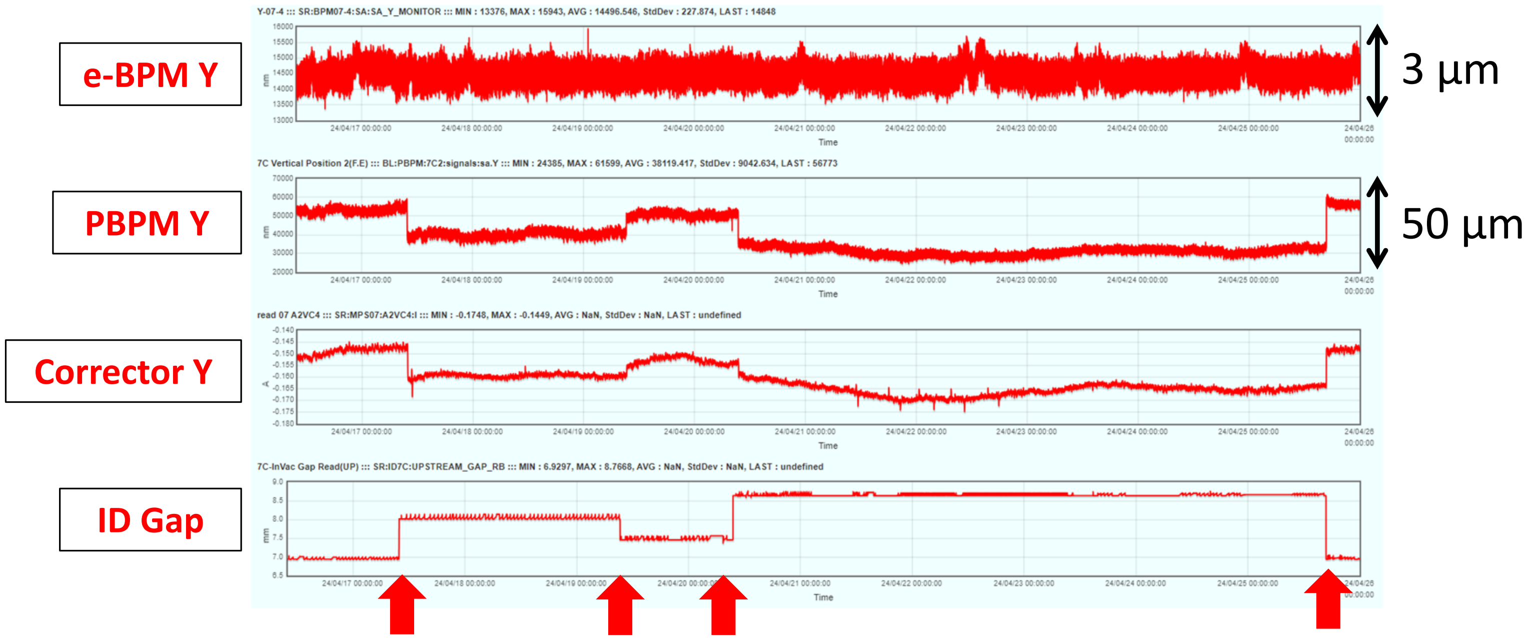
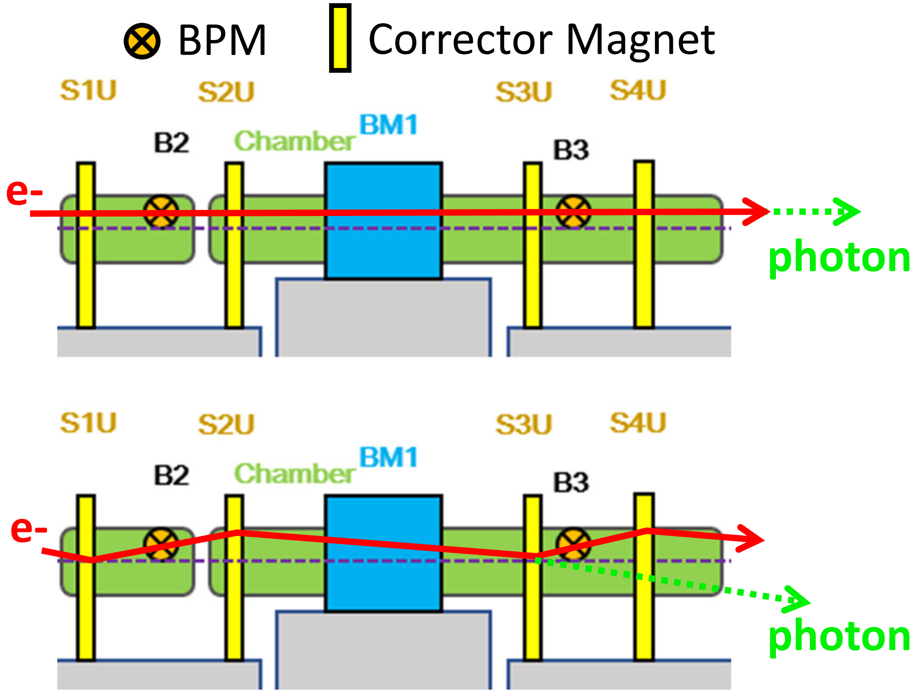
Photon position without PBPM feedback





Data on the vertical positions, corrector magnet and ID gap over two weeks (left)

- The orbit feedback at PLS-II adjusts the electron orbit by changing the corrector magnet current
- As the electron orbit is changed by orbit feedback, the central position of the photon beam is also changed

Configuration of BPMs and Corrector Magnets in PLS-II (right)

- The electron position measured by BPM passes the center because the orbit feedback is working
- BPM readings show the electron position as centered, but orbit deviation can occur

