SOLEIL BEAM ORBIT STABILITY IMPROVEMENTS

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Abstract

SOLEIL beam orbit stability is being significantly improved. A first effort was set on long term stability for specific beamlines (new 160 m long Nanoscopium and Hard X-rays beamlines). BPM and XBPM steel supports will be replaced for reducing their sensitiveness to temperature drift. Thermal expansion of INVAR and fused silica stands has been measured. INVAR has been selected for the new BPM supports. A second effort aimed at improving the orbit stability of beamlines based on bending magnets. We plan to use their first XBPM in the global orbit feedback loops (slow and fast). For that purpose new XBPM electronics called Libera photons will be used. SOLEIL, having contributed to the development, tested extensively the first series. A third effort focused on noise source location. An application developed in-house has identified local orbit perturbation sources introducing spurious spectrum lines at 46, 50 and 54 Hz on the orbit. They originate from fans rotating close to ceramics chambers of kickers, FCT and shaker. Their suppression decreases the vertical integrated noise down to 300 nm RMS in the 0.1-500Hz frequency range.

INTRODUCTION

Beam orbit stability is a key parameter for synchrotron light source performances. In this paper we describe the latest developments that have been conducted at SOLEIL in order to improve beam orbit stability: new INVAR BPM stands, location and suppression of perturbation created by fans cooling ceramic vacuum chambers and integration of bending magnet XBPM data in orbit feedback loops.

HIGH STABILITY STANDS FOR BPMS AND XBPMS

BPM Supports Status

Straight section BPMs are presently supported by stands 1200mm high, made of steel and stainless steel. Their coefficients of thermal expansion are respectively 12ppm/K and 17ppm/K. With air temperature in the tunnel regulated at 21°C ±0.1°C, BPM support heights can drift by about 4µm. As orbit feedback systems are based on BPM measurements, a movement of the BPM block will induce a movement of the vertical beam position. The effect of a temperature drift on position measurements is shown on Fig. 1.

For Hard X-ray beamlines and for the new 160 m long beamline Nanoscopium, beam size at source point is around 10µm in the vertical plane. A 4µm beam movement due to a temperature drift is outside the 1µm beam orbit stability specification at those locations (one tenth of the beam size). In order to reduce this temperature dependence, it has been decided to design new BPM supports for those straight sections.

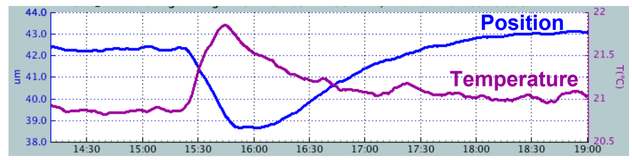

Figure 1: Dependence of a BPM vertical position measurement (blue) with nearby air temperature (pink).

Tests of Low Thermal Expansion Materials

The study focused on two materials known for their good temperature stability: INVAR36 and fused silica.

A test bench has been set up in order to measure their respective coefficient of thermal expansion (Fig. 2).

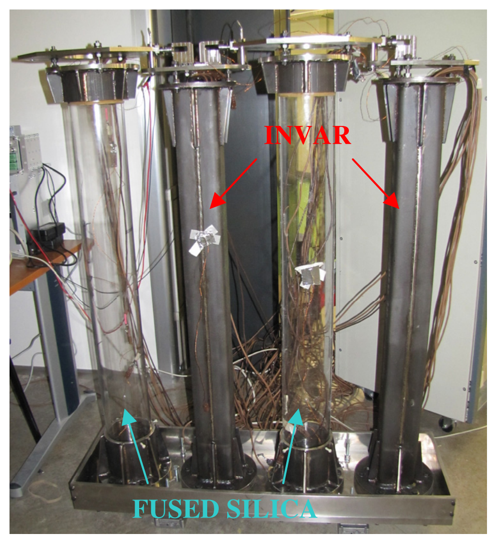

Figure 2: INVAR and fused Silica expansion measurement bench.

At first, an INVAR column is heated up to 30 °C. Accordingly to its thermal expansion coefficient, the top plate goes up with temperature. Two other columns made of fused silica are kept at ambient temperature and hold capacitive sensors PI D-510 [1]. Those no-contact sensors can measure their distance from a metallic target with a resolution better than 100nm. A total of 36 thermocouples survey and control column temperatures.

The thermal expansion coefficient can be calculated by measuring the INVAR top-plate displacement, (Fig. 3).

