ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOPT065

OPERATION OF X-RAY BEAM POSITION MONITORS WITH ZERO BIAS VOLTAGE AT ALBA FRONT ENDS

J. Marcos*, U. Iriso, V. Massana, R. Monge, D. Yépez
ALBA Synchrotron, Cerdanyola del Vallès, Spain

Abstract

Blade-type X-ray Beam Position Monitors (XBPMs) are customarily operated with a negative bias voltage applied to the blades in order to prevent the transference of photoelectrons between the blades, and hence to maximize the signal at each blade and to avoid cross-talk. This was the selected approach at ALBA since the start of its operation for users in 2012. However, over the years the insulation provided by the ceramic pieces separating the blades from the support structure has degraded progressively, giving rise to an ever-increasing leakage current not related with the photon beam to be monitored. On 2020 the level of these leak currents had already become comparable to the photocurrents generated by the photon beam itself, making the readings from many of the XBPMs unreliable. Following the example from other facilities, we decided to remove the bias voltage from the blades and to test the performance of the XBPMs under these conditions, with such good results that we apply this method also for the new, non degraded, XBPMs. In this paper we present the approach used at ALBA to analyse XBPM data, and our experience operating them with zero bias voltage.

INTRODUCTION

The general layout of the Front Ends (FEs) for Phase-I beamlines at ALBA was described in Ref. [1]. In particular, each FE is equipped with one blade-type XBPM in order to monitor the position of the photon beam at a distance of 7–10 m from the source point. Monitors were manufactured by FMB-Berlin [2] according to the designs developed by K. Holldack at BESSY [3]. Each XBPM makes use of four narrow blades which intercept the edges of the photon beam distribution. The photoelectrical currents generated at each blade are measured using a low current monitor, and combined in order to get an on-line estimation of the horizontal and vertical position of the centre of the beam

SIGNAL PROCESSING

The difference-over-sum of the current of right/left and top/bottom blades are used to define the raw position parameters associated to the XBPM:

$$X = \frac{(I_1 + I_3) - (I_2 + I_4)}{I_1 + I_2 + I_3 + I_4}, \quad Y = \frac{(I_1 + I_2) - (I_3 + I_4)}{I_1 + I_2 + I_3 + I_4}. \tag{1}$$

These dimensionless parameters are related to the real displacement of the photon beam with respect to the centre of the XBPM, X_{pos} and Y_{pos}. For convenience, at ALBA we assume that this relationship is linear. More precisely, the coordinates of the photon beam position X_{pos} and Y_{pos} are related with the output of the XBPM in terms of X and Y through the expressions:

$$X \simeq C_{xx}X_{\text{pos}} + C_{xy}Y_{\text{pos}}, \quad Y \simeq C_{yx}X_{\text{pos}} + C_{yy}Y_{\text{pos}}, \tag{2}$$

where C_{xx} and C_{yy} are the typical sensitivity coefficients which give the response of the XBPM to a given displacement of the beam along horizontal and vertical directions, respectively; the two additional coefficients, C_{xy} and C_{yx}, characterize any source of cross-talk between the two planes. These cross-talks can be due to either an improper alignment of the XBPM blades or to a lack of symmetry of the photon beam footprint.

In a practical situation, the X and Y parameters are obtained from the photocurrents measured at the XBPM through Eq. (1), and the photon beam position is determined by inverting Eq. (2):

$$\begin{aligned} X_{\text{pos}} &\simeq \frac{C_{yy}X - C_{xy}Y}{C_{xx}C_{yy} - C_{xy}C_{yx}} \\ Y_{\text{pos}} &\simeq \frac{-C_{yx}X + C_{xx}Y}{C_{xx}C_{yy} - C_{xy}C_{yx}}. \end{aligned} \tag{3}$$

In the particular case with zero cross-talk between planes, $C_{xy} = C_{yx} = 0$, the expected result $X_{\text{pos}} = X/C_{xx}$ and $Y_{\text{pos}} = Y/C_{yy}$ is recovered.

It has to be taken into account that all four coefficients C_{xx}, C_{xy}, C_{yx}, and C_{yy} in Eq. (2) depend on the characteristics of the photon beam distribution delivered by the source; therefore, in the case of Insertion Devices (IDs) those factors are a function of all the parameters defining their emission of radiation: the gap opening for planar devices, the phase displacement for APPLE-type undulators etc.

