CORRECTION OF INSERTION DEVICE INDUCED ORBIT DISTORTIONS AT THE SLS

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Abstract

Corrections of insertion device (ID) induced orbit distortions at the SLS are performed by means of feed forward schemes down to the micron level at the corresponding photon beam position monitors (XBPMs). The remaining orbit fluctuations are suppressed by XBPM feedbacks which are an integral part of the fast orbit feedback system. As a result, sub-μm RMS stability at the XBPMs is achieved while the ID settings are varied.

INTRODUCTION

Undulators and wigglers exhibit small variations of the field integral and thus a finite residual deflection angle, which is depending on the ID operating parameters. This dipole kick causes orbit distortions whenever the ID parameters are altered. The fast orbit feedback (FOFB) [1] is able to decouple different beamlines, i.e. an orbit distortion induced by moving the ID of one beamline is not observable by the others under the condition that the frequency is of the order of a few Hz. However, since the orbit distortion is a predictable and unique function of the ID gap and, in some cases, can also be quite large, it is advantageous to take steps to cancel the predicted distortion in advance, by means of a hardwired ID feed forward (IDFF) table, in order to ease the burden of the FOFB.
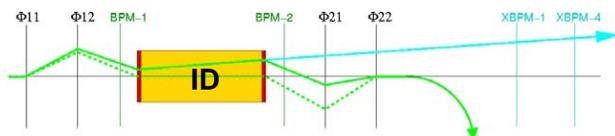
IDFF CORRECTION SCHEME

Figure 1: Illustration of the ID feed forward correction scheme (IDFF). The analogue Bergoz BPMs (ABPMs) "BPM-1/2" and the slow correctors at $\Phi_{12/21}$ are not included in the FOFB loop whereas the fast correctors at $\Phi_{11/22}$ as well as the XBPMs are integrated in the FOFB.

In addition to the digital beam position monitors (DBPMs) [2] the data acquisition for the compilation of IDFF tables involves the dedicated local analogue Bergoz BPMs (ABPMs), which are positioned immediately up- and downstream of each ID, as well as the XBPMs in the beamline front-end, in order to keep the photon beam at its predefined position. The procedure which is illustrated in Fig. 1 is performed in the following two steps:

- Assuming that the orbit distortion is created by kicks at entry and exit of the ID (which is most likely the case due to the typical edge field behaviour), these kicks are determined by analyzing the response of all 72 storage ring DBPMs to the gap variation by means of response matrix inversion using TRACY-2 [3][4]. The deflection angles of the correctors at Φ_{12}, Φ_{21} adjacent to the ID (not part of the FOFB) are adjusted to compensate for the edge kicks (basically this is a 2-corrector orbit correction) as indicated by the solid green line in Fig. 1.

- Reading local ABPMs and XBPMs the photon beam position is fitted using weighting factors adapted to the gap-dependant significance of the different monitors since XBPMs provide no relevant information at large gaps due to their strong photon beam profile dependence. The adjacent correctors at Φ_{12}, Φ_{21} are adjusted by the appropriate kicks in order to keep the photon beam fixed (see green dotted line in Fig. 1).
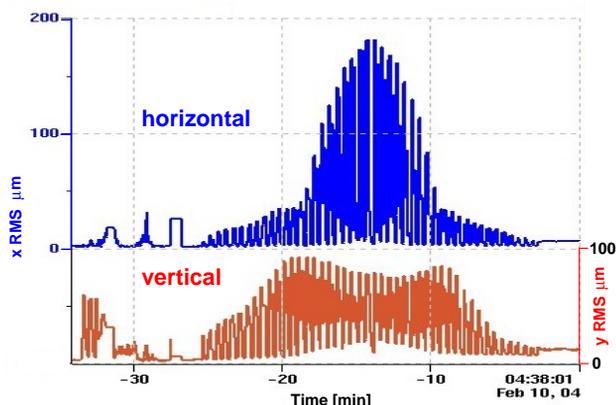

Figure 2: Horizontal and vertical RMS orbit response of all DPMs during IDFF recording for one of two electromagnetic undulator **UE212** at the surface/interface spectroscopy (SIS) beamline. Applying the estimated correction after each IDFF step restores the original RMS values within a few μm (see comb like shape). This IDFF table generation for one ID parameter takes $\approx$20 min. The FOFB is switched off during the entire measurement.

The correction of the subsequently resulting residual orbit distortion is left to the FOFB which mainly changes the deflection angles of the first fast correctors at Φ_{11} and Φ_{22}. As a result the IDFF tables rely on the proper operation of the FOFB. The IDFF tables are recorded in a step-by-step fashion using a CORBA based high-level application [5] which

takes minutes to hours depending on the complexity of the ID (see Fig. 2). Thus they can only account for the static but not for the dynamic effect of the ID change. In-vacuum IDs typically move at gap speeds of up to ≈0.5 mm/s.

