Beam stability diagnostics with X-ray beam position monitor in the Taiwan Photon Source

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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

- To monitor the beam position and density fluctuation, non-destructive blade-type BPMs and quadrant PIN photodiodes BPMs (QBPMs) are installed in the front ends and beam lines of Taiwan Photon Source (TPS) .
- For the blade-type BPM, blade uses vapour deposition (CVD) with metal (Au, Pt and Ti) coating for good photoemission and it 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.
- In the TPS, two blade-type BPMs are installed in each beam line 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.

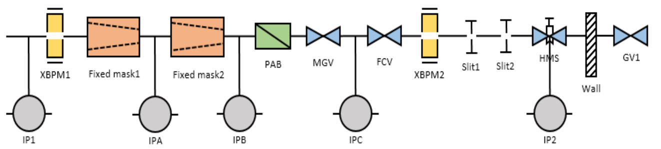

Fig. 1: Layout out of front-end instrumentation.

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.
- 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)
- 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.
- Another type of electronics is a home-made device with 0.5 Hz update rate 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.

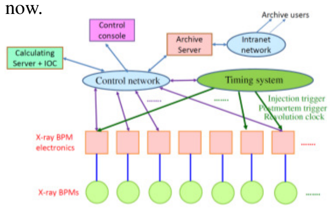

Fig. 2: Layout of the X-ray BPM electronics setup in the front end.

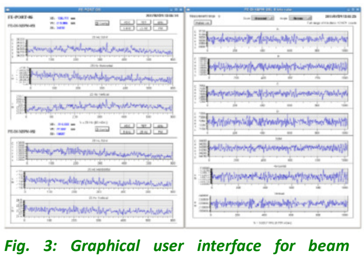

Fig. 3: Graphical user interface for beam position monitoring produced by the extensible display manager (EDM).

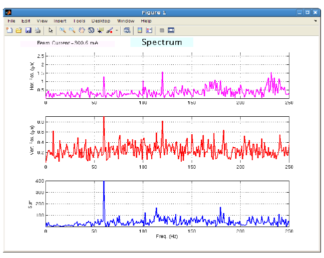

Fig. 4: Beam position spectrum as observed at the TPS-05A QBPM2.

Beam Position Observation

- For calibration XBPM, 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.
- 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 for the gap of in-vacuum undulator (IU) is 7 mm.
- The calibration factor varies with gap as shown in Fig. 6.
- Figure 7 shows 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.

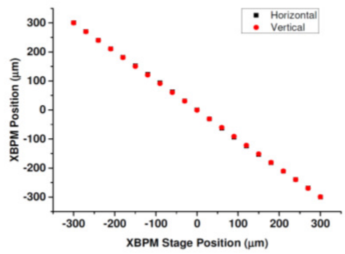

Fig. 5: Photon beam position vs. stage position in the first XBPM of front end 25 for k_x = 6.48 and k_y = 2.61 mm..

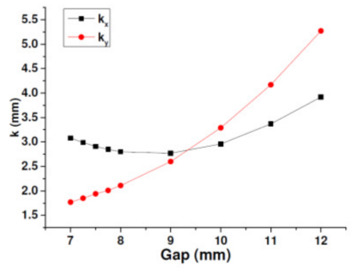

Fig. 6: Calibration factor versus gap in the first XBPM of the front end 23.

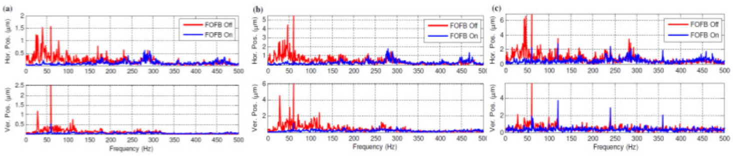

Fig. 7: The spectrum of electron/photon beam motion (a) in the e-BPM027 installed upstream of front-end 05; (b) in the first XBPM of the front end 05; (c) in the QBPM2 of the beam line 05A.

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.
- For the home-made XBPM electronics, the update rate is only 0.5 Hz. Therefore, the I_0 and ΔI_0 is defined as $I_0 = \sum_{i=1}^{N} s_i/N$ and $\Delta I_0 = \sum_{i=1}^{N} \sqrt{(s_i - I_0)^2/N}$, where s_i is the i^{th} sum signal.
- For the other XBPM electronics, the sampling rates are much higher, the data can be acquired during one or several seconds and the power spectral density would be $PSD(f) = 2D(f)D^*(f)/T$.
- The integrated root-mean-square intensity variation (ΔI_0) from frequency f_1 to f_2 is $\Delta I_0 = \sqrt{\int_{f_1}^{f_2} PSD(f)df}$.
- 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. 8.

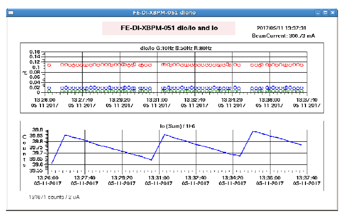

Fig. 8: Graphical user interface of $\Delta I_0/I_0$ in the 1st XBPM in front end 05.

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.
- Most of the XBPMs 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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