The calibration procedure to determine the sensitivity coefficients for a given configuration of the ID is based in introducing a known displacement of the XBPM with respect to the photon beam (change in X_{pos} and Y_{pos}) and recording the change in the output parameters (X and Y). The displacement is introduced by means of a two-axes linear stage at the base of the vacuum vessel that contains the XBPM. During the calibration the delivered photon beam is kept as steady as possible by means of the accelerator's orbit feedback, and the XBPM is displaced with respect to it over a rectangular grid. The resulting pairs of $(X_{\text{pos}}, Y_{\text{pos}})$ and (X, Y) data points are fitted according to Eq. (2) around the position where $X = Y = 0$, allowing to derive the value of the sensitivity factors. Such a measurement is carried out for a representative number of configurations of the ID, giving as a result a set of look-up tables for the sensitivity coefficients.

* jmarcos@cells.es

ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOPT065

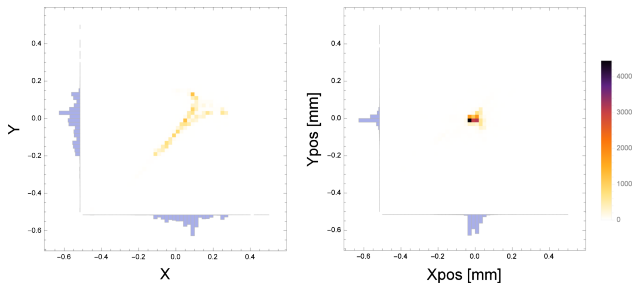

Figure 1: 2D histogram of the XBPM readings on FE29 over a period of 4 weeks. *Left:* raw (X, Y) parameters without BM background subtraction. *Right:* calculated photon beam positions $(X_{\text{pos}}, Y_{\text{pos}})$ calculated after applying BM subtraction and the sensitivity factors corresponding to each ID setting. The dimension of the bins is (0.02×0.02) in the two cases.

Finally, during the operation of the XBPM, the required values of the coefficients are obtained by interpolation of the corresponding look-up tables.

Bending Magnet Background Subtraction

The presented scheme works fine as far as the currents in Eq. (1) are associated to the photon source that we are interested in. In the case of XBPMs for ID sources, however, the blades do not collect only photons from the ID but also from the adjacent bending magnets (BMs), upstream and downstream from the ID. In those instances where the photocurrents associated to that background of BM radiation are not negligible, the resulting parameters X and Y and the association photon beam positions get distorted.

In order to mitigate this effect, at ALBA instead of operating with the directly measured photocurrents I_i we operate with background subtracted ones, defined as:

$$I_i^{\text{ID}} = I_i - I_i^{\text{BM}}, \quad \text{for } i = 1 \ldots 4 \tag{4}$$

where I_i^{BM} corresponds to the contribution of BM background radiation to the photocurrent measured on blade i. These background currents are estimated by measuring the photocurrents on the XBPM when the corresponding ID is not emitting radiation (fully opened gap for permanent magnet-based IDs or switched-off power supply for electromagnetical ones) at a certain value of the electron beam current. The measured values are afterwards rescaled under operational conditions taking into account the electron beam current at the time of applying Eq. (4).

The correction of BM background turns out to be particularly critical in the case of ID delivering soft X-rays ($E_\gamma < 1$ keV). As an illustration, Figure 1 shows the case of the XBPM at FE29, with an APPLE-II (EU71) source delivering photons above 80 eV [4]. Figure 1 summarizes the output of the XBPM for a whole run of the accelerator (4 weeks), along which the ID underwent many configuration changes. These changes modified the balance between the ID and the BM contributions to the blade currents, and led to the large dispersion of the raw (X, Y) values displayed in the left side of the figure. Only after the removal of the BM background one is able to reconstruct a meaningful position for the photon beam (right hand side of the figure), which keeps stable within the level guaranteed by the electron beam trajectory straightness inside the ID.