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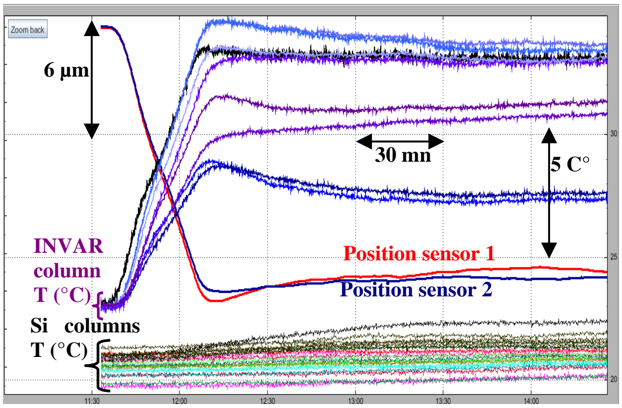

Figure 3: Temperature and proximity sensor measurements for the INVAR column heating.

In a second phase, INVAR and fused silica columns are swapped in order to measure the silica thermal expansion coefficient. Experimental results from measurements are very close to the theoretical ones (Table 1). Both materials are stable enough for new BPM stands. Although fused silica has a better thermal stability, its mechanical integration is more complex than INVAR. For this reason, INVAR has been chosen. Additional measurements have been done in order to measure if the magnetic properties of INVAR close to the beam (at BPM place) could affect machine performances. No visible effects have been detected. New INVAR BPM stands will be installed in August 2011.

Table 1: INVAR 36 and Fused Silica Thermal Expansion Coefficients

Thermal expansion coefficient (20-30 °C)	INVAR 36	Fused silica
Theoretical value	1.2 ppm/K	0.6 ppm/K
Experimental value	1.2 ppm/K	0.5 ppm/K

NOISE SOURCE IDENTIFICATION

From the beginning of SOLEIL operation, all beam orbit spectrum measurements showed characteristic lines at 46, 50 (mains), 54, and 108 Hz. Their origin has recently been found: several fans cooling down ceramic vacuum chambers. Localization method, technical solutions for suppressing the noise and resulting stability figures are given in this section.

Location Method

Noise sources can be located from beam orbit spectrum measurements. For each BPM, position data at are synchronously recorded at 10 kHz; then amplitude and phase components of beam orbit spectrum are calculated. By extracting a single frequency from those measurements, a pseudo AC orbit can be reconstructed [2]. Then, by looking at the location of the most efficient corrector that corrects this pseudo orbit, the noise source responsible of that frequency can be located.

A dedicated diagnostic tool has been developed and tested. To verify its efficiency, a 230Hz excitation was applied to the shaker. For both sets of correctors available at SOLEIL (slow and fast [3]), the tool targeted the corrector closest to the shaker as the most efficient to damp the perturbation (Fig. 4).

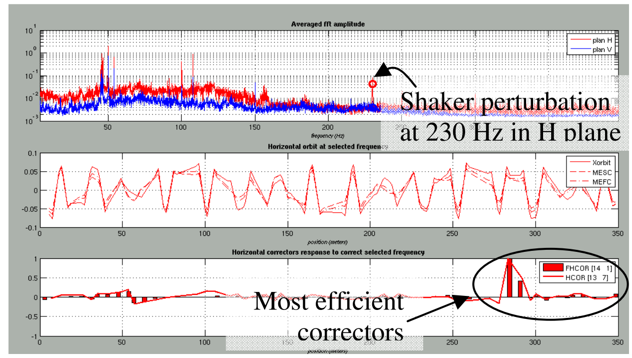

Figure 4: Diagnostic tool for noise source localization. A deliberate excitation at 230 Hz is located.

Once the diagnostic tool has been validated, the method was applied to unknown noise sources. The method showed the presence of a 50 Hz noise source in the injection section. After some investigations in this area, we found out that the perturbation was created by the cooling fans of the kicker ceramic vacuum chambers; almost all 50 Hz perturbation disappeared when stopping the fans from kickers and also a part of 46 Hz spectrum lines.

In the same way, we could show the other spectrum lines at 46, 54 and 108Hz were due to the cooling fans of the shaker and FCT ceramic chambers (Fig. 5).

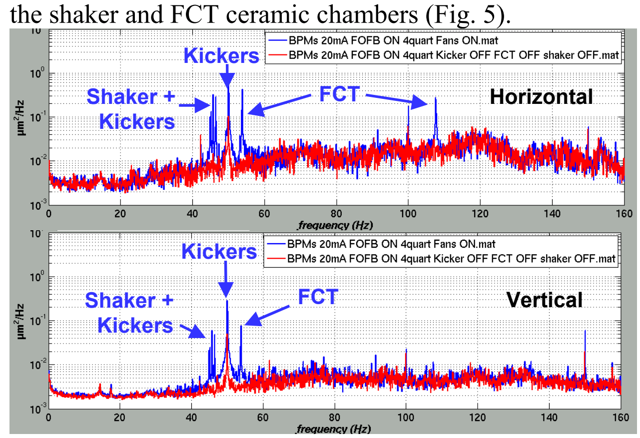

Figure 5: Beam orbit power spectral density measurements (averaged over all BPMs) when fans are switched ON (blue curves) and OFF (red curves).