This method, described in detail in [6], has now reached maturity and is routinely applied to all in-vacuum undulators at the SLS. For the generation of the IDFFs for the elliptical undulators (EPUs) only the local ABPMs have been used up to now. Inclusion of XBPMs requires further refinement, since the photon beam profile varies as a function of the polarization state of these devices [7].
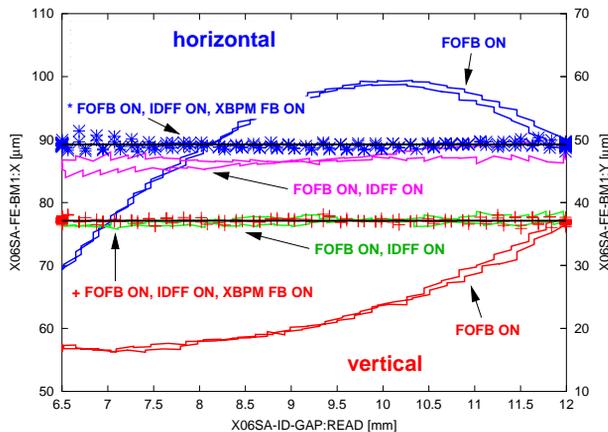

Figure 3: Stabilization of the horizontal and vertical photon beam position at the XBPM of a protein crystallography (PX) beamline ≈8.6 m away from the source point of the in-vacuum ID **U24** during gap variations at a speed of 0.1 mm/s by means of FOFB, FOFB + IDFF tables and FOFB + IDFF tables + XBPM feedback.

Fig. 3 depicts the horizontal and vertical photon beam position at one of the protein crystallography (PX) beamlines ≈8.6 m away from the source point of the in-vacuum ID **U24** (recently replaced by an **U19** [8]) as a function of the ID gap in the relevant range $6.5-12$ mm for three cases:

1. Solely the FOFB is running without applying any IDFF table (curved solid lines). The curves appear to be split into two lines due to small hysteresis effects when opening and closing the ID gap.
2. The FOFB is running and the IDFF tables are active (solid, almost flat lines) which confines the residual photon beam movement to ≈10 μm.
3. The FOFB is running, the IDFF tables are active and the XBPMs are included in the FOFB loop by means of the XBPM feedback [1] (star/cross-dotted lines).

As a result the residual photon beam variation is of the order of 1 μm if the gap speed is reasonably low ≈0.1 mm/s since the XBPM feedback is running at an update rate of only 1 Hz and uses moderate PID parameters in order to reduce the loop noise. Fig. 4 indirectly illustrates the effect of the IDFF tables during 85 h of user operation at the same PX beamline. For changing gaps <8.5 mm (magenta line) the XBPM feedback corrects for the residual distortions induced by the ID **U19** in the presence of IDFF tables

(see circles in Fig. 4) equivalent to the ones used in Fig. 3. Since the ID gap was operated at a speed of 0.5 mm/s transients are visible on the XBPM readings which could not be attenuated by the slow XBPM feedback.
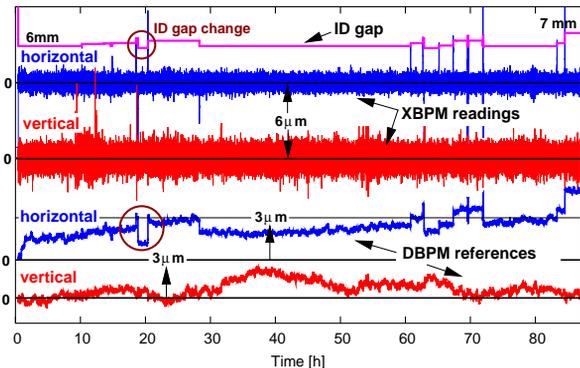

Figure 4: Slow XBPM feedbacks provide sub-μm RMS photon beam stability ($\sigma_x = 0.37$ μm, $\sigma_y = 0.5$ μm) at the first optical elements of presently three beamlines (exemplified by the data taken at a PX beamline over 85 h of FOFB and "top-up" operation) [1]. For changing gaps <8.5 mm (top magenta line) the XBPM feedback corrects (see circles) for the residual distortions induced by the ID **U19** in the presence of IDFF tables as shown in Fig. 3.

CONCLUSION

The described IDFF correction scheme has reached maturity and is routinely applied to all in-vacuum undulators at the SLS. The inclusion of XBPMs for EPUs and the electromagnetic undulators **UE212** still requires further refinement. In conjunction with slow XBPM feedbacks which are an integral part of the FOFB sub-μm RMS photon beam stability has been achieved while the ID settings are varied at moderate speed.

REFERENCES

[1] M. Böge et al., "User Operation and Upgrades of the Fast Orbit Feedback at the SLS", Contribution this Conference.

[2] V. Schlott et al., "Performance of the Digital BPM System for the Swiss Light Source", DIPAC'01, Grenoble, May 2001.

[3] J. Bengtsson, "TRACY-2 User's Manual", Internal SLS document, PSI, Villigen, 1997.

[4] M. Böge, "Update on TRACY-2 Documentation", SLS-TME-TA-1999-0002, PSI, Villigen, 1999.

[5] M. Böge, J. Chrin, "Integrating Control Systems to Beam Dynamics Applications with CORBA", PAC'03, Portland, May 2003.

[6] T. Schmidt, J. Chrin, A. Streun, D. Zimoch, "Feed Forward Corrections for Insertion Devices at the SLS", PSI Scientific Report 2003, Vol. VI, March 2004.

[7] J. Krempaský et al., "The Use of Photon Monitors at the SLS", EPAC'04, Lucerne, July 2004.

[8] G. Ingold et al., "Progress Report: In-vacuum Undulators", PSI Scientific Report 2003, Vol. VII, March 2004.