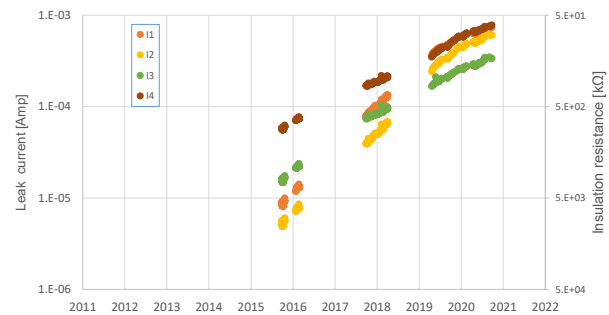

Figure 2: Evolution of leakage current on the 4 blades of the XBPM for FE13, with an in-vacuum device (IVU21) as a source. The operating bias voltage was −50 V.

BIAS OPERATION

Blade-type XBPMs are customarily operated applying a negative bias to the blades. This voltage allows to accelerate the photoelectrons away from the blades, reducing the crosstalk between them and, in principle, optimizing their position sensitivity. However, a known issue with these devices is the progressive degradation of the insulation provided by the ceramic piece separating the blades from the copper holder piece [5]. Due to the presence of a bias voltage, this degradation gives rise to a leakage current through the insulation, which superimposes to the photocurrent signal associated to the photon beam. Therefore, leak currents act as an additional background that, if not taken properly into account, can distort the determination of the photon beam position. As the insulation's degradation advances, the level of the leak currents increases, and they can eventually become comparable to the photon beam signal. When this stage is reached, the effective dynamic range of the instrument is drastically reduced and the position data obtained from it becomes less reliable.

In the case of ALBA, a bias voltage of −50 V was selected at the beginning of the accelerator operation in 2012. Upon installation of the XBPMs, the level of insulation provided by the ceramic pieces was well above 100 GΩ. However, in all cases the blades' insulation has degraded over the years, and by mid-2020 it had decreased down to a value between 100 MΩ in the most favorable case and 50 kΩ in the worst case. As an example, Figure 2 shows the evolution of the insulation of the most affected XBPM (installed in FE13, with an in-vacuum undulator source [4]) during the last years of operation. It can be seen that the leakage currents at the end of the period were above 0.1 mA, which is at the same level that the photocurrents generated at nominal electron beam current ($I_{\text{beam}} = 250$ mA).

ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOPT065

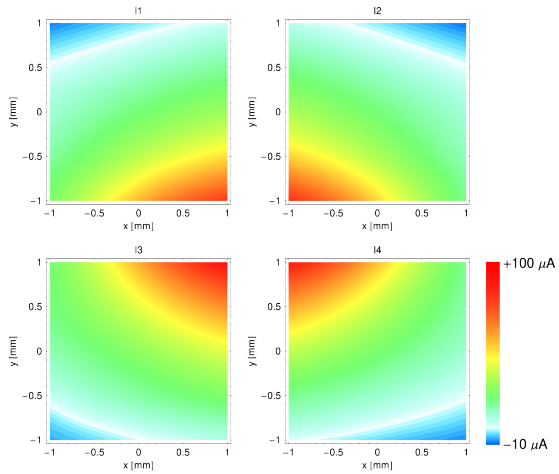

Figure 3: Contour plots of currents measured on the four blades of FE13 XBPM at zero bias when scanning its position over an area of ±1 mm along both horizontal and vertical directions. Data was acquired at an electron beam current of I_{beam} = 100 mA and for an undulator gap opening of 8 mm. The white colour contour indicates the boundary between positive and negative blade current values.

Zero-bias Operation

Given the difficulty of replacing the ceramic pieces, it was decided to test the same solution that was already implemented at Diamond Light Source some years ago [5]: removing the bias voltage altogether. A first set of tests on July 2020 showed that the removal of bias voltage decreased the photocurrents measured on the blades by a small factor (much smaller than 10, in all cases); on the other hand, the leak currents were reduced well below the 10 nA level, thus allowing to recover a difference of at least 3 orders of magnitude between the signal associated to the photon beam and the current leakage.

One of the side-effects of the bias removal is the increase in the likelihood that the photoelectrons ejected from one blade can end up in another of the blades. Due to this, and depending on the balance between the photoemission of electrons and the capture of electrons coming from the other blades, it can occur that the current measured in some of the blades has a negative value. Under these circumstances it may not be clear if the raw positions parameters X and Y as defined in Eq. (1) still have a straightforward relationship with the position of the photon beam. However, if we follow the described calibration procedure moving the position of the XBPM with respect to the photon beam, in the absence of bias the currents measured on each blade still display a smooth change with position, as shown in Fig. 3, even if in some regions they get a negative value. When the measured current values are combined using Eq. (1), the obtained (X, Y) values resemble the displacements introduced into the XBPM with a fair degree of linearity, as shown in Fig. 4. After reconstructing the original positions by means of Eq. (3), the obtained estimations in the inner region within ±0.2 mm have a relative error smaller than 5%.

