THE USE OF PHOTON MONITORS AT THE SWISS LIGHT SOURCE

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Abstract

The photon beam position monitors (PBPM) in a synchrotron facility are important tools for beam-line and machine diagnostics. In the last two years a number of PBPMs have been installed and commissioned at the Swiss Light Source (SLS). Their readouts have been systematically studied and the results have been correlated with data from the digital beam position monitor (DBPM) system. It turns out that the PBPMs help understanding the influence of insertion device gap changes on photon beam position and thus on photon flux and/or energy resolution near the beam-line experimental stations. In addition to the global fast orbit feedback (FOFB), a local slow feedback based on PBPM data has been implemented to remove remaining systematic effects of the DBPM system and to stabilize the photon beam to a micron level at the experimental station.

INTRODUCTION

The PBPMs are installed in beam-line front-ends. Careful design of a PBPM is required in order to obtain a useful device for monitoring the beam position [1]. This is especially the case for synchrotron radiation monitors of insertion device (ID) beam-lines such as the PBPM for the U19 undulator, as shown in Fig.1.

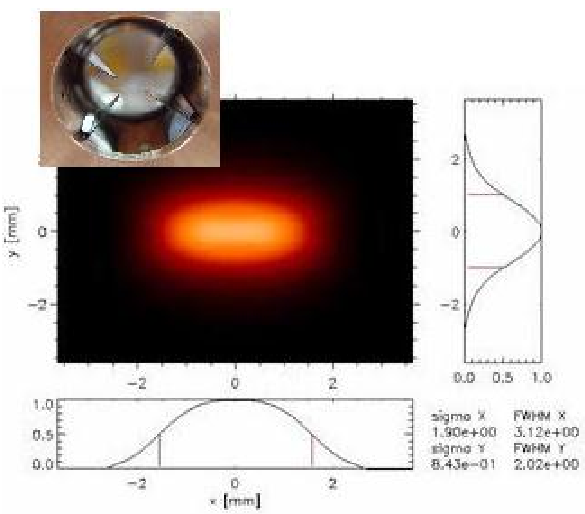

Figure 1: U19 synchrotron radiation power map weighted by tungsten photo-yield at 10 m from the ID source point, K=1.78 [2]. The correct blade geometry optimization allows a position dynamic range in the order of half the beam width in both vertical and horizontal direction. The PBPM monitor blade geometry in the upper panel has been designed and manufactured by FMB Feinwerk- und Meßtechnik GmbH in collaboration with BESSY.

THE USE OF PHOTON MONITORS AT THE X11MA BEAM-LINE

The X11MA Surface/Interface Microscopy beam-line (SIM) of the Swiss Light Source has two Apple-II type electromagnetic undulators (UE56). Effective transfer of the high brightness photon beam to the experimental station requires precise control of each of the source sizes, their positions and angles. Thus, a dedicated system of chicane magnets and RF as well as photon BPMs is used to actively direct and spatially separate the photon beam into the beam-line. Photon energy changes are usually achieved through simultaneous motion of the IDs and the monochromator. Two dimensional scans performed with the PBPMs, which are mounted on motorized stages, and the front end double slit onto a Si photodiode have shown (see Fig. 2) that position changes of the photon beam are directly connected with these energy scans [3].

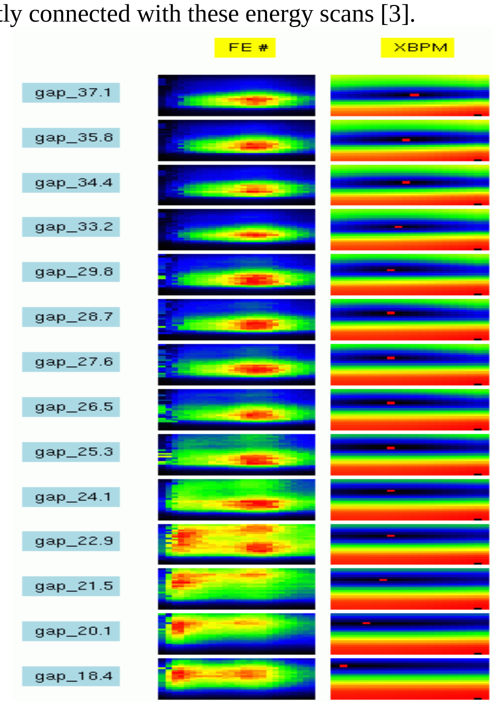

Figure 2: Pseudo-colour image plots (red is maximum, black minimum) of synchrotron light angular distribution obtained from two dimensional scans of (i) 2mm x 1mm front end double slits (FE# slit opening 100µm x 100µm) with Si diode detector, (ii) 1mm x 0.5mm PBPM monitor stage, for different upstream undulator gaps.

