SLOW ORBIT FEEDBACK AND BEAM STABILITY AT ALBA

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Abstract

ALBA is a 3 GeV 3rd generation synchrotron radiation source built nearby Barcelona providing service to users since May 2012. In this paper we summarize the performance of the Slow Orbit Feedback system (SOFB) which is continuously running during user's operation in order to deliver a stable photon beam to the Beamlines. Besides, we also analyze the long term stability of ALBA Storage Ring along one year of operation using as a reference the readings of the X-Ray Beam Position Monitors (XBPMs) installed in the Front Ends (FEs).

INTRODUCTION

Since May 2012 ALBA facility is open to external users. The Storage Ring (SR) runs for periods of around 4 weeks on a 24h/7 days basis. During operation with users two injections in the SR are carried out customarily per day. Along 2012 the injected electron beam current was 100-105 mA, while since the beginning of 2013 the current at injection has been increased up to 120 mA.

STATUS OF THE SOFB

The Slow Orbit Feedback has been running in ALBA since the start of user's operation. The system is based in a Matlab graphical user interface, correcting the orbit at a fixed rate each 3 s. The correction is based in a SVD inversion of the response matrix. The used response matrix is measured weekly, and the inversion uses Tikhonov regularization. The electron Beam Position Monitor (BPM) data is sampled at 10 Hz, and 18 of those values are averaged in the Tango device server, in order to reduce the noise. The energy contribution to the horizontal orbit is corrected using the RF frequency, once the accumulated RF change reaches 10 Hz, corresponding to 1 μm of horizontal orbit. The orbit is corrected to the center of the quadrupoles, according to the Beam-Based Alignment (BBA) data [1].

In the last year, two main upgrades have been made to the SOFB system:

1. Inclusion of a Front End (FE) XBPM.
2. Noise reduction in the correction.

Inclusion of the XBPM of the Mistral Beamline

As reported in last year IPAC [2], changes in the position of the photon beam at the Beamlines (BLs) were observed along the operation, whilst no motion was detected in the SR BPMs. In particular, BL09-Mistral, with a bending magnet as a source, perceives a large motion of the source point after each injection, while the orbit changes remains well under the sub-micron level in the nearby BPMs.

In order to improve the photon stability, since July 2012 the reading of the XBPM installed in FE09 has been included in the vertical SOFB loop. This particular XBPM has a Staggered Pair Monitor (SPM) configuration [3], providing only information on the vertical position of the photon beam. After adjusting the weight of this new monitor with respect to the BPMs, the photon source point is now more stable after injection (see Fig. 1). The main drawback is that now the response matrix is not square, and we cannot ensure a perfect theoretical correction to the golden orbit. In practice, the only effect is a micron level change in the two BPMs adjacent to the bending magnet after injection.

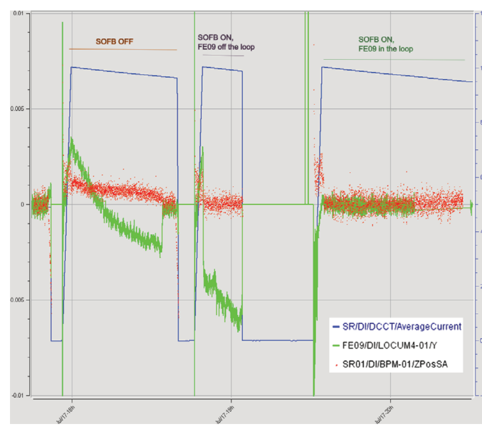

Figure 1: Comparison of photon beam motion at the XBPM of FE09-Mistral (green line) after injection with (i) SOFB off, (ii) SOFB on using only BPM data, (iii) SOFB on including the FE09-XBPM in the correction loop. Red points show as a reference the vertical position of the electron beam at a particular BPM.

Noise Reduction

It has been observed that even if the machine is quiet (no ID gap change, no activity in the experimental hall), the SOFB would introduce noise at the correction frequency. In order to reduce it, the SOFB algorithm has been modified to only correct modes with amplitude larger than a given threshold: after reading the values from the BPMs, the orbit is decomposed into SVD modes; only the modes with amplitudes larger than the threshold are corrected. This threshold is set at the values that the Libera BPM units of ALBA can distinguish between noise and real motion. Figure 2 shows the vertical orbit in a particular BPM for 45 minutes for several values of the threshold as well as the

