ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPGW027

EVALUATION AND REDUCTION OF INFLUENCE OF FILLING PATTERN ON X-RAY BEAM POSITION MONITORS FOR SPring-8

H. Aoyagi†, Y. Furukawa, S. Takahashi, JASRI/SPring-8, Hyogo, Japan

Abstract

SPring-8 constantly provides various several-bunch mode operations, which combine single bunches and train bunches. Recently, influence of filling pattern on the accuracy of the XBPMs became apparent, so that we started a systematic evaluation. It was found that the influence was caused by suppression of current signal due to space charge effect, which could be quantified by observing a behaviour of the current signal while changing the voltage of photoelectron collecting electrodes. In order to mitigate the space charge effect, we examined some methods, such as, changing operation parameters of the XBPMs and the undulators. As a result, we successfully reduced the influence of filling pattern.

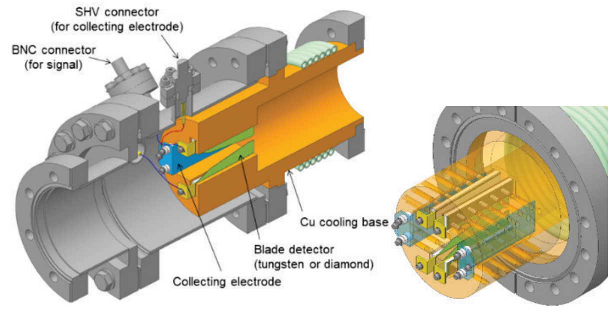
INTRODUCTION

Conventional photoemission-based X-ray beam position monitors (XBPMs) have been operating for more than 20 years for providing a stable beam at SPring-8, the world's highest-class brilliant light source thanks to a combination of high stability of the 8 GeV storage ring and in-vacuum undulators. The XBPMs, installed at beamline front-ends, are required to withstand severe high heat load that other facilities do not receive. SPring-8 constantly provides various several-bunch mode operations, which combine single bunches (isolated bunces) and train bunches (partial full-filling) [1]. The bunch current has been gradually increasing compared to the early stage of SPring-8, and reached up to 5 mA/bunch in a single bunch and 0.38 mA/bunch in partial full-filling. The bunch current of 1 mA/bunch corresponds to 4.8 nC in the storage ring. The typical current signal from each blade of the XBPMs for insertion devise beamlines (ID-BLs) is about 70 µA during user operations, whose ring current is 100mA. As the bunch current increases, it became apparent that the XBPM readouts are distorted when the filling pattern was changed.

Structure of XBPMs

The XBPMs are equipped with blade-shaped detector heads made of tungsten or diamond as a base material [2]. Four blades are configured to measure the beam position in horizontal and vertical directions for the ID-BLs, and a pair of blades are configured to measure the beam position in vertical direction for bending magnet beamlines (BM-BLs). Figure 1 shows the structure of the XBPMs for the ID-BLs. In order to collect photoelectrons emitted from the detection element, positive voltage (normally HV = +100 V) is applied to the charge collecting electrodes. The electrodes are essential to obtain stable current signal. In this paper, we describe evaluation and reduction of influence of filling pattern on the XBPMs quantitatively and systematically.

† aoyagi@spring8.or.jp



(a) 3D section view (b) Transparent view

Figure 1: Structure of the XBPM [3].

INFLUENCE OF FILLING PATTERN

Systematic Observation

We observed the distortion of the XBPM readouts in the several-bunch modes systematically using the beam position in the multi-bunch mode ("160 bunch train x 12") as the reference [4]. In the multi-bunch mode, the load on the accelerator is the least. Figure 2 shows the results of three of the several-bunch modes. We found that nine out of 33 XBPMs for the ID-BLs were significantly affected. The largest influence was seen in "2/29-filling + 26 bunches" mode. Table 1 shows the bunch current for each filling pattern and the deviations of the XBPM readouts for the ID-BLs (33 units in total). It can be seen that there is a definite correlation between the bunch current of trains and the deviation. Because the current signal from the blades is small for the BM-BLs (10 units in total), they are not affected by filling-pattern. Therefore, the fact that the deviation is still seen for the BM-BLs suggests that the electron orbit of the storage ring is considerably affected by the filling pattern.