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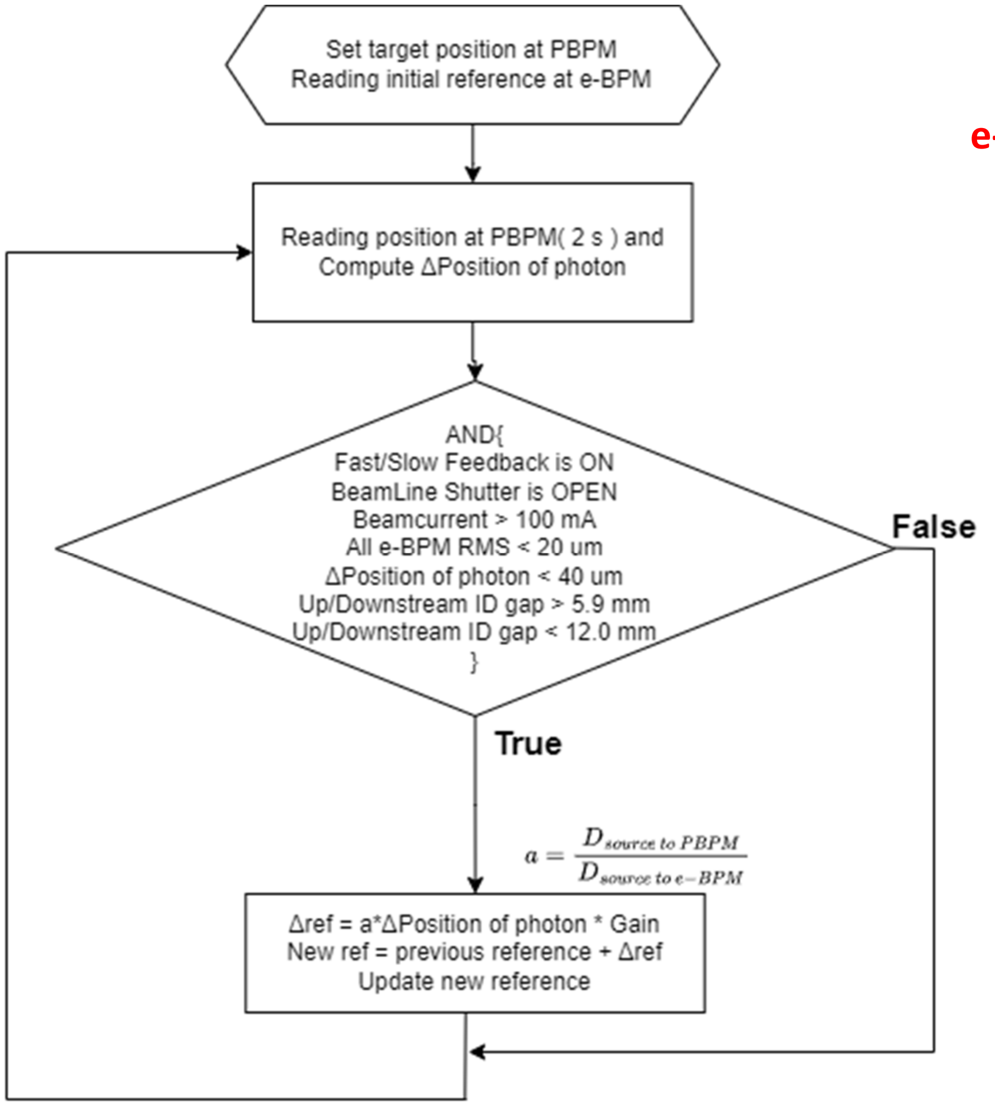
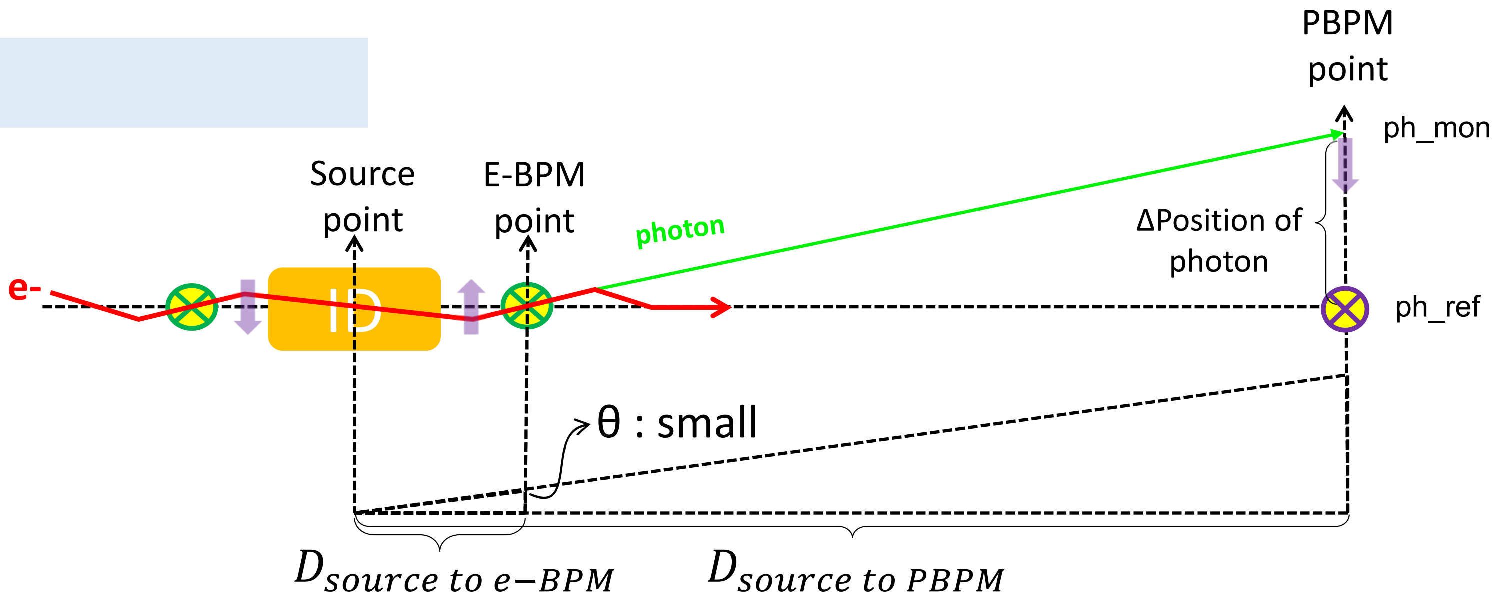
PBPM Feedback Algorithm





Algorithm

- Assumption : angle effect is dominant for PBPM

1. Set reference point at PBPM (ph_ref)
2. Reading PBPM data (ph_mon)
3. Calculate the difference between ph_ref and ph_mon
4. Using the distance between the source point and the BPM and PBPM, adjust the electron beam to realign the photon beam to the reference position.
5. Repeat steps 2 to 4

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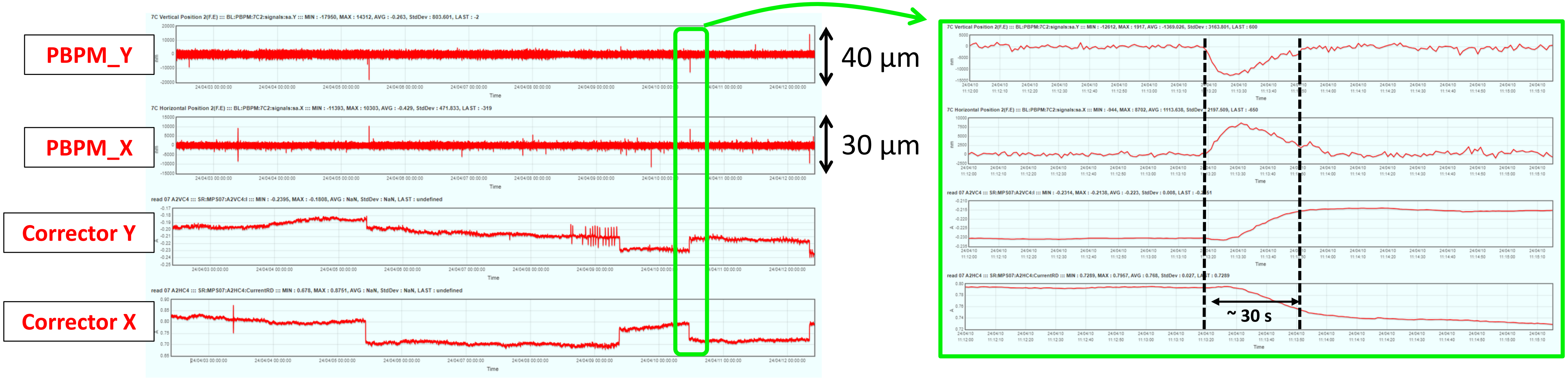
Results of applying the feedback algorithm



Data on the central position from the PBPM and Corrector Magnet Current over two weeks (left)

- After applying PBPM feedback, the photon beam stability is improved

PBPM feedback response for a minute (right)

- Maintains the photon beam centered, even with significant changes in the corrector magnet's current

