INSERTION DEVICE PHOTON BEAM STUDIES WITH X-RAY MONITORS

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The use of the X-ray photon monitors for the commissioning of the insertion devices is the main subject of this report. It turns out, that changing the gap of an insertion device is accompanied by angular shifts of the synchrotron radiation in the front end. This may impact the synchrotron radiation beam flux and energy, or, in the case of dual type undulators, deteriorate the conditions for the phasematching. A photon monitor could also be used for the first time for machine feedback to eliminate systematic orbit drifts in the storage ring.

INTRODUCTION

The X-ray beam position photon monitors (XBPM) are installed in beamline front-ends. Careful design of an XBPM is required in order to obtain a useful device for monitoring the beam position [1], especially in the case of an insertion device [2]. All monitors were designed and manufactured by FMB Feinwerk- und Meßtechnik GmbH in collaboration with BESSY. Currently the read-out electronics is limited to 10 Hz beam position update. A systematic study of the beam positions in the last months revealed significant effects of the insertion device [ID] gap change on the beam position. All IDs are equipped with correctors which are supposed to compensate eventual ID "dipole-kicks" so as to minimise the impact of an ID gap change on the machine orbit. So far such feed-forward compensations were made by means of RF BPMs. Because the XBPMs measure beam position changes directly from the source point, they might be better candidates for feed-forward compensation. In order to highlight the effect of an ID gap change we compare the XBPM data with front end double slit scans and Bergoz BPMs in the ID straight section.

MONITORING THE XBPM POSITION

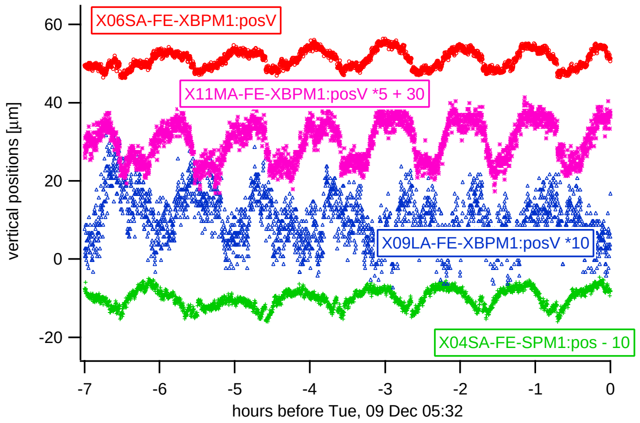

Fig. 1: (color) A seven hours shifted baseline plot of vertical positions of four XBPMs during which the insertion devices at coresponding straight sections were kept at constant energies. The mean vertical position of the X06 XBPM is ≈55 μm, rms= 2.5 μm.

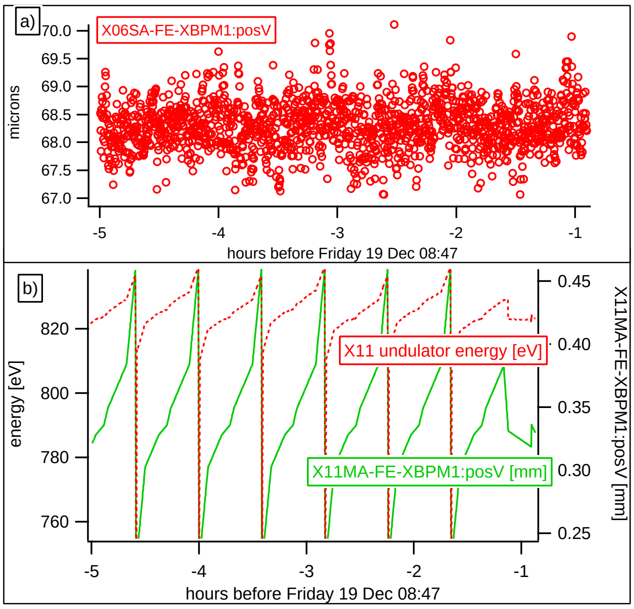

Fig. 2: a) Archiver data of the X06 XBPM vertical positions during fast orbit feedback and active XBPM feedback used to eliminate systematic oscillations seen in Fig. 1 in the vertical plane near the X06 straight section. b) The same archiver time span of the X11 vertical XBPM position show large position offsets well correlated with the X11 upstream undulator energy. There is no impact of ID gap change on the X06 straight section.

Fig. 1 shows a shifted baseline plot of four XBPMs during 7 hours. The baseline for each XBPM is obtained by normalizing data to a position mean value. The plots are shifted in order to highlight XBPM position trends in time. The origin of the systematic oscillations with a period of about 1 hour is not clear yet. Most likely they are due to air temperature variations at the location of the four channel digital RF BPM system electronics in the technical gallery. These variations may result in a fictitious electron beam change on the order of 1 μm which is then corrected by the global orbit feedback system. For example, this effect yields photon beam position oscillation with rms ≈ 2.5μm at the XBPM of the Protein Crystallography beamline X06, which is about 8.8 m away from the radiation source point. Such oscillations are enough to produce undesirable beam flux changes over 1 hour data acquisition.

