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BEAM STABILITY DIAGNOSTICS WITH X-RAY BEAM POSITION MONITOR IN THE TAIWAN PHOTON SOURCE

C. H. Huang†, P. C. Chiu, C. Y. Wu, Y. Z Lin, Y. M. Hsiao, J. Y. Chuang, Y. S. Cheng, C. Y. Liao, C. K. Kuan, K. H. Hu, K. T. Hsu
NSRRC, Hsinchu 30076, Taiwan

Abstract

To monitor the stability of photon beams, X-ray beam position monitors (BPMs) with quadrant PIN photodiodes or blades are installed in the beam lines and front ends. Although there are about 200 electron BPMs installed in the storage ring, the beam-line managers or users prefer X-ray BPMs to monitor beam stability. Among the beam lines, different electronics are used to acquire data at various sampling rates. A method to calculate the beam intensity fluctuation within different frequency ranges is described in this report. The results of calculations are shown in the control system and saved in the archive system thus helping to monitor and analyse beam quality on- and off-line. Initial experiences with this system will be discussed in this report.

INTRODUCTION

An X-ray beam position monitor (BPM) is a device used to measure the centroid of the synchrotron radiation. Many devices have been used to detect the beam position such as: fluorescent screens, split plate ionization chamber, blade-type BPM, quadrant PIN photodiodes BPMs (QBPMs) and so on. For continuous use, non-destructive blade-type BPMs and QBPMs are installed in the front ends and beam lines of the Taiwan Photon Source (TPS) to monitor the beam position and density fluctuation.

The first blade-type BPM is used in the front end of an insertion device (ID) reported by Mortazavi et al. in 1986. Shu et al. at the Advanced Photon Source used chemical vapour deposition (CVD) diamond as the blade material with metal (Au, Pt and Ti) coating for good photoemission [1]. This blade-type BPM provides submicron resolution at high power density absorption capability. The heat load in a beam line becomes greatly reduced downstream of the double crystal monochromator making the QBPM a good candidate to monitor the beam position due to its reduced sensitivity to beam profile [2].

In the TPS, two blade-type BPMs are installed in each front end with one being located at the entrance to the front end and the other downstream of the fast closing valve as shown in Fig. 1. Numbers and types of X-ray BPMs are different for most beam lines, due to different consideration.

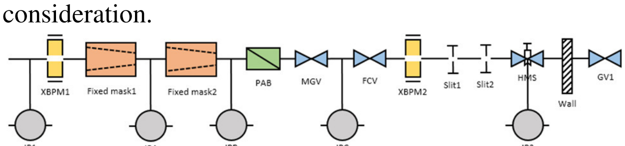

Figure 1: Layout out of front-end instrumentation.

† huang.james@nsrrc.org.tw

In this paper, the data acquisition electronics for X-ray BPMs is introduced first, followed by a discussion of beam position observations with X-ray BPMs. In order to define a reference to quantify beam stability, we discuss this issue in the third part.

SYSTEM SETUP

For the X-ray BPMs (XBPM) in the front end, we use two kinds of electronics to acquire and evaluate the beam position with the old and new version of the Libera Photon system. These devices provide several acquisition types for different sampling rates. An input/output controller (IOC), based on the experimental physics and industrial control system (EPICS), is embedded in these devices and the acquisition data are transferred to the control network through process variables (PVs). For example, the slow acquisition (SA) data is 10/25 Hz and the fast acquisition data is 160 Hz/5 kHz for the old/new version electronics. The layout of the XBPM in the front end is shown in the Fig. 2. For the XBPMs in the beam line, there are three types of electronics in use now. One uses the FMB Oxford F-460 to convert the current to voltage and read the voltage with a NI-9220. For this type of electronics, the data can only be read by the local computer and the sampling rate is 2 kHz now. Another type of electronics is a home-made device with 0.5 Hz update rate and its data are published in the control system while fast data can only be acquired by local instruments now. A third type is used with a new Libera Photon system. The display of the position with various sampling rates is done by the extensible display manager (EDM) and Matlab, shown in Fig. 3. The spectrum of the beam motion can also be shown in the control console as shown in Fig. 4.