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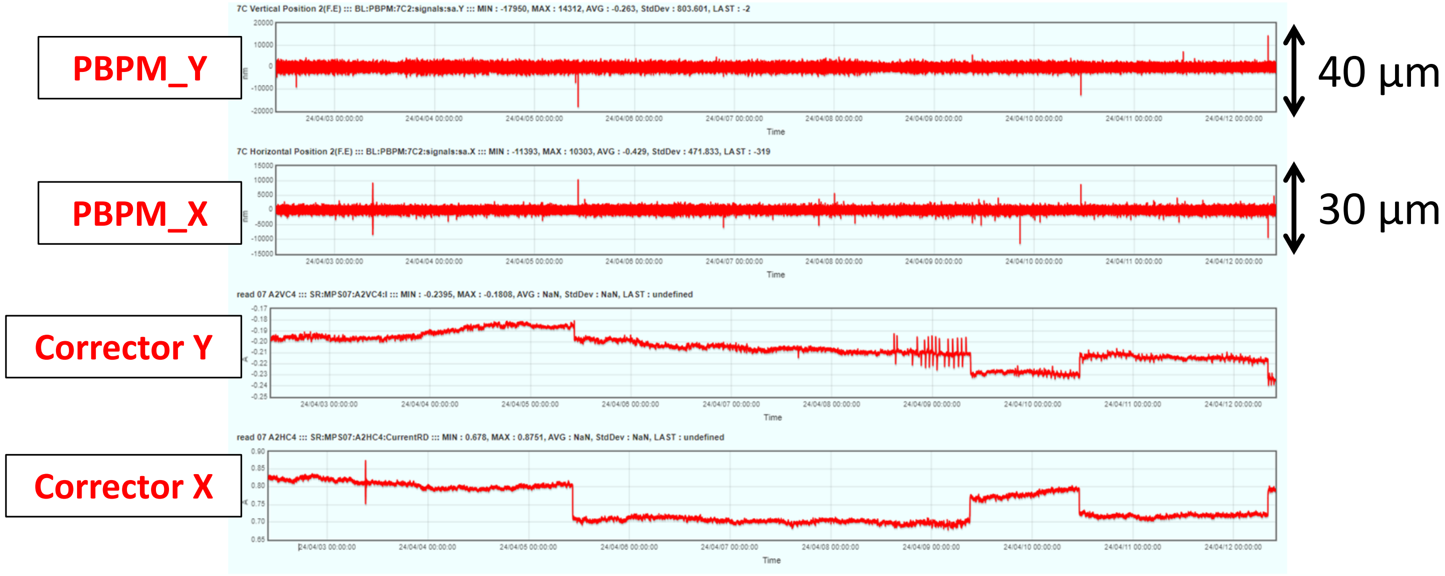
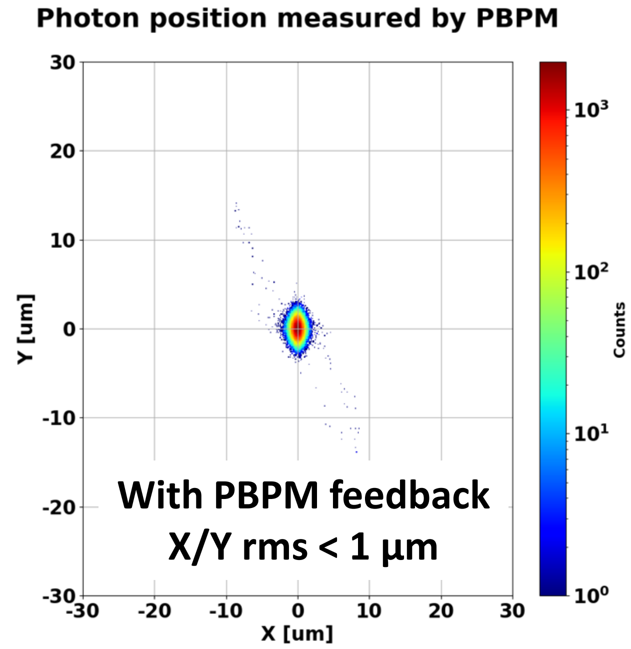
Photon Position with PBPM feedback





Data on the central position from the PBPM and Corrector Magnet Current over two weeks (left)

- After applying PBPM feedback, the photon beam stability is improved

Change in the central position of the photon beam over two weeks (right)

- Position deviation rms under 1 µm

songdonghyun@postech.ac.kr

Photon Beam Stability

Beamline	3C		4C		5A	5C		6D	7A	
Hori./Vert.	X	Y	X	Y	Y	X	Y	Y	X	Y
rms [μm]	0.47	2.20	0.81	0.69	0.38	0.54	1.00	0.61	0.56	0.79

Beamline	7C		8A	9A		9B	9C		10D	11C	
Hori./Vert.	X	Y	Y	X	Y	Y	X	Y	Y	X	Y
rms [μm]	0.66	0.97	1.24	0.93	1.02	0.27	1.42	1.90	1.04	0.68	0.95

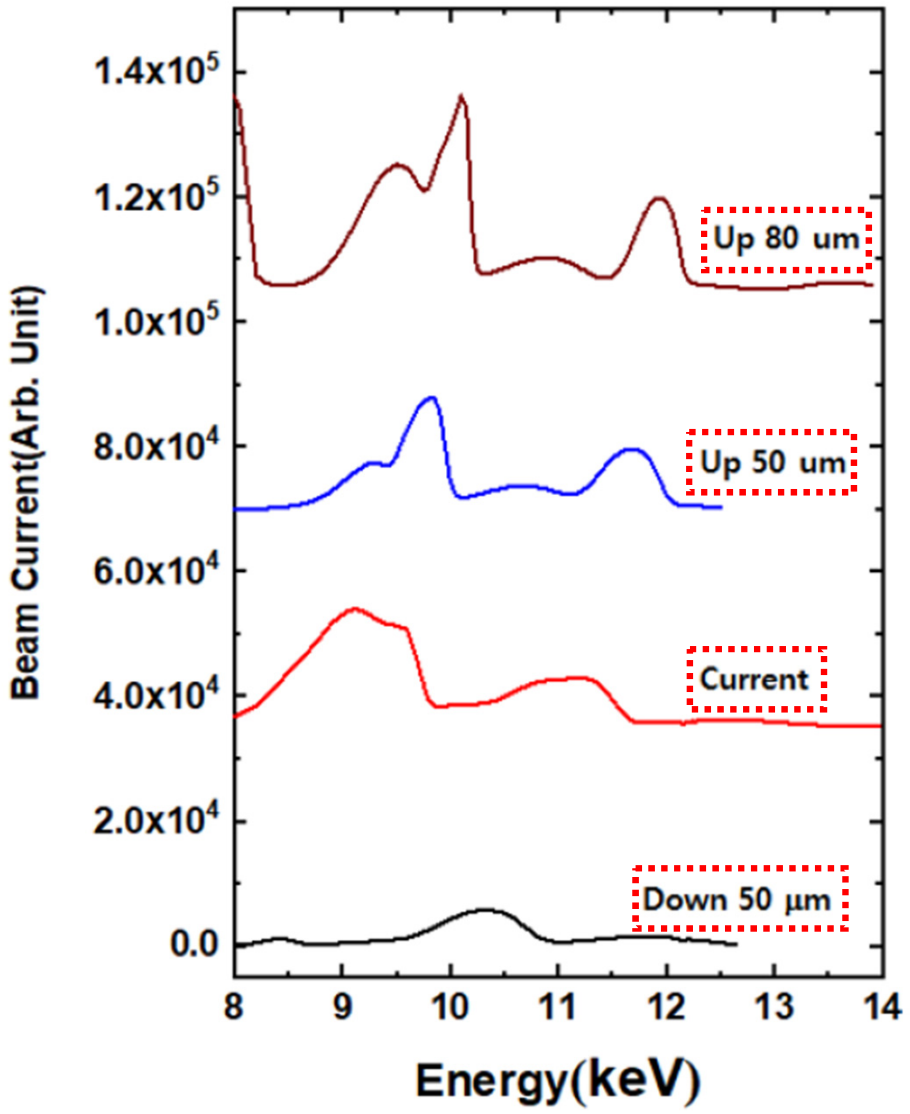
rms values of photon beam position over 18-weeks

