BEAM POSITION ORBIT STABILITY IMPROVEMENT AT SOLEIL

L. S. Nadolski*, L. Cassinari, J-P. Daguerre, J-C. Denard, J-M. Filhol,
N. Hubert, N. Leclercq, A. Nadji, Synchrotron SOLEIL, Gif-sur-Yvette, France

Abstract

SOLEIL is the French 2.75 GeV high brilliance third generation synchrotron light source delivering photons to beam-lines since January 2007. Reaching micrometer to sub-micrometer level stability for the photon beams is required but very challenging. Since September 2008, a fast orbit feedback has been running for daily operation. The performance of the system will be presented with respect to those achieved with the slow orbit feedback system. Status of the interaction of both feedback systems will be discussed. Moreover new X-BPMs have been installed on the front-ends of dipole and undulator based beam-lines. A total number of 9 vibration sensors are now installed in the storage ring tunnel, on the experimental slab, and outside the building in order to help locating the different noise sources. Detailed results will be presented and debated.

INTRODUCTION

Reaching the micrometer to sub-micrometer stability is a key point in a third generation light source like SOLEIL [1]. Users ask for a stability at least as good as one tenth of the beam sizes [2]. This requirement are very challenging for low emittance storage rings, running with very low coupling values. For long beam-lines, for beam-lines (BLs) using grazing incidence, sensitivity on the beam position and angle is critical.

In order to cope with beam residual position perturbations, two feedback systems have been developed over the years. As described in the first section, very recently both systems have successfully been used together. The second section presents velocimeters which have been installed and commissioned since summer 2008 in order to help us identifying noise perturbation sources.

ORBIT FEEDBACKS

Slow Orbit Feedback

A Slow Orbit FeedBack (SOFB) has been set into operation in May 2007. The system makes use of 120 Beam Position Monitors (BPMs), of 56 corrector magnets located in the sextupole magnets. The RF-frequency is used in the horizontal plane to compensate for circumference variations. The SOFB correction rate is $0.1\,Hz$ using a standard Singular Value Decomposition (SVD) based algorithm with 56 singular values in both planes. When not running top-up operation mode, a few BPMs have to be excluded of the correction loop due to their current dependence. The SOFB is very efficient for correcting long term orbit distortions for bending magnet (BM) and insertion device (ID) based beam-lines. Its main drawback comes from its correction rate which is too slow for taking care of insertion device perturbations (residual closed orbit distortions and transients from feedforward correction systems) induced by user-free ID controls. Other examples of noise sources to be corrected for are the $3\,Hz$ rate booster operation, overhead crane motion in the experimental hall, dichroism experiments using fast switching magnetic devices (see Ref. [2] for details).

Fast Orbit Feedback

For curing short term perturbations, a Fast Orbit FeedBack (FOFB) was put into operation in September 2008. Using 48 air coils located upstream and downstream of all the 24 straight sections and 120 BPMs, this system, distributed in Libera units, has been running for user operation very efficiently since September 2008 (see Ref. [3, 4] for details). Its bandwidth extents from DC to $150\,Hz$ with correction frequency of $10\,kHz$. Its main drawback resides in the long term orbit drifts not well corrected for the BM based BLs.

Running both feedback systems at the same time was not possible until recently since they were fighting against each other. The main reason originates from the different locations of the corrector magnets of both systems generating different residual orbits. After only a few iterations of the SOFB, the FOFB correctors get fully saturated.

Architecture Improvements

For robustness the FOFB control architecture has been greatly improved over the last months. A dedicated TANGO device server has been written in order to supervise all the equipment of the FOFB, namely Libera BPM electronics, fast corrector magnets, and 2 sniffer boards (used as diagnostics). This architecture allows us to have robust and reliable methods to assure that the FOFB is running safely. An active logic has been developed to stop the feedback for different scenarios such as: lost of TANGO connection with a BPM, a corrector, beam lost, timing issue between BPMs.

In addition the control of the fast corrector power supplies has been upgraded. The TANGO communication is now more than 10 times faster (10 Hz). Diagnostics have been added in order to monitor time-wise the average, minimum and maximum peak values of the data sent to the power supplies by the FOFB. This enables us to diagnose

* nadolski@synchrotron-soleil.fr

in an efficient way troubles with power supplies, sources of noise, origin of FOFB interruptions, behavior of the FOFB with running insertion devices, and so forth.

The user interface for running the FOFB is still done using a MATLAB™programme, but all the logic is now deported in TANGO.