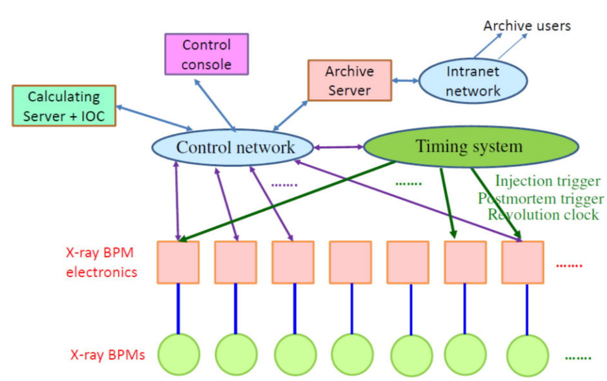

Figure 2: Layout of the XBPM electronics setup in the front end.

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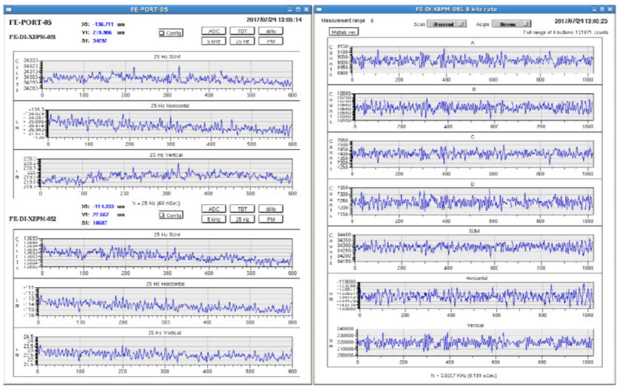

Figure 3: Graphical user interface for beam position monitoring produced by the extensible display manager (EDM).

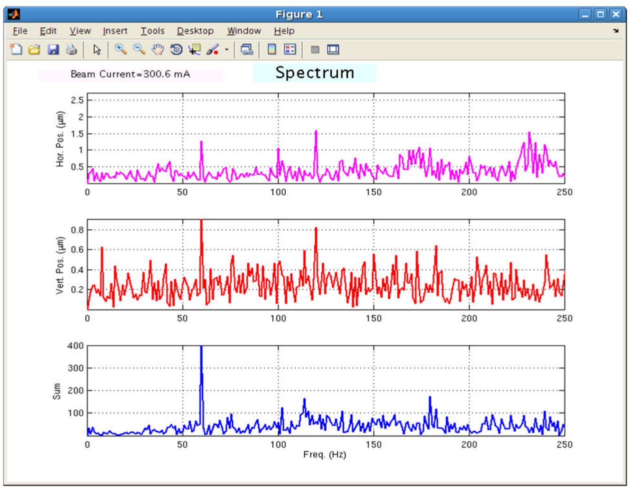

Figure 4: Beam position spectrum as observed at the TPS-05A QBPM2.

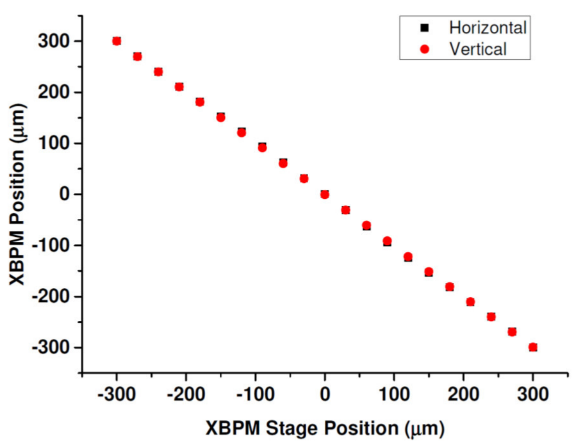

Figure 5: Photon beam position vs. stage position in the first XBPM of front end 25 for $k_x = 6.48$ and $k_y = 2.61$ mm.

BEAM POSITION OBSERVATION

Before application of the XBPM to get the beam position, the calibration factors k_x/k_y must be determined. At first, the XBPM stage is moved to adjust the reading counts for all four blades to be almost equal. Then the stage is moved alone in the horizontal and vertical direction for +/- 0.3 mm to determine the calibration factor [3]. This range is compatible with the in-vacuum undulator (IU) gap of gap of 7 mm. Figure 5 shows the beam position readings vs. stage position in the first XBPM of the front end 25 (XBPM25-1) when k_x = 6.48 and k_y = 2.61 mm. The calibration factor varies with gap as shown in Fig. 6. For the second XBPM in the front end, both XBPM position readings indicate a horizontal and vertical movement by similar magnitudes while the stage is moved in the horizontal direction only. As the stage is moved along the vertical direction, the position coupling is much smaller (~ 10 %). More studies are required to correct this unexpected behaviour in the second XBPM.