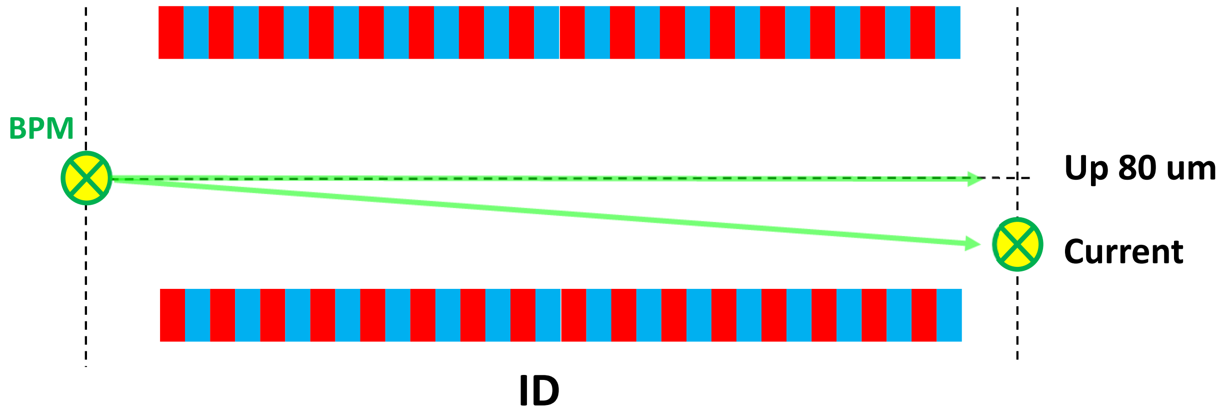
- PBPM feedback was implemented to 13 beamlines
- During the 9-user beamtime spanning 18-weeks, photon beam position stability was maintained within a few μm
- PBPM feedback on PLS-II works effectively

songdonghyun@postech.ac.kr

Contents

Photon Energy Spectrum





BPM alignment error due to ground motion, alignment work, etc

Energy Spectrum by Electron Orbit Adjustment

- The sharpness of the energy spectrum varies with changes in the downstream electron orbit
- Precise beam alignment within the ID could be achieved through adjustments to the electron orbit
- We attempted to estimate the beam alignment inside the ID by measuring the photon beam profile using PBPM scanning

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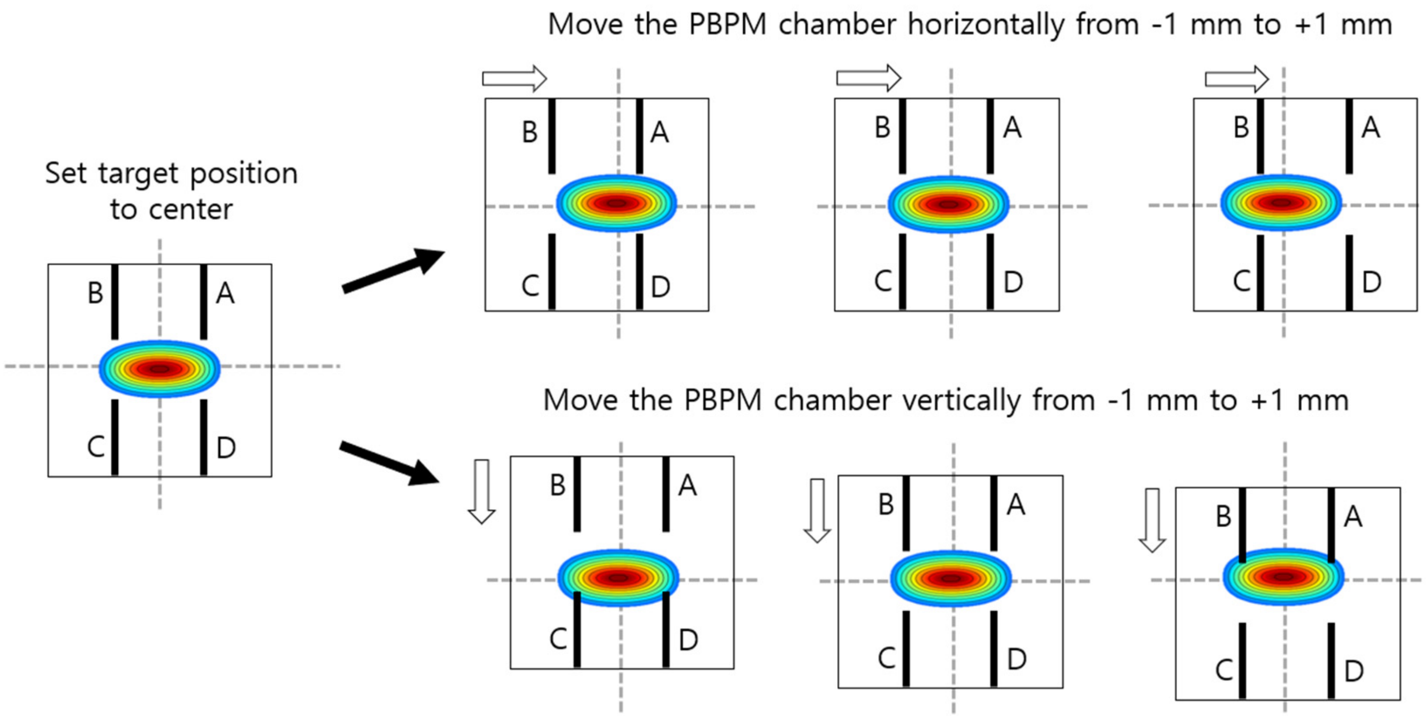
PBPM Blade Signal Scan (H/V)



Blades Signal Measurement

- Position the PBPM at the center of the photon beam
- Move the PBPM horizontally and vertically to measure the signal from each blade

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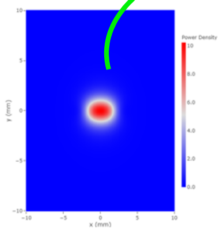
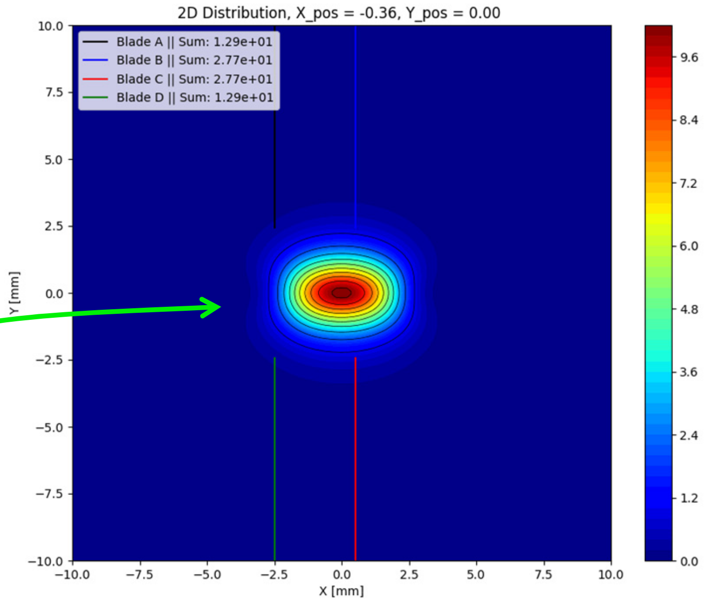
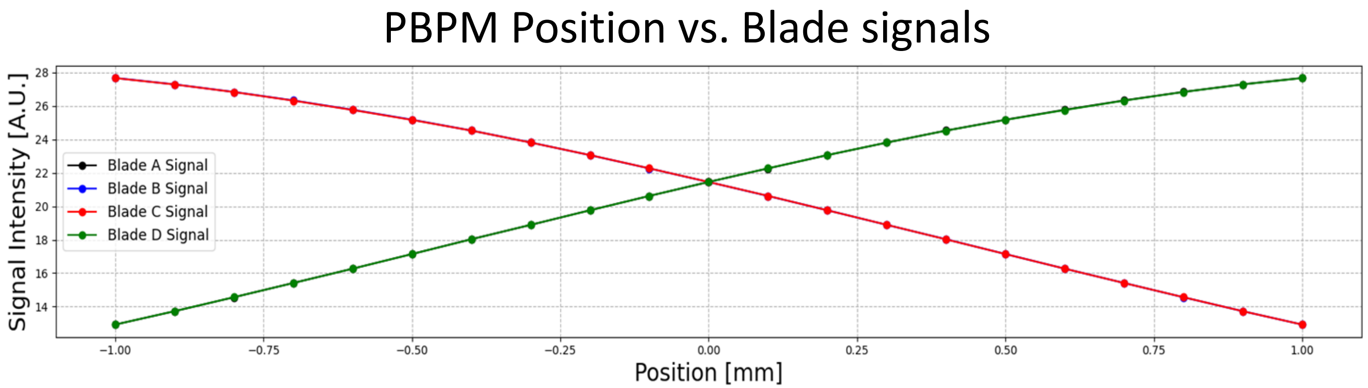
Simulation of Blade Signals

