INTRODUCTION OF PHOTON BPMS IN SOLEIL GLOBAL ORBIT FEEDBACK SYSTEMS

N. Hubert#, L. Cassinari, L. Nadolski

Synchrotron SOLEIL, Saint Aubin, BP 34, 91192 Gif-sur-Yvette, France

Abstract

SOLEIL global orbit feedback systems (slow and fast), based on 122 electron Beam Position Monitor (e-BPM) readings, are in operation since 2008 and give very satisfying performances (0.1Hz-500Hz vertical noise below 300 nm RMS and long term (8h) drifts below 1µm RMS).

Whereas each straight section is equipped with an upstream and downstream e-BPM, there is no e-BPM next to a dipole magnet. For that reason, photon BPMs (x-BPMs) in the dipole beamline frontends give additional information that can be used to better stabilize the source point in the dipoles. In fact x-BPMs provide also a better position angular measurement resolution, as they are located at 4 meters from the source point.

Results presented in this paper show that vertical position stability on bending magnet beamlines can be improved by including their x-BPM measurements in the global orbit feedback systems.

As a first step x-BPMs have been introduced in the Slow Orbit FeedBack system (SOFB) that corrects the orbit with a repetition rate of 0.1Hz. In a second step x-BPMs will be introduced in the Fast Orbit FeedBack system (FOFB) running at a repetition rate of 10 kHz.

INTRODUCTION

SOLEIL synchrotron is a third generation light source in operation since 2006. Orbit stability is a key parameter for the beam quality delivered to the 26 beamlines. Very good performances have already been achieved for long term and short term stability as reported in Ref. [1]. Combined slow and fast orbit feedback systems [2] keep the horizontal and vertical position and angle within the standard stability requirement: less than 10 % of the beam size and divergence, respectively. Nevertheless, continuous effort is done to improve even more the SOLEIL beam orbit stability taking into account new demands for stabilizing the closed orbit. Currently, integration of the photon beam position monitors (x-BPMs) in the feedback loops is being studied. Two x-BPMs are located several meters away from the source point and have a better sensitivity than the electron beam position monitors (e-BPMs). Moreover, bending magnet beamline x-BPMs can give additional information for the orbit stability, since the SOLEIL lattice does not have any e-BPM next to a bending magnet source point (Fig. 1).

nicolas.hubert@synchrotron–soleil.fr

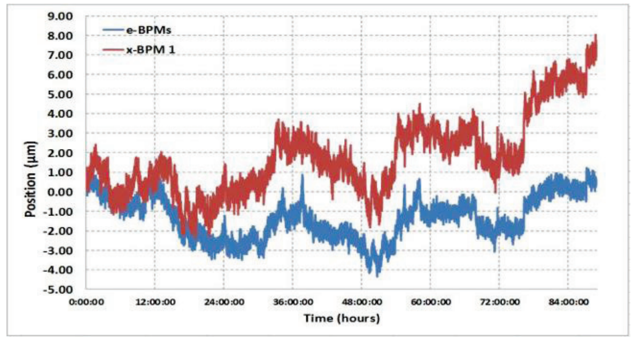

Figure 1: Vertical beam position measured by a dipole x-BPM at 4.7m from the source point (red curve). As a comparison, the projection of the position calculated from position and angle of the electron beam at source point is plotted in blue. The stability observed on the x-BPM is not as good as the one observed on e-BPMs.

CONTEXT

Orbit Feedback Systems

The SOLEIL beam orbit is stabilized using two interleaved orbit feedback systems based on the reading of the 122 e-BPMs of the machine. The slow system acts every 10 seconds on a set of 57 corrector coils located in the sextupole magnets (arcs). The fast system acts every 100 µs on a different set of 50 air-coil correctors located upstream and downstream of every straight section. Both systems are global, that is to say that the information from all e-BPMs is taken into account to compute the setting values for each corrector. An interaction process [2] allows having both systems efficient on a common frequency range: from DC to 0.05Hz for the slow orbit feedback (SOFB) and from DC to 200 Hz for the fast orbit feedback (FOFB).

Photon BPMs

SOLEIL beamlines frontend are equipped with blade x-BPMs, manufactured by FMB [3] after a design from BESSY. The position measurement given by this kind of x-BPM is based on the beam halo detection and thus is strongly dependent on the photon beam shape. On bending magnet source points, the beam shape is constant whereas for the insertion devices, it hugely depends on its configuration (gap, phase, photon polarisation …). For this very reason, only x-BPMs on bending magnet beamlines can be included at the moment in the orbit feedback loops (vertical plane only).

