SOLEIL BEAM ORBIT STABILITY IMPROVEMENTS

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Abstract

The electron beam orbit stability has been significantly improved at synchrotron SOLEIL. Low frequency noise sources have been located and identified: the fans installed on the storage ring to cool down the ceramic chambers of the kickers, shaker and FCT, were slightly wobbling the electron beam orbit at 46, 50, 54, and 108 Hz. The location method and the solutions that allow reducing the noise from 0.8 µm RMS down to 0.3 µm are presented. Besides, a new 160 m long beamline, NANOSCOPIUM, is being installed on a canted straight section. Its photon beam position stability requirements are very tight calling for the following improvements: addition of 2 more BPMs and fast correctors in the orbit feedback loops, new INVAR stands for BPM and XBPM integrating Hydrostatic Level System sensors. This paper is also discussing other projects that did or will contribute to the improvement of beam orbit stability: installation of 175 temperature sensors on the storage ring, a new analog feedforward correction system for insertion devices, and the use of the bending magnet X-BPM vertical beam positions in the slow and fast orbit feedback loops.

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.

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. Location 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 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 [1]. Then, by looking at the location of the most efficient corrector that corrects this pseudo orbit, the noise source responsible for that frequency can be located.

A dedicated diagnostic tool has been developed and tested. To verify its efficiency, a 230 Hz excitation was applied to the shaker magnet. For both sets of correctors available at SOLEIL (slow and fast [2]), the tool targeted the corrector closest to the shaker as the most efficient to damp down the perturbation (fig. 1).

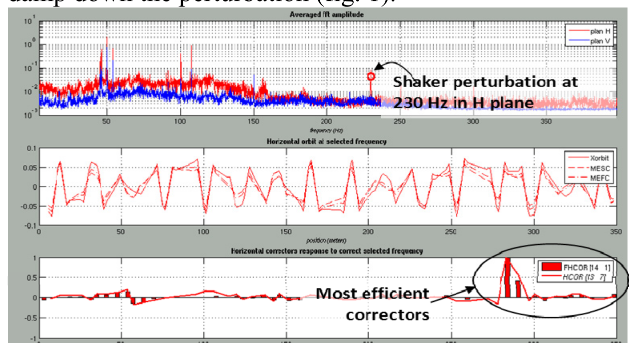

Figure 1: Diagnostic tool for noise source localization. An intentional excitation at 230 Hz is located.

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 perturbations disappeared when stopping the fans from kickers as well as part of 46 Hz spectrum lines. In the same way, we could show the other spectrum lines at 46, 54 and 108 Hz were due to the cooling fans of the shaker and FCT ceramic chambers (fig.2).

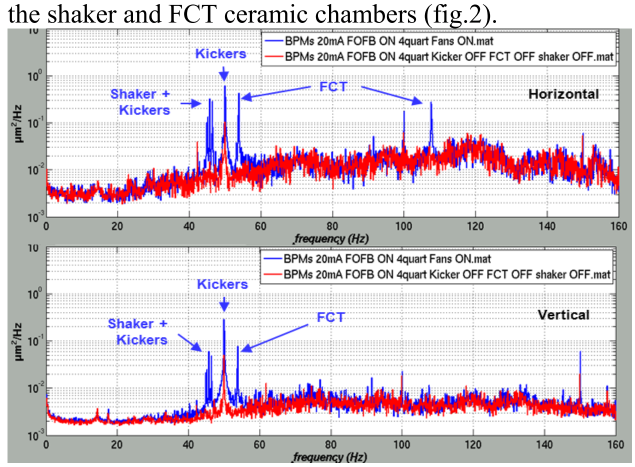

Figure 2: Beam orbit power spectral density (PSD) measurements (averaged over all BPMs) when fans are switched ON (blue curves) and OFF (red curves).

Technical Solutions

Perturbations created by fans are due to the rotating magnetic field of the motor. Measurements showed a 120 mT magnetic field closed to 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. 3). The final fan supports have been designed shortly after the identification of the proper fan location.

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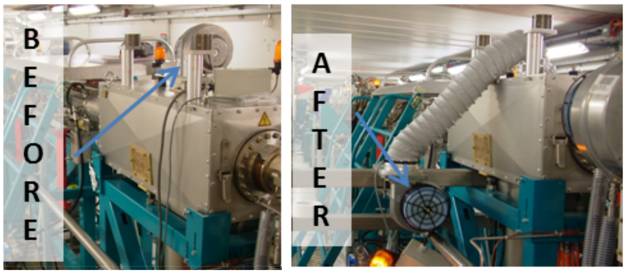

Figure 3: Kicker K2 fan at initial position (left) and with adjustable support (right).

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 500 Hz has been divided by a factor of 2 in both planes. The resulting integrated noise (0.1-500 Hz) in the horizontal plane is now below 750 nm RMS and in the vertical plane down to 280 nm RMS (fig. 4).

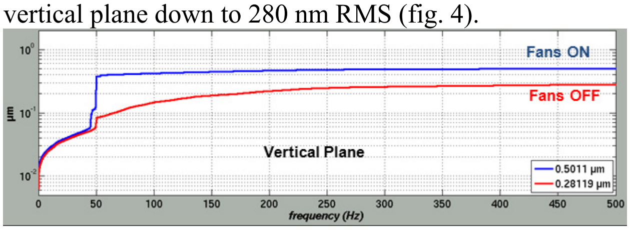

Figure 4: Integrated PSD (averaged over all BPMs) on the 0.1-500 Hz range in the vertical plane. With fans switched OFF (red curves) integrated noise is below 300 nm.