Power density calculated by SPECTRA







Photon Distribution and Blade signals

- Assume that four straight lines represent the blades
- The signal size is determined by summing the distribution values corresponding to each straight-line

- In an ideal horizontal scanning, the signal from two right blades or two left blades should overlap

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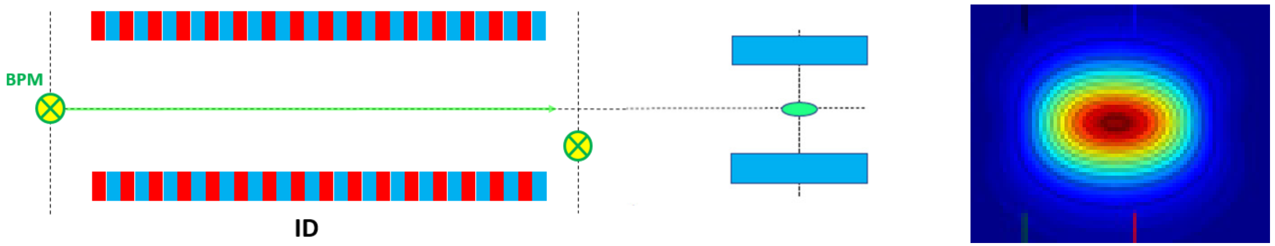
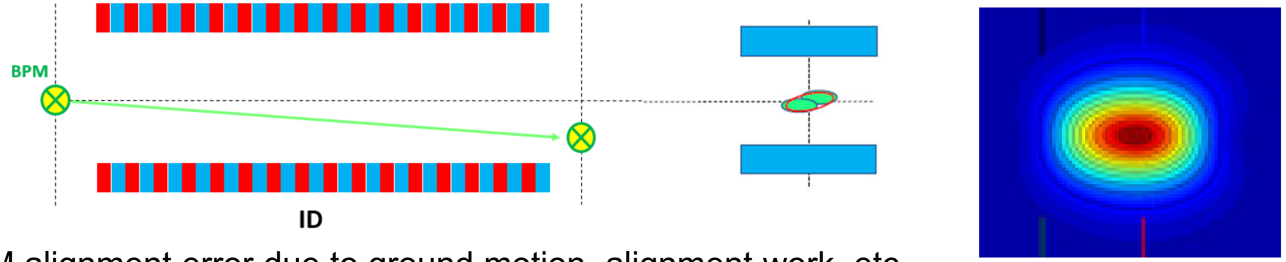
Incident Angles of Electron Beam in ID

(1) Electron beam enter ID without incident angle



(2) Electron beam enter ID with incident angle



BPM alignment error due to ground motion, alignment work, etc

Estimating the Distortion of Photon Beam Distribution Caused by Incident Angles

- (1) If the electron beam is well aligned with the ID, the distribution of the photon beam is symmetrical
- (2) If the electron beam is not aligned properly, the distribution becomes asymmetrical

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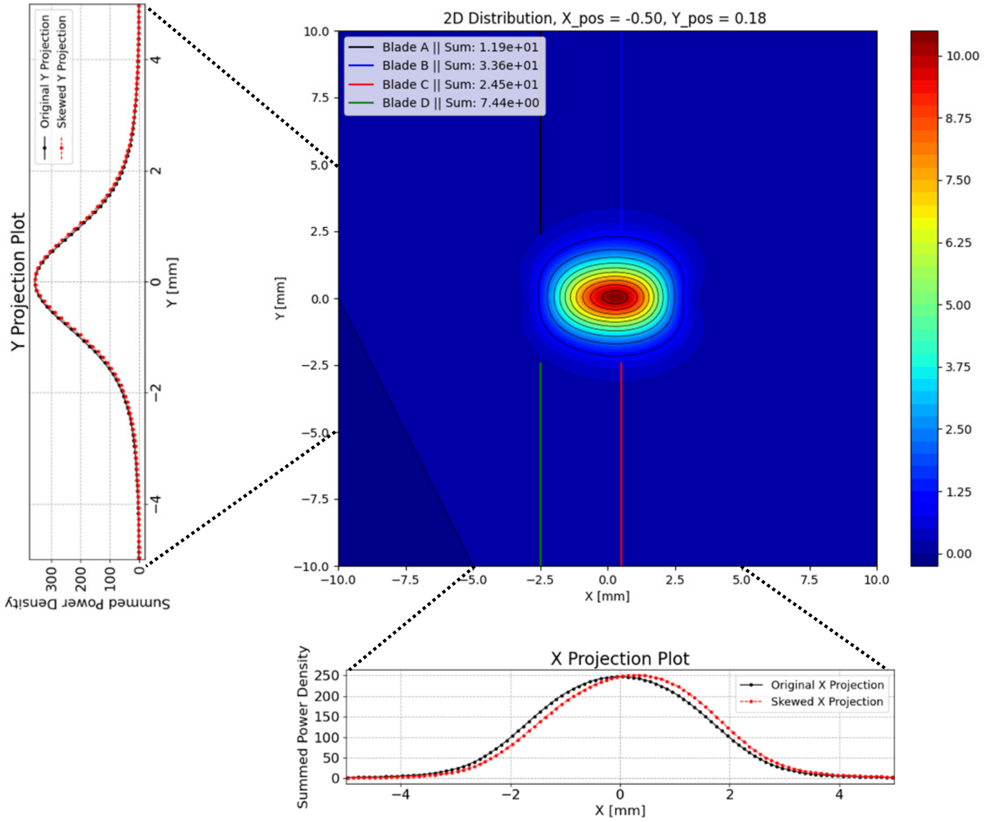
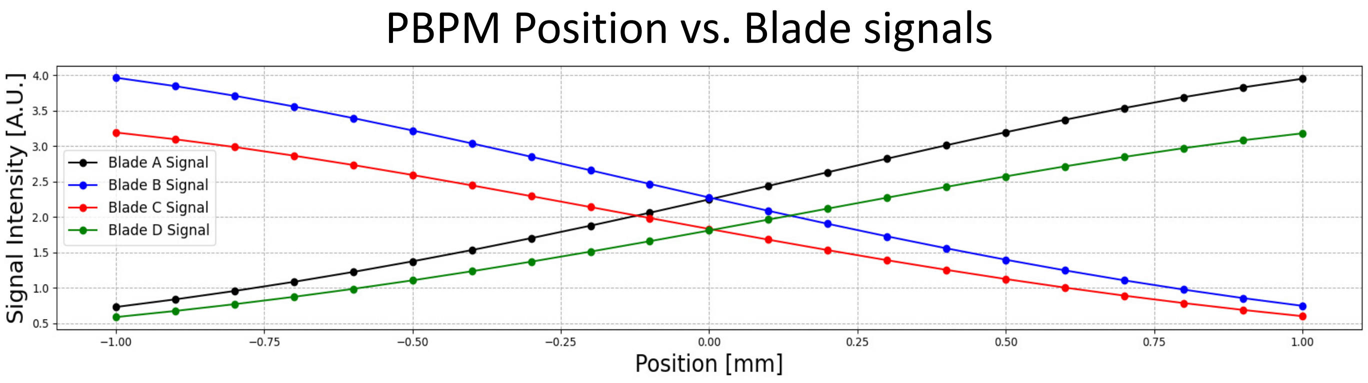
Simulation of Blade Signals





Photon Distribution and Blade signals
- Recalculate the blade signal value by applying a skewed distribution

- As the photon beam distribution becomes skewed, differences in the signals from each blade occur
- The intensities of these signals vary depending on the horizontal and vertical spacing of the blades