The correction algorithm has been modified so that the variation of the circumference is directly taken care by the horizontal fast orbit correctors. In order to avoid building up of the fast corrector magnet strengths leading to their saturation, a slow MATLAB™loop has been implemented to unload the DC current values of the fast correctors. The principe is to predict the closed orbit if all fast correctors were set to zero and to correct for this orbit offset using the SOFB correctors and the RF-frequency. This loop was runnning within a MATLAB™application every 8 hours then automatically at a $0.1\ Hz$ rate and is called DC Feedback. The current steps (ΔI_{SOFB}) to be set in the SOFB corrector magnets are given by:

$$\Delta I_{SOFB} = R^{-1}_{SOFB} \Delta x_{FOFB} \tag{1}$$

where R^{-1}_{SOFB} is the SVD-wise inverse orbit response matrix of SOFB evaluated only for the BPMs and slow correctors used in the slow feedback loop. Δx_{FOFB} is the predicted closed orbit by the DC part of FOFB correctors, namely:

$$\Delta x_{FOFB} = R_{FOFB} < I >_{FOFB} \tag{2}$$

where R_{FOFB} is the FOFB orbit response matrix evaluated for BPMs and fast correctors used in the fast feedback loop.

This configuration has been running since September 2008 with the only drawback of the large drift on BM based BL.

Interaction Between Both Feedback Systems

In order to get an excellent orbit stability for both BM and ID based beam-lines, a solution where both slow and fast orbit feedback systems work simultaneously without frequency dead band has been developed.

After simulation and beam based experiments, the candidate solution consists in making both feedbacks communicating. Otherwise the system is completely unstable after only a few SOFB iterations. The main reason is the non-identical location of the fast and slow corrector magnets leading to large difference of the residual closed orbits of each system, especially in the arcs where the efficiency of the FOFB is known to be poor.

This new interaction mode is made of two parts:

- The FOFB system does not correct anymore around the golden orbit but around the SOFB residual closed orbit which is updated before each step of the SOFB.
- The SOFB feedback corrects at a$0.1\ Hz$ rate both for the orbit distortion read on the BPMs (Δx_{SOFB}) and the orbit reconstructed by unloading the DC part of the fast correctors (Δx_{FOFB}, cf. DC feedback). The current values (ΔI_{SOFB}) sent to the slow correctors can be expressed as:

$$\Delta I_{SOFB} = R^{-1}_{SOFB}(\Delta x_{SOFB} + \Delta x_{FOFB}) \tag{3}$$

where Δx_{SOFB} is defined as the difference between the orbit read-back on the BPMs and the golden orbit defined after a careful beam-based alignment.

Performance

This new composite feedback has been set into operation during the last user run with success. As expected the orbit stability has significantly improved in the arcs. So this solution combines advantages of both feedbacks (See Fig. 1).

Since second part of March 2009, SOLEIL is running top-up operation [1]. The direct result is a thermalization of the equipment of the storage ring, especially the BPMs (suppression of current dependence) leading to a better overall orbit stability of the photon beam for the users, namely a 1 to 2 μm peak stability.

Now it appears that the main disturbance of the beam stability comes from the not properly working storage ring air conditioning units, leading to local variations of the tunnel temperature up to $\pm 1°C$ well above the $\pm 0.1°C$ target value. A delicate tuning of these units has been launched.

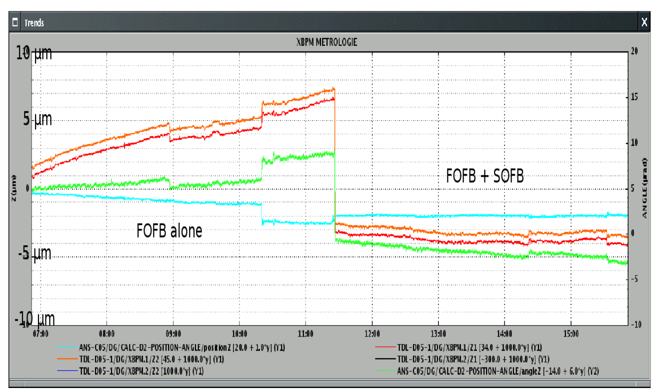

Figure 1: Orbit stability for a BM based beam-line with only FOFB running (left) and with both feedback systems runnings. Data from XBPM and BPM (blue) are compared.

VIBRATION MONITORS

Equipment Description

Since summer 2008, online vibration survey of the SOLEIL site has been available thanks to the acquisition of 9 vibration sensors distributed in the storage ring tunnel (one station on a quadrupole, an girder, an IDBPM, and a XBPM), the experimental hall (two stations on the slab near an infrared and a hard X-ray BL), and two stations located outside the synchrotron building (close to the utility system building and to the main traffic road). Each sensor has 1 (vertical) or 2 (horizontal and vertical) channels.