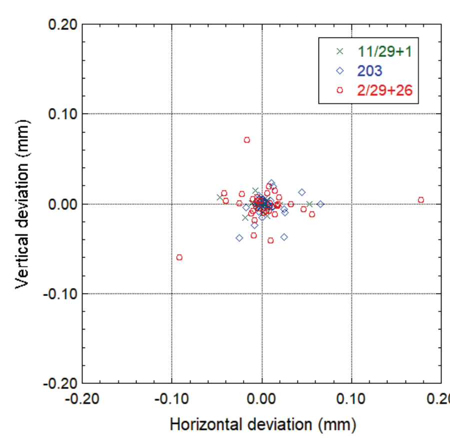


Figure 2: Deviations of XBPM readouts from the reference positions due to variations of the filling patterns of the storage ring.

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPGW027

Table 1: Bunch Current and the Deviation of the XBPM Readouts. The deviations are indicated in root mean square (RMS). The distance from the source points to the XBPMs for the ID-BLs is 20.3 m (typical), and for the BM-BLs is 16 m (typical).

Filling pattern	Bunch current (mA/bunch)		Deviation of XBPM readouts (μm RMS)		
			ID-BL		BM-BL
	Train	Isolated	Horizontal	Vertical	Vertical
Multi	0.05	—	3.6	2.0	1.3
11/29 + 1	0.10	5.0	13.9	5.8	3.0
203	—	0.52	17.6	12.6	6.0
11 x 29	0.31	—	27.7 → **11.2** *	14.6 → **6.7** *	4.3
1/7 + 5	0.24	3.0	33.5	15.2	5.4
2/29 + 26	0.38	1.4	40.3 → **17.6** *	20.5 → **10.6** *	8.0

*: after treatment

Mechanism

The main cause of this phenomenon is considered to be the influence of space charge effect of emitted photo-electrons when the blades are irradiated with intense X-ray beam [4]. The role of the collecting electrode is shown schematically in Fig. 3. The influence of the space charge effect is small under weak X-ray (Case 1). By applying positive voltage to the collecting electrodes, the influence is reduced and stable current signal is obtained (Case 2). When mild X-ray irradiates the blades such as in the multi-bunch mode, the space charge effect is still negligible level (Case 3). However, as in the several-bunch mode with high bunch current, the space charge effect is not sufficiently mitigated by the collecting electrodes (Case 4).

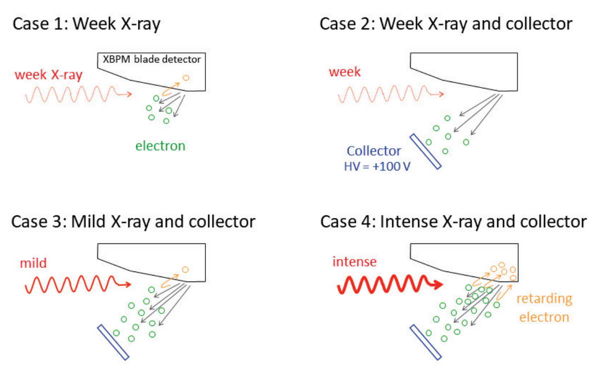
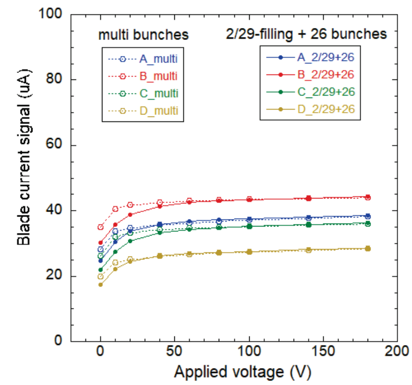