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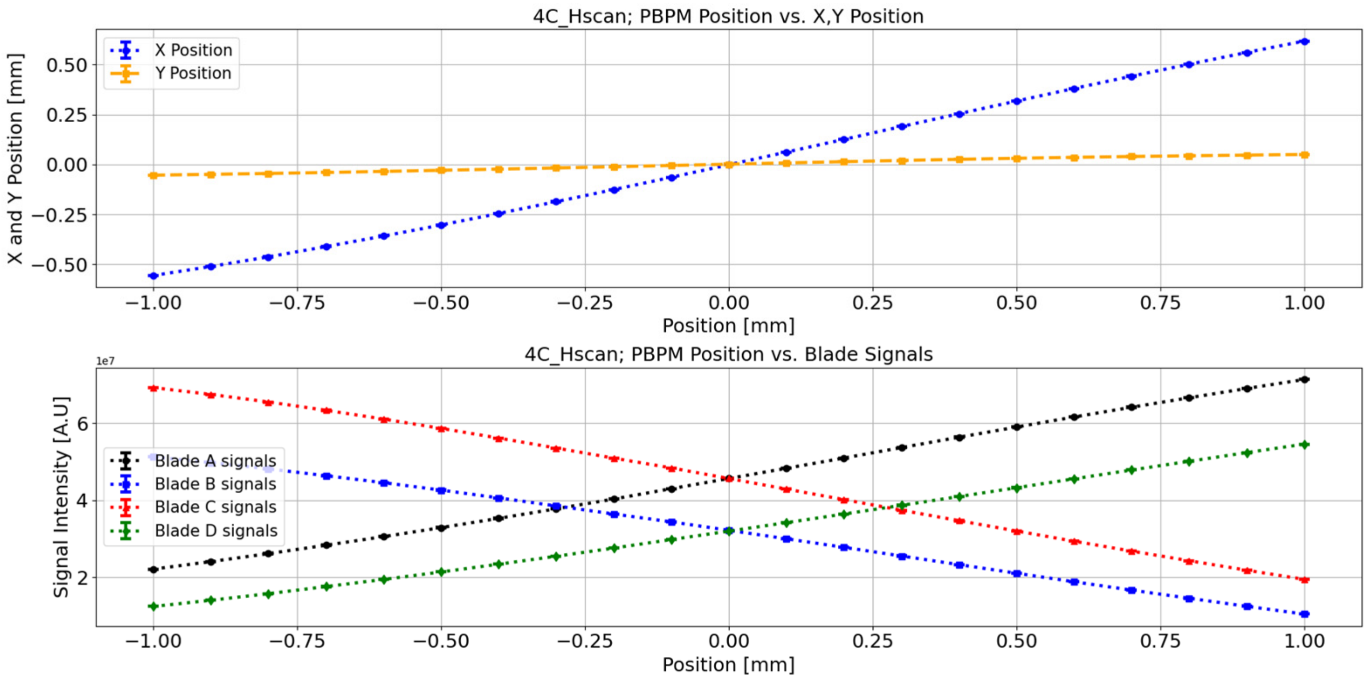
Result of the PBPM Scanning Measurement



PBPM blade signal scan

- During a horizontal axis scan, the signal from the PBPM blades was measured.
- Asymmetry in the blade signals was detected,
  indicating potential misalignment of the electron beam