DEVELOPMENTS FOR NEW 160 M LONG BEAMLINE

Nanoscopium [3], a new 160 m long beamline is under construction. Because of its length, the small vertical beam size at source point (10 µm) and a strong focalization, its stability requirements are very tights and calling for the following developments: addition of 2 more BPMs and fast correctors in the orbit feedback loops, new INVAR stands for BPMs and XBPMs integrating Hydrostatic Level System (HLS) sensors.

Additional BPMs and Correctors

Nanoscopium insertion device is located on a canted straight section [4]. In the middle of the section a new quadrupole triplet has been installed with 2 additional BPMs, 1 slow corrector and 2 fast correctors for both transverse planes. Orbit feedback loops (slow and fast) have been modified to include those new BPMs and correctors.

INVAR BPM and XBPM Supports

Straight section BPMs are presently supported by 1200 mm high stands made of steel and stainless steel. Their coefficients of thermal expansion are respectively 12 ppm/K and 17 ppm/K. With air temperature in the tunnel regulated at 21°C ± 0.1°C, BPM support heights can drift by about 4 µm. As orbit feedback systems are based on BPM measurements, a movement of the BPM block will induce a movement of the vertical beam position. In order to reduce this temperature dependence, it has been decided to design new BPM supports for this straight section.

Two materials, known for their good temperature stability, have been studied: INVAR 36 and fused silica. Their respective coefficient of thermal expansion have been measured on a test bench (fig. 5), by heating one column (INVAR or fused silica) while the other was kept as reference.

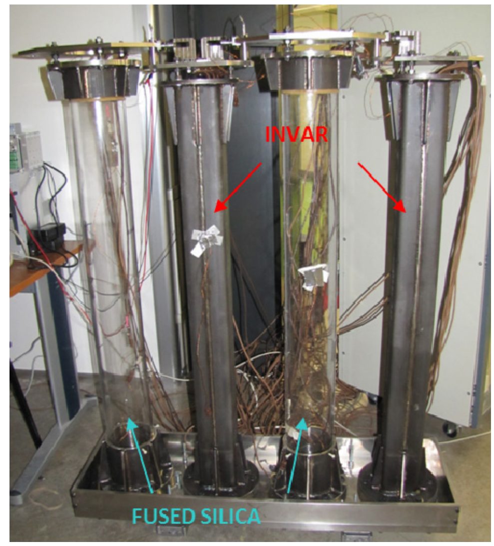

Figure 5: INVAR and fused Silica expansion measurement bench.

Expansion is measured by no-contact capacitive sensors [5]. 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 location) could affect machine performances. No measurable effect has been detected on the beam. New INVAR BPM stands have been 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

HLS System

A dedicated HLS system is built for this beamline. It will survey beamline slabs movements. The network will start from straight section with sensors installed inside BPM and XBPM supports (fig. 6).

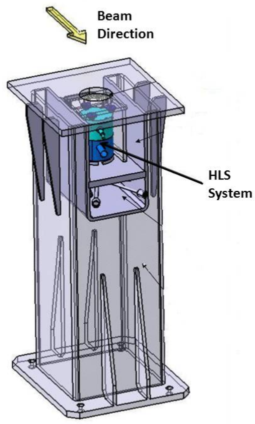

Figure 6: Drawing of the INVAR XBPM support for Nanoscopium. HLS sensor is hosted directly in the stand.

TEMPERATURE SENSORS

In order to check the air regulation efficiency in the tunnel, 175 sensors have been installed on the machine. They are fixed on mechanical stands that could be expanded due to temperature changes and affect beam orbit stability. By correlation with air regulation system sensor measurements, this system is also very useful to check and improve its performances in the tunnel.

A NEW ANALOG FEEDFORWARD SYSTEM FOR INSERTION DEVICES

Over the last 2 years an analog feedforward system has been developed in-house and successfully implemented on 3 electromagnetic insertion devices HU256. As a result the performances in term of tracking between power supplies, flexibility for users, and beam stability have been significantly improved [6].

INTEGRATION OF BENDING MAGNET XBPM DATA IN ORBIT FEEDBACK LOOPS

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. Since January 2010 extensive tests have been carried out on Libera photon electronics, designed and manufactured by Instrumentation Technologies with the contribution of Synchrotron SOLEIL [7]. 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 (10 kHz sampling rate). Nevertheless, Libera Photons have the same interfaces, synchronization mechanism and data sampling rates as Libera Electrons. Then, they can easily be integrated into an already existing dedicated network equiped with Libera Electrons. A particular care has been taken to data processing latency that has been carefully adjusted between BPM and XBPM.

BOOSTER POWER SUPPLY EFFECT COMPENSATION

A dedicated current loop fed by an in-house developed power supply has been installed in the booster tunnel in order to cancel out the impact of the booster power supplies on the storage ring closed orbit [8]. During each injection, the booster power supplies are switched on during 10 seconds. The horizontal closed orbit is disturbed by 10 to 20 µm peak. The orbit distortion has both a DC and a 3 Hz component (frequency corresponding to the booster cycle). A digital feedforward system based on the reading out of the dipole, quadrupole, and sextupole magnets enables us to cancel out the perturbation down to noise level reducing the 3 Hz component by a factor 9.

CONCLUSION

Beam orbit stability is a figure of merit for light source performance. SOLEIL beam stability has been significantly improved by improving insertion device feedforward system and by suppressing perturbations induced by the ceramic vacuum vessel cooling fans and by booster cycling operation. Resulting 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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