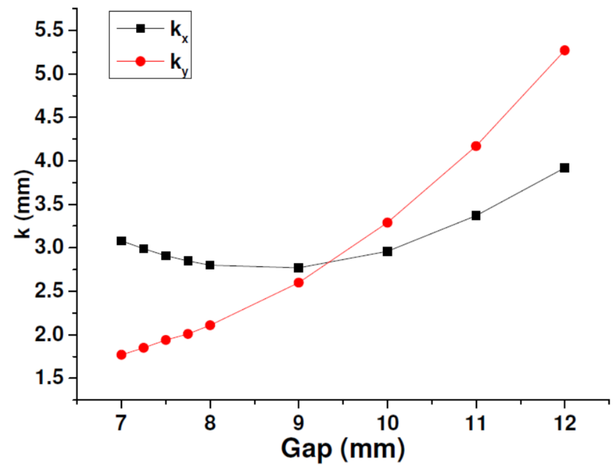

Figure 6: Calibration factor versus gap in the first XBPM of the front end 23.

In order to correlate the photon beam motion relative to the electron beam motion, the spectrum of the electron beam motion upstream of the front end 05 is recorded. The photon beam motion detected by the first XBPM in the front end 05 (XBPM05-1) and by the QBPM in the beam line 05A is also shown in Fig. 7 showing that the spectrum of the electron beam motion is similar to the photon beam motion at XBPM05-1 but the photon motion at XBPM05-1 is higher than the electron motion. For the QBPM2 at BL05A, several peaks at the mains frequency and its harmonics can be observed which do not appear in the electron BPM and XBPM05-1. These peaks are generated by electronics noise which may be due to contamination on the beam line side and need to be clarified and corrected.

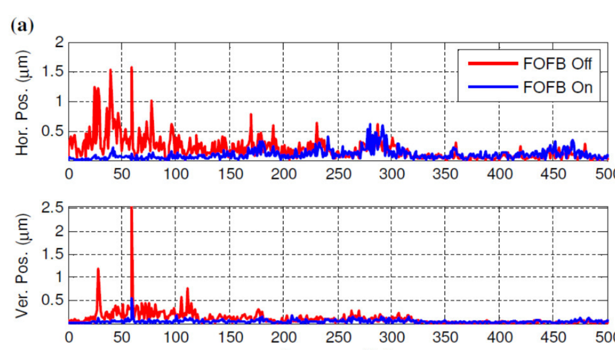

Figure 7a

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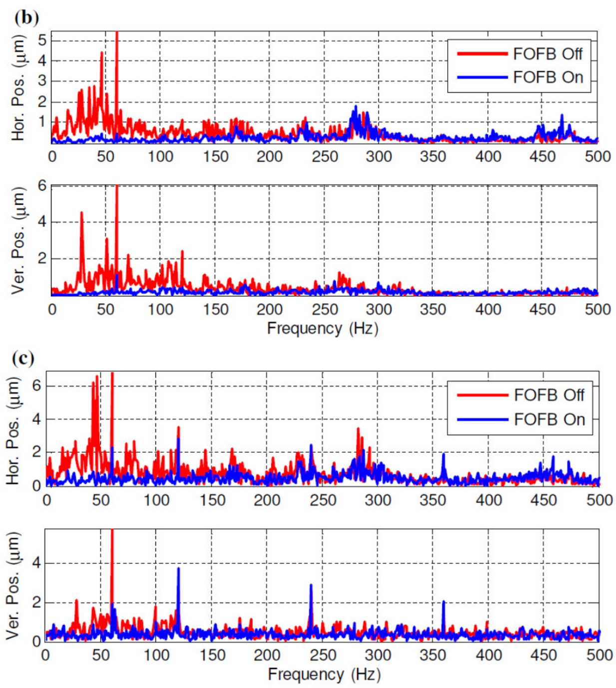

Figure 7: The spectrum of electron/photon beam motion (a) in the e-BPM027 installed upstream of front-end 05; (b) in the first XBPM of the front end 05; (c) in the QBPM2 of the beam line 05A.