The photon monitors with their long lever arms, showing much more sensitive position resolution than the RF

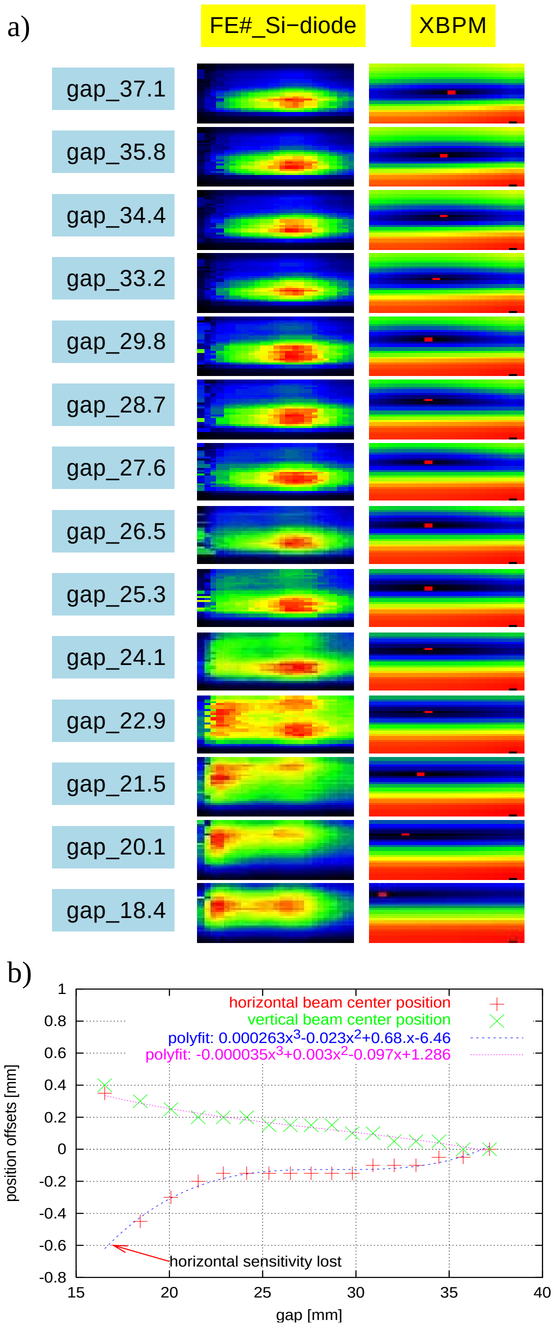

Fig. 3: (color) a) Pseudocolor image plots (red is maximum, black minimum) of synchrotron light angular distribution obtained from two dimensional scans of (i) 2mm x 1mm front end double slits with opening of 100μm x 100μm, (ii) 1mm x 0.5mm XBPM monitor stage, for different upstream undulator gaps. The downstream undulator was fully open. In (ii) the minimum (highlighted on purpose in red color) is the beam centre position which drifts in both directions when changing the gap. In (i) a Si diode was used as detector. b) Beam centre position drifts evaluated from (ii)

BPMs, motivated the beam dynamics group [4] to implement a slow feedback with the goal of eliminating the aforementioned systematic oscillations of the beam orbit. The feedback acts on an asymmetric four corrector bump in such a way that a selected photon beam position remains stable. Fig. 2a shows the same vertical XBPM positions as in Fig.1 with such a feedback active on the X06 XBPM in the vertical direction. The rms of the vertical beam position at the X06 XBPM is now reduced to $\approx$0.5μm. Of course, position oscillations at the X09 and X04 monitors are still present (the feedback is active just at the X06 straight section). However, the oscillations near the in XBPM X11 (Fig. 2b) have now another origin. Namely, the users at the X11 beamline were performing dichroic measurements and for this purpose the insertion device energy was periodically changed between 837 and 750 eV. It is clearly visible how well the XBPM vertical position is correlated with the insertion device energy change. This is an indirect proof of the correct optimization of the photon monitor blade geometry - the **monitor is sensitive mainly to undulator radiation**, the bending magnet contamination is negligible. On the other hand this means, that there is a significant systematic beam position drift upon insertion device energy (gap) change.

PHOTON RADIATION ANGULAR DISTRIBUTION

A photon monitor calculates a beam position centre on the basis of vertical and horizontal photoelectric current asymmetries [3]. If we denote A_y (A_x) to be a vertical (horizontal) asymmetry calculated as photocurrent difference of upper-lower (left-right) blades divided by the total photocurrent sum, one can express the beam centre position in the xy plane transverse to the synchrotron radiation as $P_{xy} = \sqrt{(A_y^2 + A_x^2)}$. Since photon monitors are mounted on a movable stage, we can verify the P_{xy} at a given insertion device energy (gap) setpoint by scanning the whole photon monitor horizontally at different vertical positions. In this way we obtain a two dimensional map of the synchrotron radiation angular distribution. Another way to measure this distribution is a two dimensional pin-hole scan. By means of front-end double slits with 100μm x 100μm aperture we mapped the angular distribution of the synchrotron radiation over a 2mm x 1mm surface perpendicular to the beam axis. A Si diode placed at the end of the beamline is used to detect radiation intensity. A comparison of such scans for different energies of the upstream X11 U56 undulator is shown in Fig. 3a. Because the Si-diode detector response increases exponentially at higher photon energies (lower gaps), the image plot shows off-axis features of the 2nd undulator harmonic at lower gaps. Therefore the beam axis position is not evident for lower gaps, but nevertheless, a consistent beam centre drift can be seen between scans in both directions.In Fig. 3b the beam centre position drifts are evaluated from XBPM 2D scans, whereby the XBPM positions were set to zero at gap 38 mm. For gaps below $\approx$18 mm the undulator "approaches" the wiggler mode, whereby the horizontal sensitivity is lost (see the arrow in in Fig. 3b) This is the limit for horizontal sensitivity of the XBPM.