Technical Solutions

Perturbations created by fans are due to the rotating magnetic field of the motor. Measurements showed a 120 mT magnetic field against fan structure radiating in all directions. The simplest solution was to move away all fans from the ceramic chambers. Preliminary tests have been carried out with temporary and tunable fan supports (Fig. 6). The final fan supports have been designed shortly after the identification of the proper fan location. Installation is taking place in May 2011.

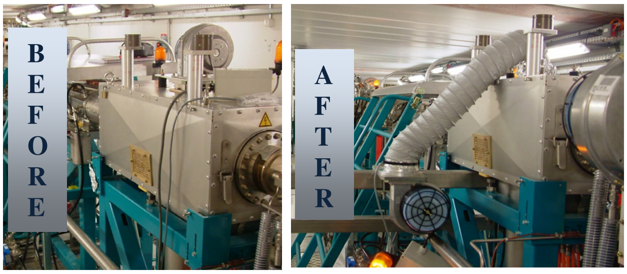

Figure 6: Kicker K2 fan at initial position (left) and with adjustable support (right).

Beam Orbit Stability Improvements

Beam orbit stability has been significantly improved by suppressing the ceramic cooling fan perturbations. The integrated noise spectrum (averaged over all BPMs) from 0.1 Hz to 500Hz has been divided by a factor of 2 in both planes. The resulting integrated noise (0.1-500Hz) in the horizontal plane is below 750 µm RMS and in the vertical plane is now down to 280nm RMS (see Fig. 7).

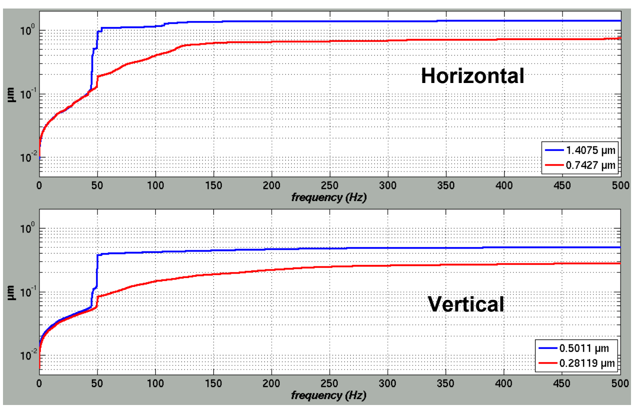

Figure 7: Integrated PSD (averaged over all BPMs) on the 0.1-500 Hz range. With fans switched OFF (red curves) vertical integrated noise is below 300 nm.

INTEGRATION OF BENDING MAGNET XBPM DATA IN ORBIT FEEDBACK LOOPS

Project

In order to improve vertical photon beam stability for bending magnet beamlines, we plan to include their XBPMs into the orbit feedback loops in the next months. This implies new developments for the XBPM electronics for synchronizing XBPM and BPM data. As we already use Libera Electron modules as BPM electronics, we decided to use the new Libera Photon modules on bending magnet frontends.

Libera Photon Electronics

Libera-Photon is a new electronics designed and manufactured by Instrumentation Technologies with the contribution of Synchrotron SOLEIL [4]. Since January 2010 extensive tests have been carried out. The overall performance is comparable to the existing analog electronics already installed at SOLEIL: Beam current dependence (1-600 µA range on blades corresponding to 10-500 mA stored in machine) is below 1 µm and resolution below 200 nm (Table 2).

Table 2: Libera-Photon Resolution Measurement in Laboratory (Electronic Noise Only)

RESOLUTION		
	SA (10 Hz)	FA (10 kHz)
Noise (µm rms)	< 0.006	< 0.160

The main advantages of Libera Photons are their interfaces, synchronization mechanism and data sampling rates, which are the same as that of Libera Electrons. They can easily be integrated into an already existing dedicated network equiped with Libera Electrons. Fast Acquisition (FA) data at 10 kHz sampling rate will be used for Fast Orbit Feedback application whereas Slow Acquisition (SA) data at 10Hz sampling rate will be used for the Slow Orbit Feedback system.

An issue arose during the development: the processing delay of FA data. This latency time has to be the same for both Libera Photons and Libera Electrons in order to be used in the same feedback loop. At first, Photon data were delayed by 280µs with respect to Electrons data. After replacing the ADC, the delay was reduced to 80 µs. Then the filtering path had to be modified in order to reduce it to an acceptable value (20µs).

We intend to include bending magnet XBPM data in the feedback loops this year.

CONCLUSION

Beam orbit stability is a figure of merit for synchrotron performance. SOLEIL beam stability has been significantly improved by suppressing perturbations induced by the ceramic vacuum vessel cooling fans. Integrated noise on 0.1-500 Hz range is now less than 300 nm in the vertical plane. Moreover new INVAR BPM supports have been designed and will be installed at the source point of the most sensitive beamlines. In the near future, bending magnets photon beam stability should be further improved by integrating their XBPM data in the global orbit feedback loops.

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