The upstream undulator shifts the photon beam position at smaller gaps in both horizontal and vertical directions (the downstream undulator was fully open). The beam centre position - indicated as red spots in the

PBPM image plot column - drifts in both directions when changing the gap. This systematic beam motion (approx. 500 µm in horizontal and 200 µm in vertical direction) could be significantly reduced [4] as a result of the PBPM studies and corresponding update of the feed forward tables (ID gap dependent offsets to magnet correctors).

The separation of the photon beam from ID1 and ID2 is achieved by symmetric or asymmetric bumps inside the ID straight section. The corresponding electron beam position can be controlled by a set of multiplexed RF BPMs [5]. Fig. 3 shows the RF and PBPM response to an asymmetric horizontal bump in the upstream ID. It can clearly be seen, that the PBPM signals are only valid over a limited range of linear response (as indicated by the arrow in Fig. 3).

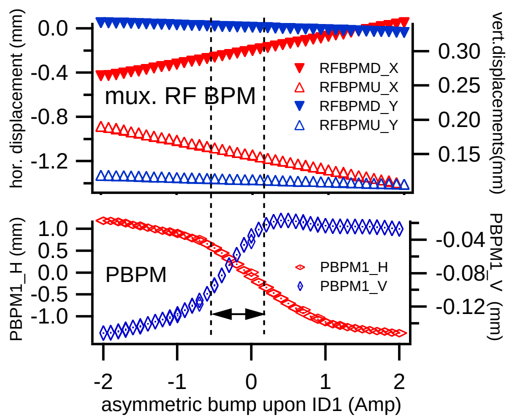

Figure 3: Multiplexed RF BPM and PBPM response to an asymmetric bump in the upstream ID of the X11MA beam-line. The arrow indicates a linear response range of the PBPM.

The horizontal angular offset to the electron beam in the linear response regime of the PBPM should produce a beam position offset of ~1.27 mm at the PBPM location. The measured horizontal PBPM offset is ~1.20 mm. Although, the usable, linear range of the PBPMs are limited, their superior position resolution in comparison to the RF BPMs show more clearly a “leakage” of the horizontal bump into the vertical, which is most likely caused by imperfections of the corrector magnets in the ID section. Thus the PBPMs have proven to be valuable instrumentation for photon beam position measurements and can be used in connection with the SLS fast orbit feedback (FOFB) [6] as will be shown in the following paragraphs.

TEMPERATURE DEPENDENCIES AND SLOW PBPM ORBIT FEEDBACK

The high position resolution of the PBPMs due to their long lever arm allows using them as external references to discover small systematic oscillations of the orbit in the storage ring. Although the PBPM position readings are not yet synchronized to the FOFB, their averaged values have been used on a slower time scale to monitor and eliminate temperature dependencies of the DBPM electronics. Fig. 4 shows the effect of this slow PBPM feedback (~2 Hz bandwidth) [7] on top of the FOFB. It considers the PBPMs vertical and horizontal reference positions to change the electron beam reference orbit (REFOFF) in such a way to keep the PBPM reading constant. In this way, it is possible to stabilize the photon beam at the location of the first optical elements of the X04S material science and the X06S protein crystallography beam-lines down to µm rms level.

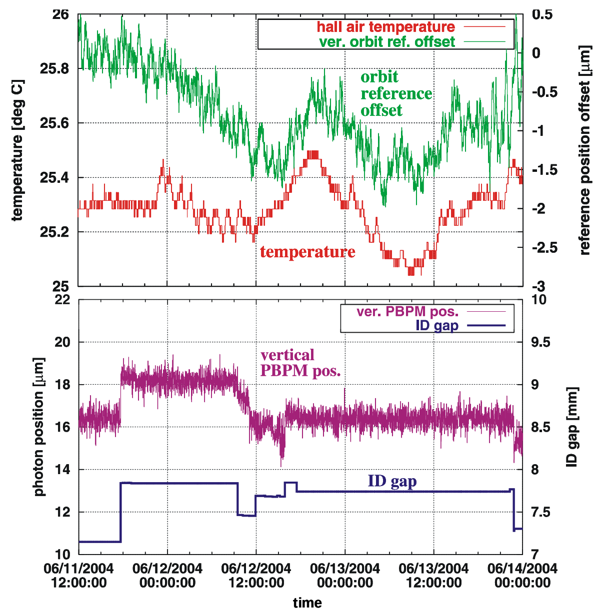

Figure 4: A slow PBPM feedback changes the electron beam reference position (top) of the two adjacent BPMs to ID X06S (only ARIDI-BPM-06SB is shown) in order to keep the photon beam stable to a sub-µm level (bottom) at the PBPM monitor. The applied asymmetric bump mainly compensates a systematic temperature dependency of the DBPM electronics. Each ID gap change leads to a new reference position for the PBPM feedback.