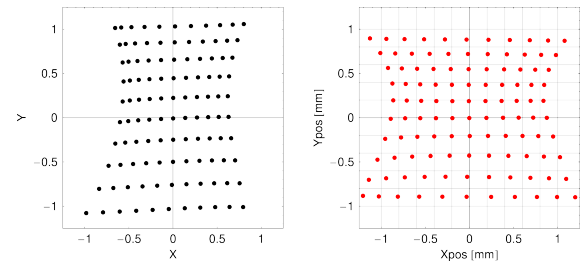

Figure 4: *Left:* pairs of (X, Y) values obtained during the calibration measurement of FE13 XBPM in the absence of bias voltage (blade current data shown in Fig. 3). *Right:* reconstructed photon beam positions in linear approximation, obtained using Eq. (3).

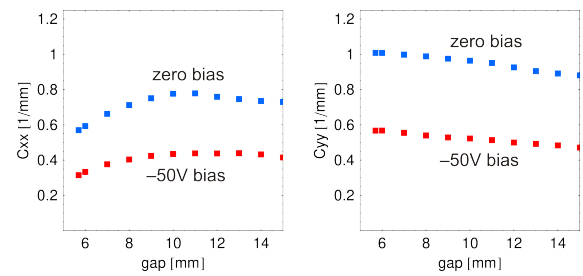

Figure 5: Main sensitivity coefficients (C_{xx} and C_{yy}) determined for the XBPM of FE13 as a function of the gap opening of the ID source, with and without bias voltage.

In fact, when the sensitivity coefficients are calculated from the calibration data, it turns out that after the removal of bias they are enhanced by a factor ~ 2 (see Figure 5) with respect to the original values determined at nominal bias, as already reported in Ref. [5]. Therefore, on top of removing the inconvenience of having to deal with ever-increasing leak currents, the removing of the bias voltage improves the sensitivity of the photon beam position measurement.

CONCLUSION

After the promising results obtained with the first tests operating at zero bias, this new scheme has been applied to all FE XBPMs at ALBA, not only for Phase-I ones. This change has required a recalibration of all XBPMs in order to determine the new values of the sensitivity coefficients, in a way similar to what has already been shown in Fig. 5. This recalibration process was carried out along 2021. In all cases, significant increases of the sensitivity (typically above a 50%) have been observed.

Currently all FE XBPMs at ALBA operate with zero bias, some of them (the first ones to be recalibrated) since the end of 2020. So far, no detrimental effects or long term drifts due to the further degradation of the insulation provided by the ceramic pieces have been observed.

ACKNOWLEDGEMENTS

The authors wish to thank Chris Bloomer from Diamond Light Source for sharing his experience and for his advice.

ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOPT065

REFERENCES

[1] J. Marcos, J. Campmany, D. Einfeld, and J. Pasquaud, "Front Ends at ALBA", in *Proc. IPAC'11*, San Sebastian, Spain, Sep. 2011, paper THPC055, pp. 3017–3019.

[2] FMB Feinwerk- und Meßtechnik GmbH, Friedrich-Wöhler-Straße 2, Berlin, Germany, http://www.fmb-berlin.de

[3] K. Holldack, D. Ponwitz, and W.B. Peatman,"Beam stability of undulator and dipole radiation on BESSY II obtained by synchrotron radiation monitors", *Nucl. Instrum. Methods Phys. Res. Sect. A*, vol. 467-468, pp. 213–220, 2001. doi:10.1016/S0168-9002(01)00585-X

[4] J. Campmany, D. Einfeld, J. Marcos, and V. Massana, "General description of IDs initially installed at ALBA", in *Proc. IPAC'10*, Kyoto, Japan, May 2010, paper WEPEA055, pp. 2609–2611.

[5] C. Bloomer and G. Rehm, "Operation of Diamond Light Source XBPMs with Zero Bias", in *Proc. IBIC'13*, Oxford, UK, Sep. 2013, paper TUPC10, pp. 376–379.