IMPACT OF AN INSERTION DEVICE GAP DRIVE

The scans in Fig. 3a clearly show horizontal beam position shift ≈600 μm and vertical beam position shift ≈400 μm. The upstream and downstream Bergoz BPMs (Fig. 4) also indicate an angular offset being created upon an energy scan in both directions. However due to the low position resolution and unknown absolute calibration it is difficult to quantify the angular offset of the photon source (moreover in the vertical direction the readouts are influenced by systematic orbit motions seen also in Fig 1). Supposing the estimated position offsets reported in Fig. 4 are true, a rough beam position comparison with Fig. 3b gives a factor 10 of difference, probably due to unknown remanent fields of the correctors in the ID straight section. Surprisingly the horizontal:vertical position offset ratio between gap 18 mm and 37 mm is ≈3:2, which is consistent with position offsets detected in Fig. 3a. Also consistent is the fact, that in all cases, i.e. XBPM scans, front-end scans and Bergoz BPMs position readouts, the horizontal offsets become significant below 23mm gap.

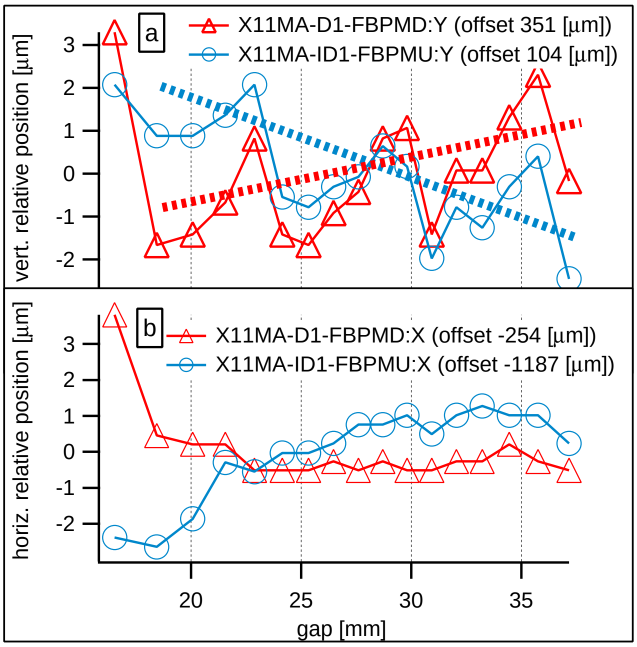

Fig. 4: Vertical (a) and horizontal (b) Bergoz beam positions of the upstream X11 undulator at different energy setpoints during an energy scan depicted in Fig.3. This scan took over 3 hours. The oscillations in the vertical direction are due to the same oscillations as in Fig 1 (highlighted dashed lines show the trend of the vertical beam position drifts). Both vertical and horizontal upstream/downstream monitor readings are going in opposite directions indicating an angle being formed in the electron beam during the gap closing. The Bergoz readouts are not calibrated, the numbers in the legend indicate estimated offsets in μm.

CONCLUSIONS

An energy (gap) change of an ID may produce significant photon beam dispacements in both horizontal and vertical direction. We quantified these displacements for the X11 upstream undulator with three devices: photon monitor, front-end double slit scan and Bergoz BPMs located in the ID straight section. The front-end double slit scans are time consuming and require the use of the whole beamline with monochromator being set on the blue edge of the undulator harmonic. On the other hand an P_{xy} image plot of an undulator XBPM turns out to be a valuable diagnostic tool. Supposing the XBPM is well designed, a P_{xy} image plot measured within ≈5 minutes gives a precise synchrotron radiation centre position.

Similar beam displacements have been observed at the X07 UE52 undulator and also at ID212 at the X09 beamline. The horizontal position drift on dual type undulators deteriorates the phasematching condition on the chicane. Consequently the beam flux decays. Vertical photon beam displacements impact the photon energy coming out from the monochromator which is very undesirable for high resolution photoemission experiments. In the near future we plan to eliminate these beam displacements by producing feed-forward tables for the ID correctors which refer also to photon monitors.

The XBPM sub-micron position resolution makes XBPMs good candidates for feedback purpose as illustrated in Fig 2. In this context the X06 beamline is a special one. Namely, it works typically with a fixed gap and thus the XBPM position readout is not perturbed by a gap change.

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