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Two photon BPMs are installed in each of the 4 bending magnet beamline frontends. They are located at 4.7 and 6.73 meters after the source point, respectively. A shutter, controlled by the beamline users, is placed between the two x-BPMs. Therefore, the first x-BPM can be included in the feedback loops whereas the second one will be used as an independent observer (Fig. 2).

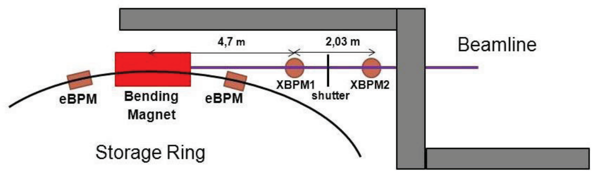

Figure 2: Schematics of a SOLEIL bending magnet beamline frontend (extraction angle = 1°). A shutter is placed between the two x-BPMs.

SOLEIL Lattice

Orbit stabilisation of a source point depends mainly on the readings of the 2 closest e-BPMs. In SOLEIL lattice, several magnetic elements are located between bending magnets (source point) and the closest e-BPM: one sextupole and one quadrupole at each side (Fig. 3).

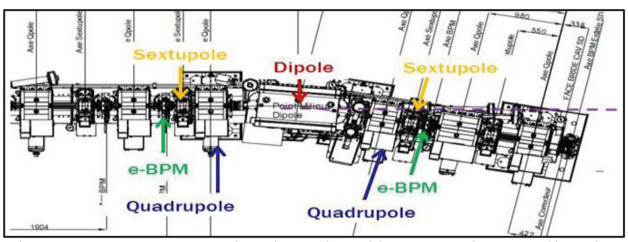

Figure 3: SOLEIL lattice detail around one dipole magnet. Bending magnet and closest BPM are separated by one sextupole and one quadrupole.

In this case, e-BPMs do not give a direct measurement of the source point in the dipole and orbit stabilization is not optimized for the source point stabilization.

Four bending magnet beamlines have two x-BPMs in their frontend as described in the previous paragraph. Those beamlines are located symmetrically around the storage ring (Fig. 4)

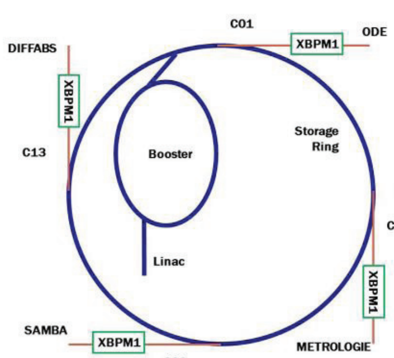

Figure 4: Bending magnet beamlines location around the storage ring. Four bending magnet beamline frontends are equipped with x-BPMs than can be included in orbit feedback systems.

INTEGRATION INTO GLOBAL ORBIT FEEDBACK SYSTEMS

Global Feedback Systems

SOLEIL slow and fast orbit feedback systems are both global, that is to say that the information from all e-BPMs is used to compute the new setpoints of the corrector coils. The RF-frequency is used as an extra knob in the horizontal plane to correct for circumference slow variation of the storage ring in the SOFB loop. Correction algorithms are based on SVD method.

To be integrated into feedback loops, x-BPMs are considered as additional BPMs in the response matrix with specific weighting factors.

The first step has been the integration into the SOFB in order to see the feasibility and also to check the efficiency on the beam stability of such the introduction.

Integration into the Slow Orbit Feedback System

First, a simulation has been done, to check that the correction process was converging when x-BPMs are included. Loop has been first closed using a theoretical response matrix, and later with an experimental one. Correction was immediately converging. It is performed using 57 singular values in both planes. The weights for each e-BPM and x-BPM are all equal to one, but can be set independently for future optimisation.

Experimental tests have been carried out over medium term periods (~5 hours). In order to compare the stability with and without x-BPMs in the SOFB loop, beamline shutters are opened, and observations are done on the second x-BPM which is not in the feedback loop (Fig. 5).

For the four bending magnet beamlines, vertical beam position stability is improved. Vertical position variations, with and without x-BPMs in the feedback loop, are given in Table 1. Introduction of x-BPMs in the slow feedback loop improves the stability by about a factor 2.

Table 1: Variation (RMS) of the vertical position on x-BPM N°2 with and without x-BPM N°1 in the slow feedback loop (experiment duration = 6 hours).