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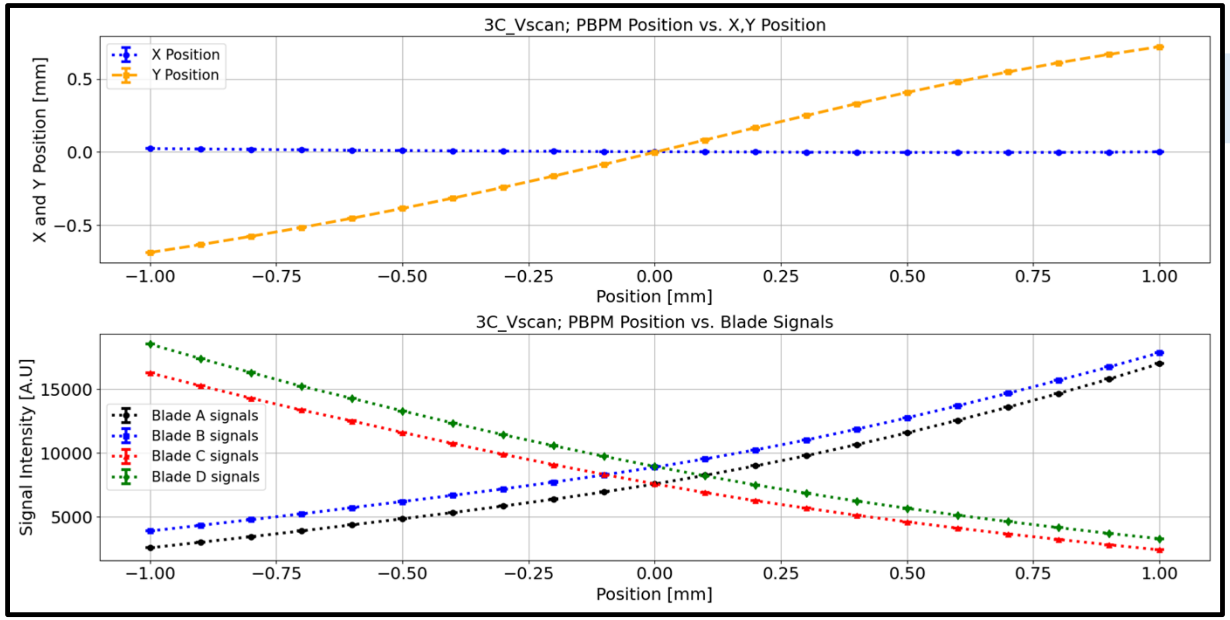
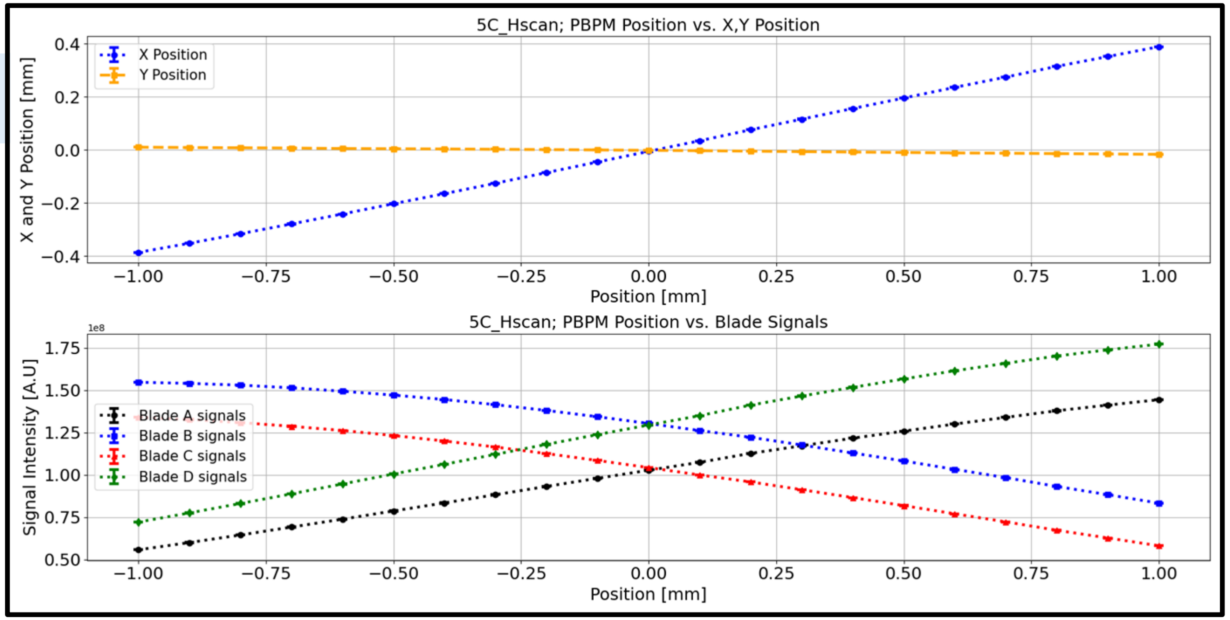
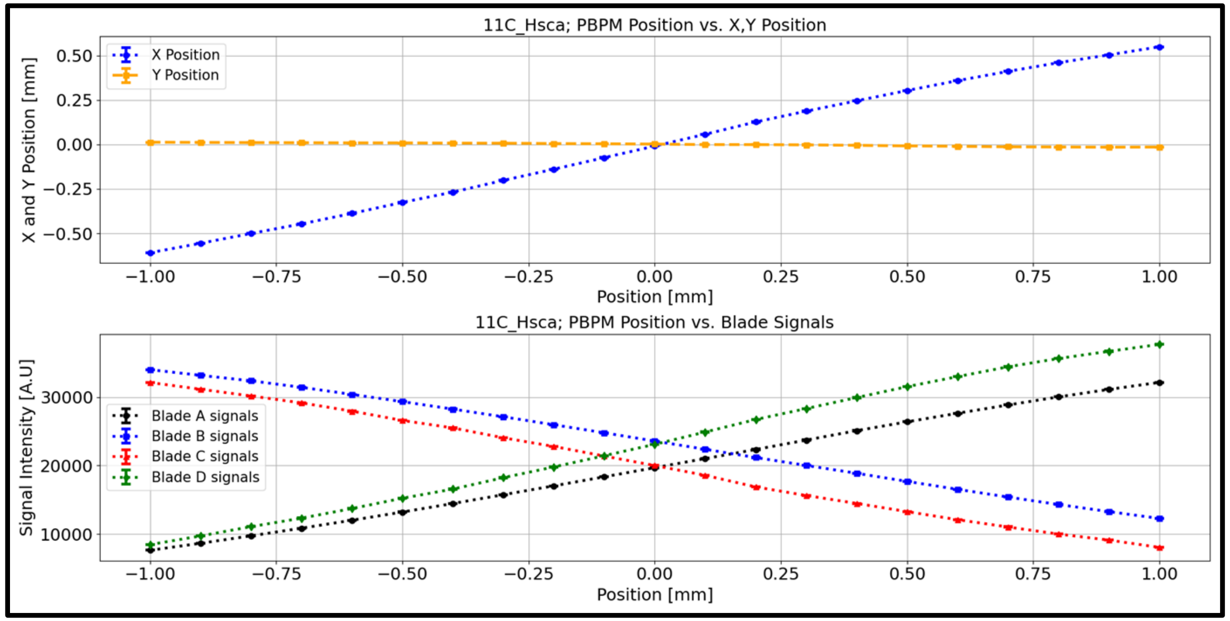
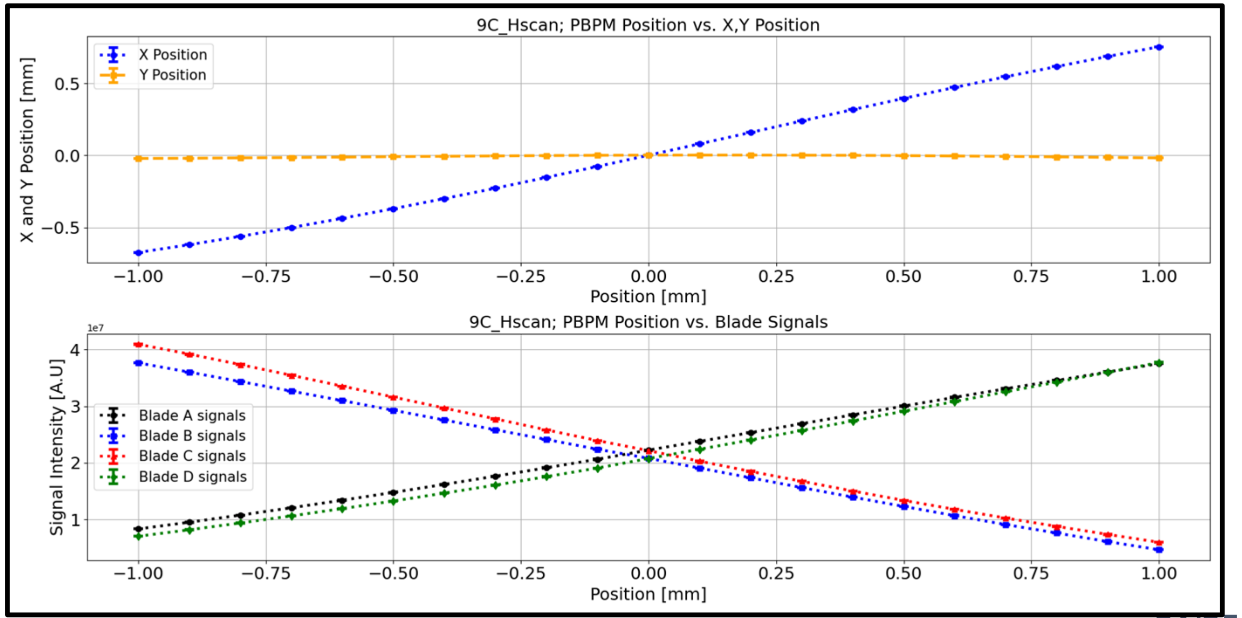
PBPM Scan









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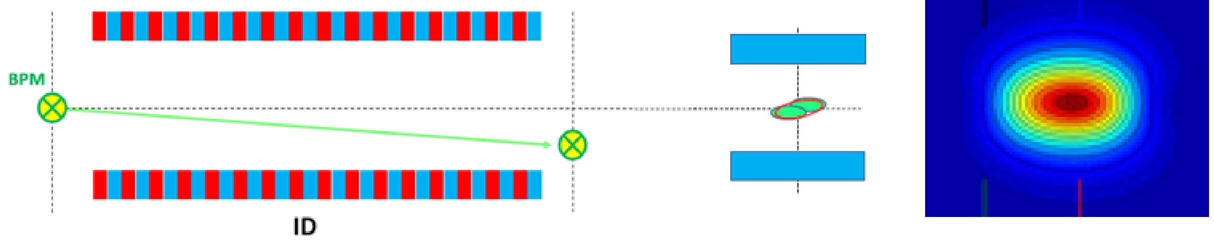
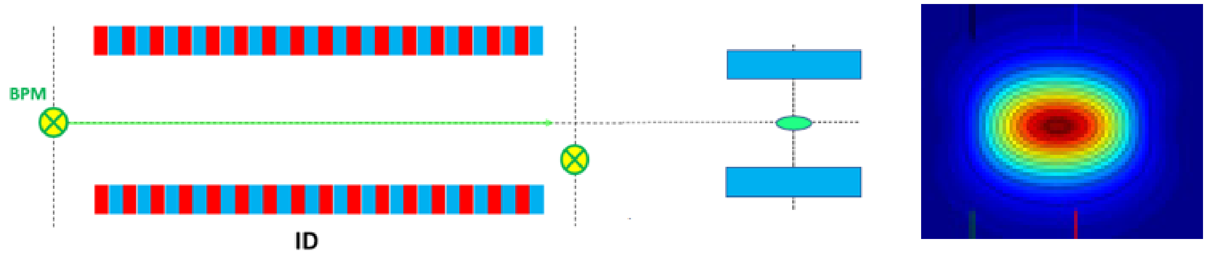
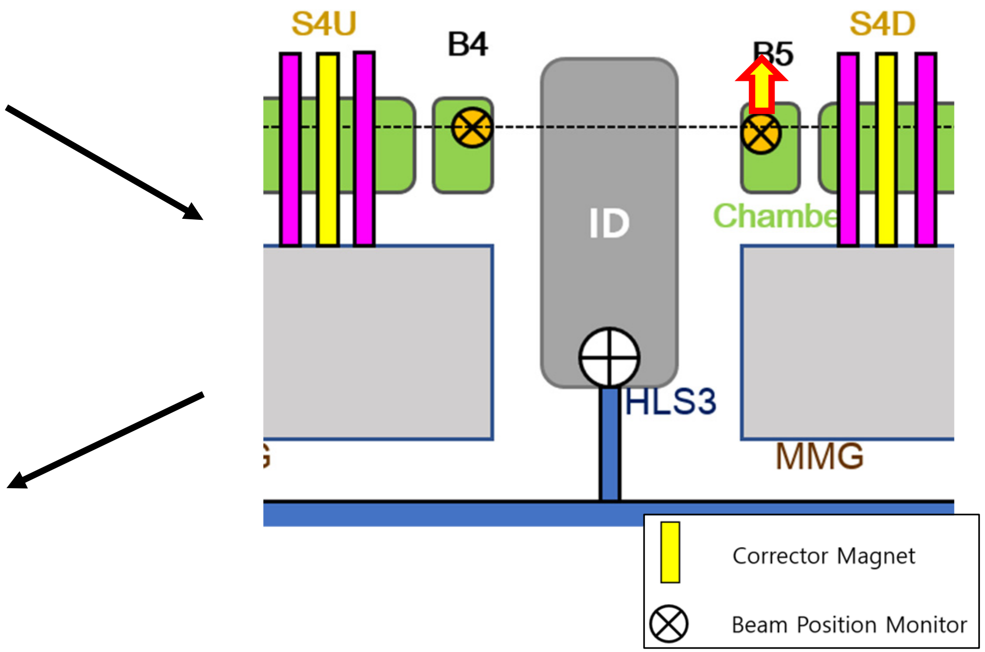
e- beam orbit distortion