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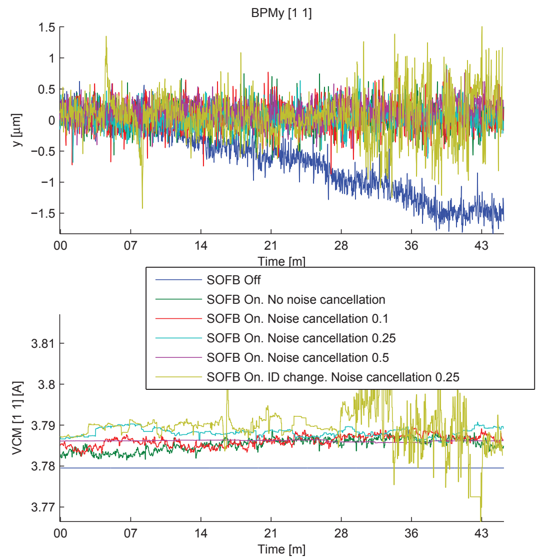

Figure 2: Noise reduction for different values of the threshold. The changes in the vertical corrector magnets (lower plot) are less frequent for higher values of the noise reduction, while the position stability (upper plot) is good in all the cases. The operational value of 0.25 is a good compromise and works well even when the ID gap are changing.

change in the nearby vertical corrector. A value of 0.25 has been selected for operation, as a good compromise between correcting the orbit and reducing the noise.

Gain and Characteristic Time of the SOFB

Due to limitation of the system (running in the Matlab environment, no dedicated device server for the SOFB), it is not possible to ensure a correction rate better than 3 s. Figure 3 shows the response of the system (in the vertical direction) to a step change in the first vertical corrector, for 4 different gains. The characteristic time of the system is $\sim$ 4 s for the 90% gain, $\sim$ 7 s for the 60% gain, $\sim$ 14 s for the 30% gain, and $\sim$ 40 s for the 10% gain. During operation the system is run at 60%.

LONG TERM STABILITY

The long term stability of the photon beam delivered to the BLs has been analyzed using the data collected by the XBPMs that have a planar ID as a source [4]: FE04 (SCW30 source), FE11 and FE13 (both with an in-vacuum IVU21 source), and FE22 (MPW80 source). These XBPMs are not included in the orbit correction loop, and hence they provide information regarding the stability of ALBA SR with respect to the BLs.

The XBPMs for these FEs consist of four tungsten blades arranged in a X-shape [3], with a size and geometry which have been adapted to the beam characteristics of each ID in order to optimize the sensitivity of the device. This type of XBPM in principle provides both the

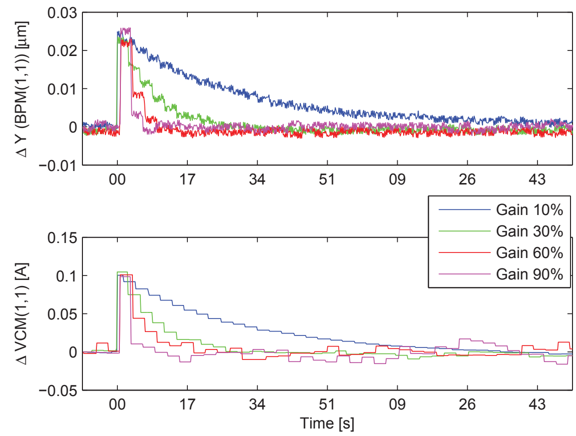

Figure 3: Response of the SOFB to a step change in the first vertical corrector. There is a small overshoot for the 90% gain.

horizontal and vertical position of the photon beam. However, in the case of the FEs with a wiggler as a source (FE04 and FE22), given the large horizontal opening of the photon beam ($\sim$ 1 mrad for the SCW30 and $\gtrsim$ 2 mrad for the MPW80), the XBPM only provides reliable information along the vertical plane. Therefore, when analyzing the photon beam stability within the horizontal plane, we will only take into account the information coming from the FEs with a IVU as a source: FE11 and FE13.

The XBPMs are located at a distance from the source point in the range 8.7–10.3 m. Their sensitivity was calibrated as a function of the configuration of the source taking profit of the X–Y motor stages which allow to move the XBPM chamber within the transversal plane.

The position readings of the XBPMs are archived continuously at a rate of 1 sample per second. We have analyzed the collected data taking three different time scales: (i) data within a 8-hour shift, (ii) data within a 4-weeks user's run, and (iii) data along one full year of operation.