Since the PBPM position readings are still subject to drifts whenever the ID gap is changed, a new PBPM reference position is set after each new gap setting. New reference positions are also set each time the FOFB is started.

INFLUENCE OF THE STORAGE RING FILLING PATTERN ON BEAM POSITION

In case of top-up, which is the standard SLS operation mode since its early commissioning, charge is refilled in individual buckets of the storage ring whenever the average current drops below a pre-defined threshold value. The rather straight forward procedure to refill by simply incrementing the bucket counter whenever injection was started resulted in an uneven and constantly changing filling pattern with up to 20% charge modulation. This in return generated sidebands in the RF front ends of the DBPM electronics, inducing non-linear behaviour of the electronics. When running the FOFB, this filling pattern effect was clearly visible on the PBPM position readings as an oscillation with a period of the bucket fill cycle (50 – 60 minutes). Before the implementation of a filling pattern feedback [8], which allows keeping a more uniform bunch pattern in the storage ring under top-up conditions, the photon beam position was varying with the same bucket fill cycle. Such vertical photon beam oscillations induce a corresponding modulation in the wavelengths of the monochromatized light. Depending on the beam-line layout, these perturbations are ranging from a few % to a few ‰. Fig. 5 shows the result of such a wavelengths variation, measured with a channeltron at the near node experimental station of the X11M beam-line.

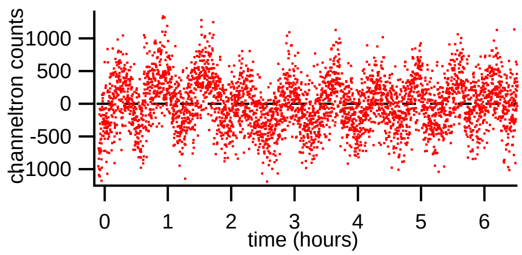

Figure 5: Oscillations in the channeltron counts at the near node X11MA experimental station are induced by a periodic bucket fill variation (courtesy T. Greber).

The effect of the filling pattern feedback on the beam stability is illustrated in Fig. 6 measured with the PBPM at the X09L beam-line.

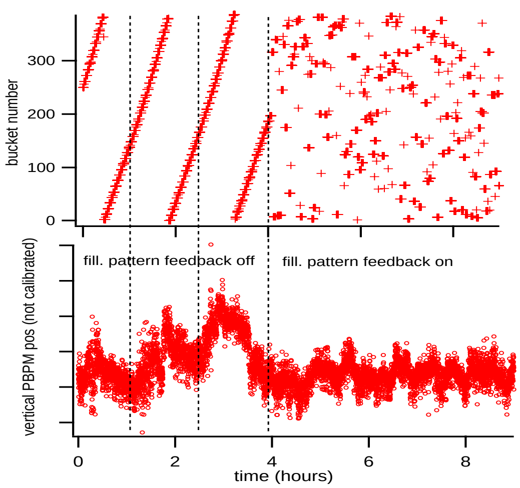

Figure 6: Effect of the filling pattern feedback measured with PBPM at the X09L beam-line. Vertical photon beam variations caused by a filling pattern dependency in the DBPM RF front end electronics are eliminated when filling pattern feedback on.

Although the PBPM position readings are not yet calibrated at this beam-line and no PBPM feedback is implemented so far, the cancellation of this systematic effect can be observed nicely. Moreover, the data is used as an external (out of feedback loop) check of the position stabilization strategies at SLS.

CONCLUSIONS AND OUTLOOK

Several scenarios for the use of PBPM at SLS have been described. Their high resolution position readings provide valuable information about beam stability at the location of the insertion devices. For complex insertion devices like the APPLE II type undulators in the X11MA surfaces and interfaces microscopy beam-line, PBPM signals have proven to be essential for spatial photon beam separation and beam-line operation as intended. PBPM signals have revealed systematic effects of the DBPM based FOFB such as filling pattern and temperature dependencies. At the Protein Crystallography (X06) and in Material Science (X04) beam-lines, the PBPM position readings are used in slow feedback applications eliminating these systematic effects of the FOFB whenever the ID gaps are closed. This standard operation mode of cascading RF and PBPM feedbacks has led to μm beam stability at the location of the beam-line's first optical elements.

In the near future, it is foreseen to synchronize the PBPM readings to the FOFB sampling rate (4 kS/s). This will be essential for the integration of the bending magnet PBPMs in the global beam stabilization scheme of the SLS.

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