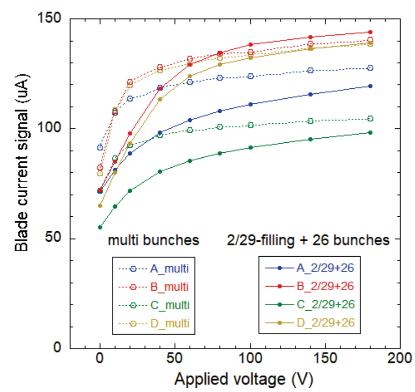
Figure 3: Role of the collecting electrodes. Positive voltage (HV = +100 V) is applied to the collecting electrodes (collector) during user operation.

Applied Voltage Curve of Collecting Electrodes

In order to evaluate the degree of the space charge effect by the collecting electrodes, the applied voltage to the collecting electrode (normal applied voltage HV = +100 V) was varied to measure the current signal of the XBPM blades [4]. As shown in Fig. 4 (a), the XBPM for BL20XU is not affected by the filling pattern. Even if the filling pattern is changed from the multi-bunch mode to the several bunch mode (the 2 / 29-filling + 26 bunches mode), the current signal from each blade is substantially flat with the same value at HV = +100 V. While, as shown in Fig. 4 (b), the XBPM for BL16XU is significantly affected. The slope is large at HV = +100 V and the absolute value changes as the filling pattern is varied. These data suggest that the space charge effect becomes significant when the current signal from each blade exceeds 100 μA.



(a) BL20XU: no influence.



(b) BL16XU: large influence.

Figure 4: Applied voltage curves of blade current signals for the ID-BLs.

In the BM-BLs, the current signal from the blades is sufficiently flat at HV = +100 V, as shown in Fig. 5. The reason is that the current signal of the blades for the BM-BLs is about 1/10 of the ID-BLs, and the collecting electrodes are configured on both sides of the blades to apply electric field effectively.

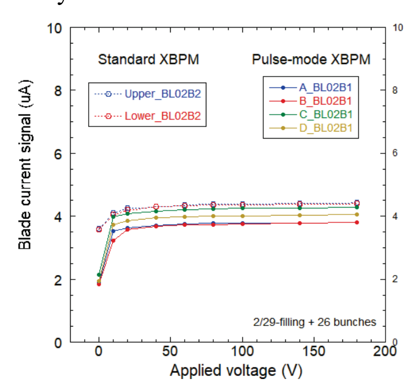


Figure 5: Applied voltage curves of blade current signal for the BM-BLs.

Mitigation of Space Charge Effect

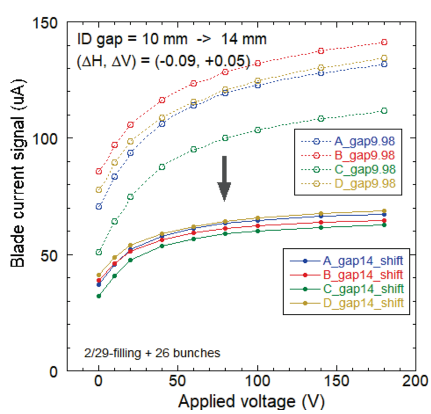
In order to reduce the influence of the filling pattern, it is necessary to mitigate the space charge effect. The tolerances of the photon bam axis adjustment, which is constantly performed at the beginning of cycles, are set to ±150 μm and ±100 μm in the horizontal and vertical direction, respectively. The following methods were examined

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPGW027

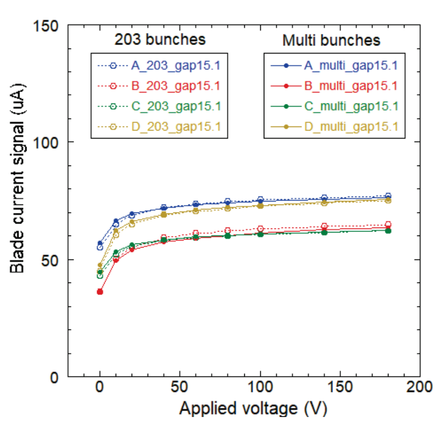
with the goal of reducing within ± 50 µm (2.5 µrad in angle) [4].