Photon Beam Stability within a Shift

Within a 8-hour shift, the typical *rms* stability of the photon beam position on the XBPMs along the horizontal plane is $\lesssim 4\,\mu$m (see Fig. 4). The corresponding *rms* stability along the vertical plane is $\lesssim 1\,\mu$m in the case of wiggler sources and $\lesssim 2\,\mu$m in the case of undulator (IVU) sources. Such a difference comes from the fact that both wigglers at ALBA operate at a fixed setting, whilst the gap of the IVUs is changed during operation; therefore, in the case of IVUs the photon beam position stability has a contribution from the small dependence of the emission angle to the gap of the device. It is interesting to compare the observed *rms* stability of the photon beam with the electron beam size/divergence at the source point: 95 μm/50 μrad within the horizontal plane and 6 μm/5 μrad within the vertical plane. Regarding the maximum variation of the beam position within one shift, along the horizontal plane it has

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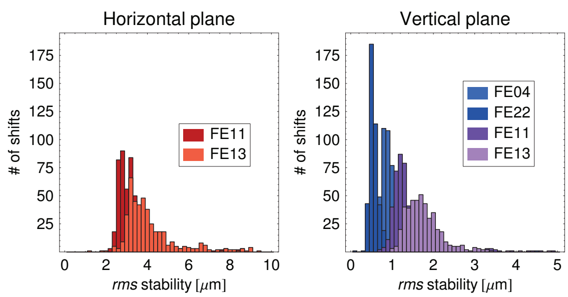

Figure 4: Stability of the photon beam position (*rms* value) at the FE XBPMs calculated over periods of 8 hours.

a typical value of $\lesssim$ 20 μm; along the vertical plane, it has a value of $\lesssim$ 5 μm in the case of wiggler sources, and $\lesssim$ 10 μm in the case of IVU sources.

Photon Beam Stability along a Run

Along a complete run of 4-weeks we have taken the variation in the average readings of the XBPMs from shift to shift as an indicator of the photon beam position stability. In the case of the horizontal plane, the maximum variation of the beam position within a single run is typically in the range 20–40 μm, but in a couple of runs variations as large as 80 μm have been observed. Along the vertical plane, the maximum shift-to-shift variation of the beam position within the same run is typically in the range 10–20 μm, but again larger deviations (up to 80 μm) have been observed in a few occasions.

Photon Beam Stability along One year

Figure 5 shows as an example of the long term evolution of the photon beam position along one year. The data corresponds to FE04 (wiggler source) and FE13 (IVU source) since the beginning of 2012 until March 2013. An analysis of the data collected by the studied XBPMs shows that:

1. Along the horizontal plane, the change in the average photon beam position from run to run is within $\pm$40 μm. Along the vertical plane, this change is usually within $\pm$25 μm.
2. At the beginning of 2012_RUN09 there was a large jump in the photon beam position measured at several XBPMs. This was the result of an incident that took place on November the 13th during the start-up of the accelerators and that involved a significant intervention on the SR vacuum chamber [5]. Once the problem was solved, some of the XBPMs indicated that the photon beam position had changed significantly with respect to its value prior to the incident, despite the fact that new BBA data was acquired. The position change was larger along the vertical plane (up to 160 μm) than along the horizontal one ($<$ 30 μm).
3. Superimposed to run-to-run changes which are apparently uncorrelated, the 1-year data for some XBPMs reveal a continuous trend of the photon beam position. It is possible that such an evolution is related to seasonal changes in the accelerator configuration, as is also indicated by a similar drift of the central RF frequency. However, accumulated data over more years will be required in order to confirm this hypothesis.

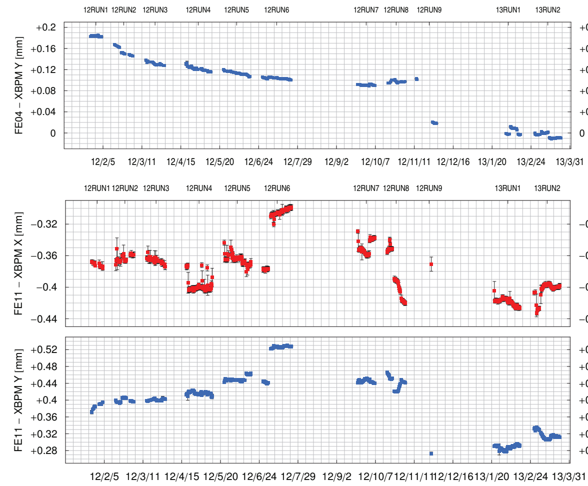

Figure 5: Evolution of the average position of the photon beam from shift to shift along one year for a XBPM with a wiggler source (*top*: FE04, information only for the vertical plane) and a IVU source (*bottom*: FE13, information for both horizontal and vertical planes). The error bars indicate the *rms* variation of the position within each shift.

Summary

The obtained results regarding the photon beam stability are summarized in Table 1.

Table 1: Photon beam stability determined by FE XBPMs for different time scales.

time period	horizontal	vertical	comment
8 hour (1 shift)	4 μm	1–2 μm	*rms*
	20 μm	5–10 μm	max-min
4 weeks (1 run)	$\lesssim$ 40 μm	$\lesssim$ 20 μm	max-min
1 year	$\pm$40 μm	$\pm$25 μm	run-ro-run

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