Electron beam enter ID with incident angle



Electron beam enter ID without incident angle





Estimation of electron beam alignment by measuring ID beam profile

- Change the electron orbit before and after the ID to adjust the incident angle
- When the electron beams are aligned, the photon beam will be symmetrical, and the difference in the blade signal will be reduced

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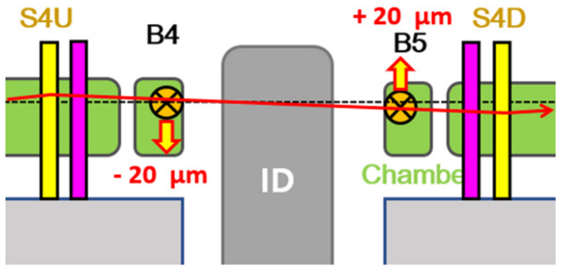
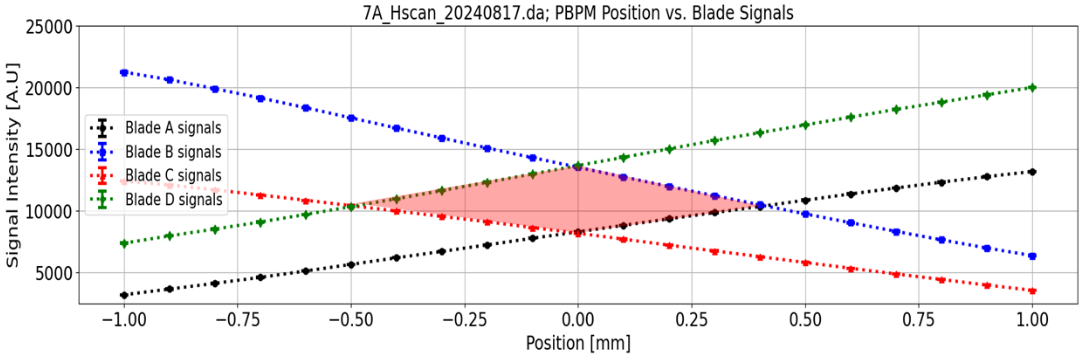
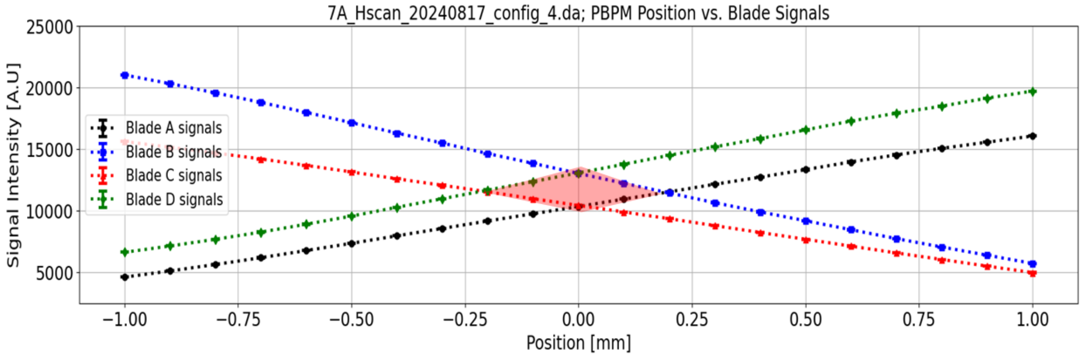
PBPM scan results after orbit change







PBPM horizontal scan result

- The signal from each blade was measured by moving the PBPM horizontally, following adjustments to the electron orbit before and after the ID.
- We observed that the signal differences decreased following these orbital changes.

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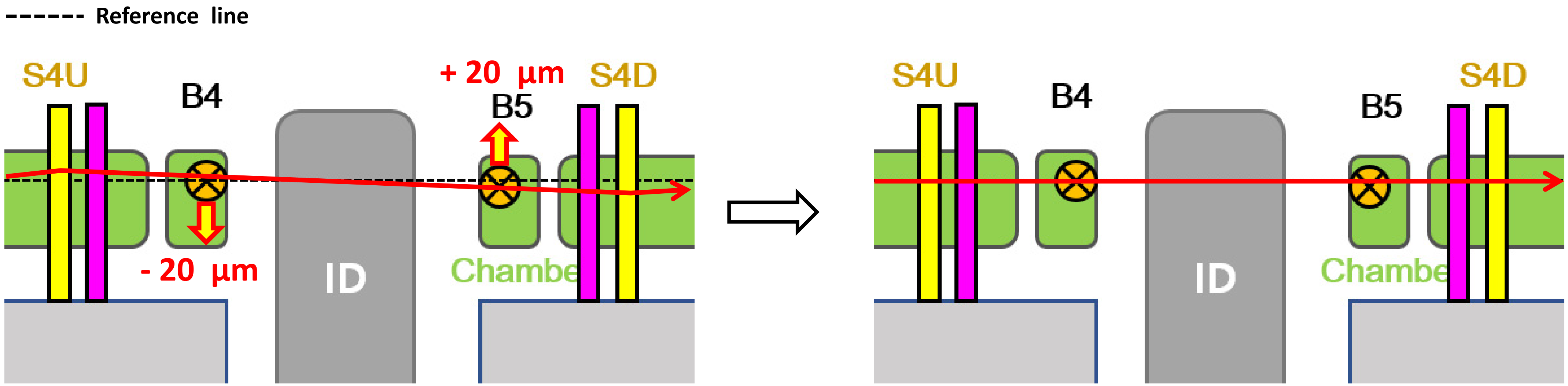
PBPM scan results after orbit change



BPM alignment error due to ground motion, alignment work, etc

PBPM horizontal scan result

- This measurement result was achieved by setting the Y offset to -20um before the ID and +20um after.

Further Study Plan

- Given that BPM alignment errors vary by beamline, we will identify and implement specific alignment conditions for each one.
- Determine the correlation between the reduction of the blade signal difference and the energy spectrum

songdonghyun@postech.ac.kr

Summary

- PBPM feedback is operational on 13 beam lines at PLS-II, maintaining the position rms of the photon beam on the beam line at less than 1 μm
- PBPM blade signal alignment was performed for electron beam alignment within the ID, and the reduction in signal differences was measured
- The correlation between signal difference reduction and energy spectrum will be studied

songdonghyun@postech.ac.kr