1. Center the XBPMs by XY stages to average the current signal from blades.
2. Widen the ID gap for fixed point observation to lower the current signal.
3. Increase the distance between the blades edges to lower the current signal.
4. Set the applied voltage to the collecting electrodes higher to operate at the flat region of the applied voltage curve.
5. Correct misalignment of the XBPMs so that blades are parallel to the beam axis. (This prevents photoemission from inner sides of the blades.)
6. Incline the blades slightly with respect to the beam axis. (Efficient electric field between outer sides of the blades and collecting electrodes allow to mitigate space charge effect.)

The space charge effect can be controlled by taking methods 1 and 2 mentioned above, for many ID-BLs affected by filling-pattern. As an example, Fig. 6 (a) shows the results at BL22 XU. It can be seen that the current signal from each blade at HV = +100 V is substantially flat after taking methods 1 and 2. For BL16XU, the method 5 was also adopted (Fig. 6 (b)).



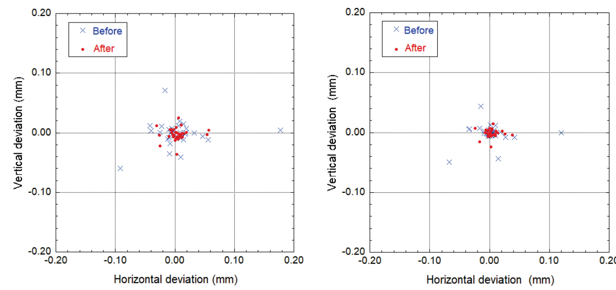
(a) BL22XU: before and after the method 1 and 2.



(b) BL16XU: after the method 1, 2 and 5.

Figure 6: Applied voltage curves after mitigation of the space charge effect.

Figure 7 shows the deviation of the XBPM readouts of all ID-BLs before and after treatments against nine ID-BLs. The deviations were decreased almost within about 50µm. The deviations after the treatment are shown in Table 1. The influence of the filling pattern is considered to affect not only XBPMs but also rf-BPMs of the storage ring. In other words, the remaining deviation indicates that the X-ray beam axis may be displaced actually when the filling-pattern is changed.



(a) 2/29+26 mode (b) 11 x 29 mode

Figure 7: Deviation of XBPM readouts from the reference positions before and after the treatments.

CONCLUSION

We systematically evaluated the influence of filling pattern on the XBPMs. For the ID-BLs, the maximum deviation of about 40.3 µm RMS in horizontal direction and about 20.5 µm RMS in vertical direction were observed in the 2/29-filling+26 bunches mode. On the other hand, for the BM-BLs, it was about 8 µm RMS in the vertical direction. We observed the applied voltage curves to the collecting electrodes of the XBPMs, and found that the space charge effect caused the deviation of XBPM readouts. We succeeded in reducing the deviation to less than half the RMS value by widening the ID gaps for the fixed-point observation, correcting the misalignment of the XBPM, and so on. Further reduction of the influence of the filling pattern is a next task, and it is necessary to take into account the influence of filling pattern on the rf-BPMs of the storage ring.

REFERENCES

[1] http://www.spring8.or.jp/en/users/operation_status/schedule/

[2] H. Aoyagi et al., "Blade-type X-ray beam position monitors for SPring-8 undulator beamlines", *Nucl. Instr. and Meth. A* 467-468, 252-255 (2001).

[3] https://www.shinku-kogaku.co.jp/

[4] H. Aoyagi et al., "Performance of the X-Ray Beam Position Monitors and Observation of Beam Drifts in the SPring-8 Storage Ring", *Proc. of PASJ2018*, WEOL06