PHOTON FLUX STABILITY MONITOR

For statistical data acquisition of beam stability during routine operation, the relative beam intensity fluctuation ($\Delta I_0/I_0$) is calculated by a dedicated sever using the sum signs from the four blades/diodes. As mentioned before, the beam position information obtained by the three types of beam position electronics can be obtained in the control network at various sampling rates. Three programs are used to calculate the $\Delta I_0/I_0$ with Matlab and to publish the results with the soft PVs of the pre-established IOC in the server. Some of the calculated results are saved in the archive server and the saved data can be acquired through the Intranet as shown in Fig. 1.

Because one program is used to deal with data acquisition from several devices, a program must be executed to check which devices are on-line. For the home-made XBPM electronics, the update rate is only 0.5 Hz. Therefore, the I_0 and ΔI_0 is defined as

$$I_0 = \sum_{i=1}^{N} s_i/N \tag{1}$$

$$\Delta I_0 = \sum_{i=1}^{N} \sqrt{(s_i - I_0)^2/N}, \tag{2}$$

where s_i is the ith sum signal. When we take N=10, the update rate of $\Delta I_0/I_0$ would be 20 seconds as shown in Fig. 8. For the other XBPM electronics, the sampling rates are much higher (160 Hz/5 kHz), the data can be acquired during one or several seconds and the power spectral density would be

$$PSD(f) = 2D(f)D^*(f)/T. \tag{3}$$

Here, $S(f)$ is the Fourier transform of the signal and T is the duration of the signal. The integrated root-mean-square intensity variation (ΔI_0) from frequency f_1 to f_2 would be

$$\Delta I_0 = \sqrt{\int_{f_1}^{f_2} PSD(f)df}. \tag{4}$$

The $\Delta I_0/I_0$ is calculated from 0-10 Hz, 0-50 Hz and 0-100 Hz for comparison and shown in Fig. 9. Note that the date does not update during injection.

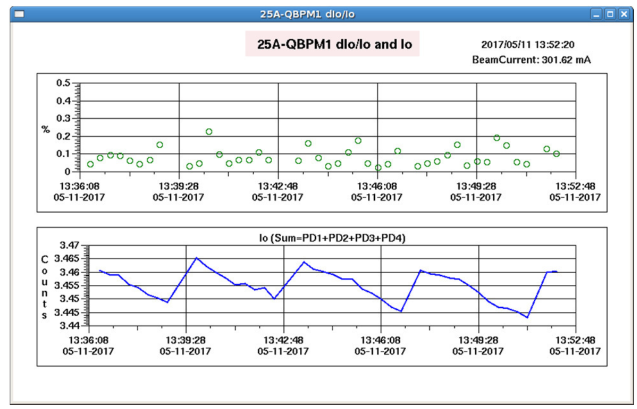

Figure 8: $\Delta I_0/I_0$ and I_0 calculated from the data of the home-made reader with 20 seconds updated rate.

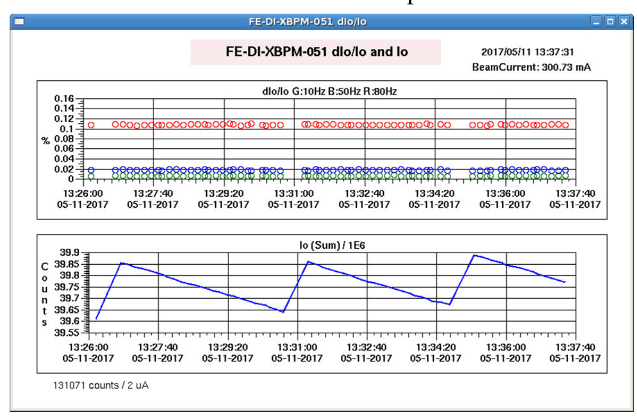

Figure 9: Graphical user interface of $\Delta I_0/I_0$ in the first XBPM in front end 05.

SUMMARY

There are two blade-type XBPMs installed in each front end to monitor the beam position and flux variation. Several types of XBPMs are installed in the beam line for different design considerations. Four types of electronics are used to acquire data. Most can be integrated into the control system to display the information in the control room. In order to monitor beam stability, dedicated programs are used to determine relative intensity fluctuation in several frequency rages to provide a reference for beam stability monitoring in each beam line. This integration provides on-line information on the photon stability to determine beam quality in each beam line.

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