Beamline name	w/o x-BPMs	w/ x-BPMs	Reduction factor
ODE	1.25 µm rms	0.37 µm rms	3.3
METRO	0.46 µm rms	0.24 µm rms	1.9
SAMBA	0.38 µm rms	0.23 µm rms	1.7
DIFFABS	0.33 µm rms	0.16 µm rms	2.1

In the same time, vertical orbit stability on the other source points (insertion device beamlines) has not been deteriorated.

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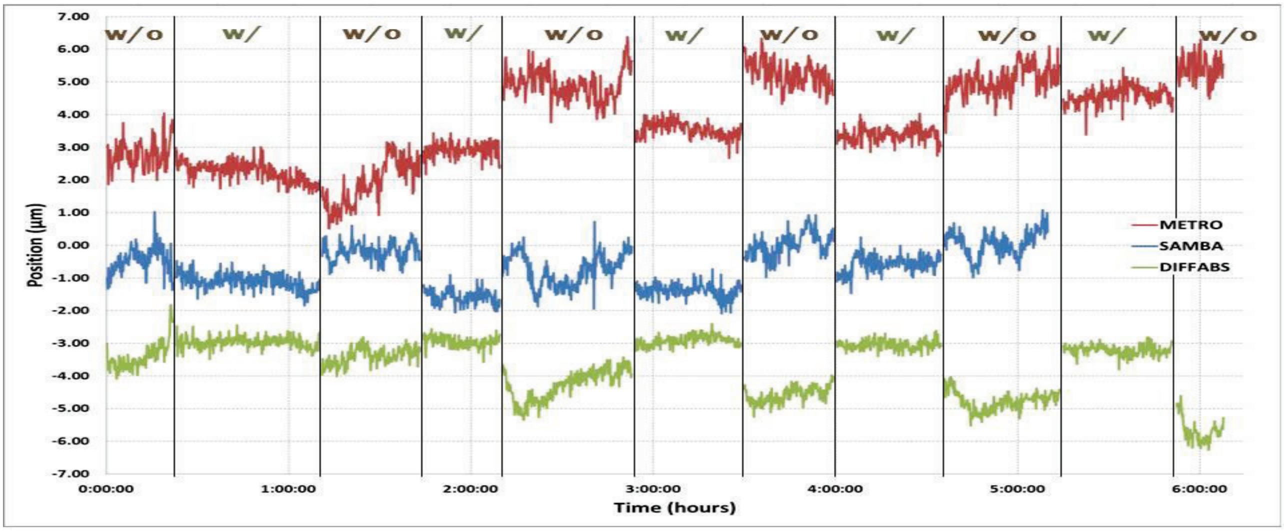

Figure 5: Vertical beam position measured on second x-BPMs (not included in the feedback loop) at the METRO, SAMBA and DIFFABS bending magnet beamlines. First x-BPM is alternatively included or excluded from the slow feedback loop. Improvement on vertical stability can be seen when the SOFB runs with the x-BPMs.

Those tests have been carried out with the slow correction loop alone. Now that it has been shown that introduction of those x-BPMs was beneficial for the vertical orbit stability, it will be shortly put in operation with the FOFB running in parallel (without x-BPMs in a first time).

Integration into the Fast Orbit Feedback System

Integration of x-BPM data into fast orbit feedback system requires additional precautions on the data synchronization point of view:

- e-BPM and x-BPM data sampling rates must be identical (10079Hz at SOLEIL)
- e-BPM and x-BPM data latency must be sensibly equal (less than 20 µs difference)
- e-BPM and x-BPM data must be synchronized and distributed over the same dedicated network

This has been done by replacing the existing electronics of the first x-BPM by Libera Photon modules [4] on the four bending magnet beamline frontends.

Moreover the FOFB algorithm has been modified to accept additional inputs.

Benefits of including x-BPMs in the FOFB have still to be demonstrated, but as almost all elements are ready, it will be under commissioning in the coming months.

CONCLUSION

Bending magnet source point vertical stability benefits from the introduction of dipole-based x-BPM in the slow orbit feedback loop. First tests have been carried out and are very encouraging. After some additional work to adapt this new configuration to the control system, it can be shortly adopted during user operation mode.

Electronics and algorithm are ready for the integration into the FOFB, and first tests will be done in the next months.

In the future, we can also expect to integrate x-BPMs from insertion device beamline frontends. Nevertheless the issue of position measurement dependence with the insertion device configuration is complex and has still to be solved.

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