These devices are velocimeters (geophones), with a lower cut-off frequency of $1\,Hz$ and an upper one of $100\,Hz$, with a $256\,Hz$ sampling frequency. The acquisition electronics is based on a PXI 4462 board from National Instrument$^{\mathrm{TM}}$. This 24 bit board is hosted in the control room. It has been chosen for its very low electronics noise performance (Common Mode Rejection Ratio of $105\,dB$). The whole system has been bought from AVLS company [5].

Data Analysis Software

The data convoluted with a Hanning window are analyzed online using a LABVIEW$^{\mathrm{TM}}$based turn-key software. Every $96\,s$, spectra of the 16 channels are displayed in term of temporal and spectral signals. An alarm threshold has been set whenever the vibration level is larger than $1\,\mu m$ peak. In such condition all temporal data are stored into a file for post-analysis.

The system is interfaced with TANGO through a datasocket server. RMS and PEAK values are archived into TANGO enabling time-wise correlation with other signals.

Fine treatment of the vibration data is performed using MATLAB$^{\mathrm{TM}}$.

Data Examples

Thanks to the 16 channels available, the geophones helps us to identify and locate source noise from the environment. Examples are daily variations of human activities on the SOLEIL site, environment noise like the traffic on the nearby road (Fig. 2). This system helps us to determine that noise observed on a beam-line was originating from a BL vacuum roughing pump.

Geophones are such sensitive devices that they were able to detect the recent Italian earthquake of April 6th (Aquila, 1500 km away). Figure 3 exhibits that earthquakes of moment magnitude larger than 4.0 in Italy are detectable. Actually the stored beam was impacted by the 6.3 Italian earthquake. Thanks to the fast orbit feedback, the horizontal disturbance of $10\,\mu m$ was damped down to only a few micrometers.

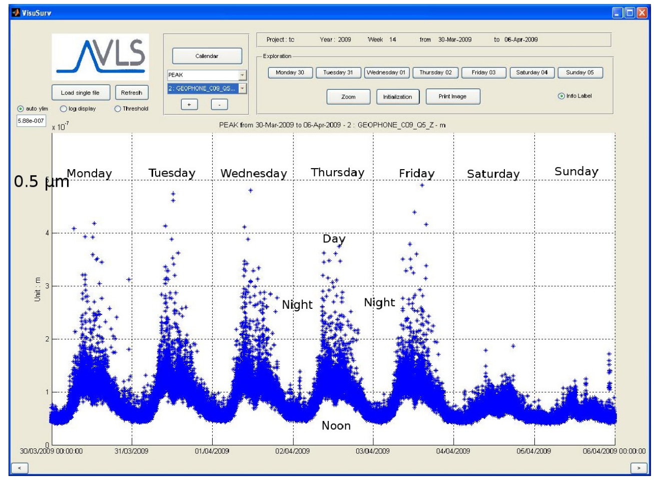

Figure 2: Environment noise (in meters) recorded over one week on a vibration sensor in the vertical plane. Weekly, daily, nightly activities are well visible.

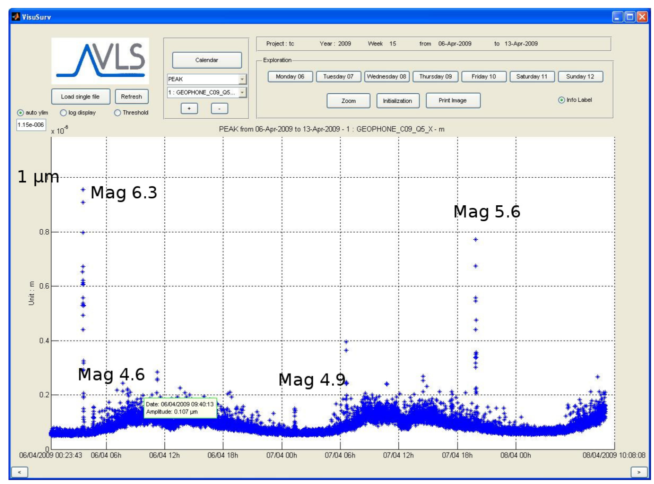

Figure 3: Detection of Aquila earthquakes (April 2009). Horizontal peak amplitude reaches up to $1\,\mu m$ at the sensor location.

CONCLUSIONS AND PERSPECTIVES

During the last months the FOFB has successfully improved the orbit electron and photon beam stability. Moreover a solution was found out to run simultaneously both slow and fast orbit feedback. Now focus is on the fine tuning of the temperature regulation of the storage ring tunnel and on the commissioning of the XBPMs.

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