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NEW BEAM LOSS MONITOR SYSTEM AT SOLEIL

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Abstract

SOLEIL is currently upgrading its Beam Loss Monitor (BLM) system from pin-diode detectors to plastic scintillators associated with photosensor modules. This new kind of monitor, associated to its dedicated electronics, can be used to record slow or fast losses. Monitors have been calibrated with a diode and with a cesium source. Both methods are compared. After preliminary tests, a first set of 20 new BLMs have been installed on 2 cells of the storage ring. Installation setup, calibration procedure and first measurements are presented.

INTRODUCTION

In the storage ring, the electron beam is subject to Touschek effects and to interactions with the residual gas, causing particle losses and impacting the lifetime. These losses may be regular or irregular, fast or slow, localized or distributed.

During SOLEIL installation in 2006, 36 coincidence pin-diode loss monitors [1] have been installed around the storage ring. This system has been in operation during 12 years but with some limitations: only slow losses are detected and the high directivity of the sensor makes the comparison between two detectors quite difficult. The count rate is indeed very sensitive to the orientation of the detector with respect to the loss source.

Recently, a new BLM system based on plastic scintillators has been tested and validated [2]. Two cells of the storage ring have been equipped with twelve (in cell 01) and eight (in cell 04) new monitors.

SYSTEM DESCRIPTION

The new BLM system had to fit the following requirements:

- Good (<10% error) relative calibration between the detectors to allow a comparison of the losses amplitudes around the machine.
- Possibility to provide slow and fast losses measurement with the same detector.

Based on the work conducted by ESRF [3] and preliminary tests at SOLEIL [2], we have installed BLM modules made of a scintillator and a photomultiplier. The plastic scintillator is a 10 mm high rod (EJ-200 [4]) wrapped into a high reflectivity aluminium foil to improve the photon flux towards the photomultiplier. The photomultiplier is a photosensor module from Hamamatsu (series H10721- 110 [5]) that embed in a small case both photomultiplier and high voltage source.

Those two elements are integrated in a compact aluminium housing (Fig. 1).

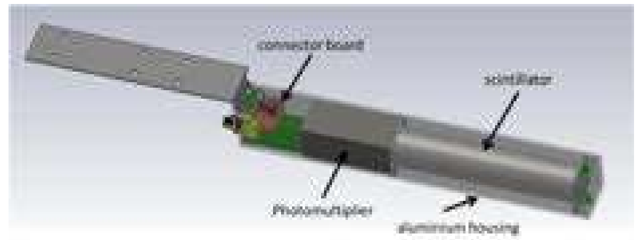

Figure 1: New BLM components integrated in aluminium housing.

The acquisition is performed by the Libera BLM electronic module which provides four 14 bits-125 MS/s ADCs together with a power supply and again control for the photosensor modules [6].

CALIBRATION

Having a relative calibration between the modules in order to be able to compare the losses amplitude measured by different detectors was one of the motivations for the upgrade of the system. We ideally targeted a relative calibration between all detectors better than 10%.

From manufacturing, the dispersion in the relative sensitivity between photosensors is very large with up to 50 % variations (Fig. 2).

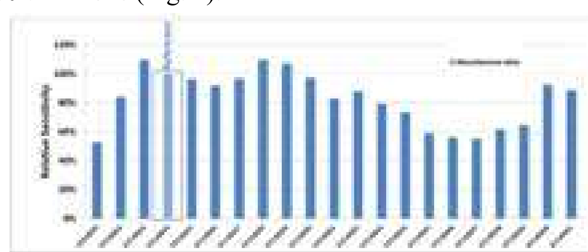

Figure 2: Photosensor relative sensitivities.

In order to verify those values, two different calibration methods have been applied, using either a LED or a cesium source.

LED (diode) Calibration Method

A dedicated housing has been manufactured to install a diode emitting at 455 nm, i.e. close to the maximum of the photosensor spectral response (250 nm to 650 nm). The output flux of the diode can be adjusted with a dedicated power-supply, whereas the photosensor is connected to the Libera BLM for acquisition and gain control (Fig. 3).

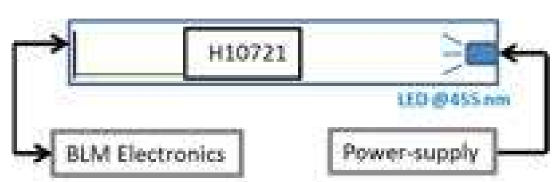

Figure 3: Setup for the calibration with a LED (diode).

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For each photosensor, the relative sensitivity with respect to a reference unit has been measured with a fixed gain. Relative sensitivities are globally found in good agreement with data provided by the manufacturer, nevertheless for some modules we notice an important (up to 30%) difference (Fig. 4).

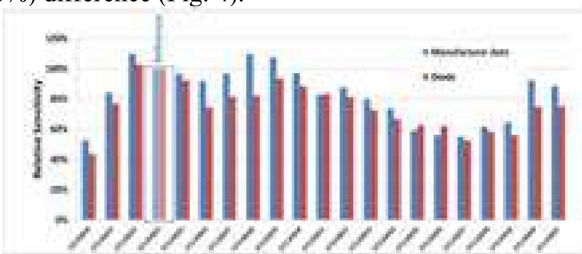

Figure 4: Relative photosensor sensitivity measured with the diode and compared with the manufacturer data.

It has to be noticed that for this diode based calibration method, only the photosensor response is considered (as it is the case for the data provided by the manufacturer).

Cesium Source Calibration Method

The use of a gamma source gives the possibility to characterize the scintillator together with its photosensor. When the BLM is fully mounted in its housing, a cesium source is placed directly on the side of the housing (Fig. 5).

Figure 5: Setup for the calibration with a cesium source.

The dependence of this kind of measurement to the source positioning along the housing has been checked. It is negligible when the source is positioned in the middle height of the scintillator [2]. Nevertheless, to be able to reproduce always the same positioning even later when the BLM are installed vertically in the storage ring, a 3D printed plastic support has been made (Fig.6). This support also eases a lot the source handling.

Figure 6: Cesium source positioning on the BLM with a 3D printed support (in black).

Keeping the cesium source at a fixed position and using always the same Libera BLM electronics unit and settings, the relative sensitivity of the scintillators with their photosensor has been measured (Fig. 7).

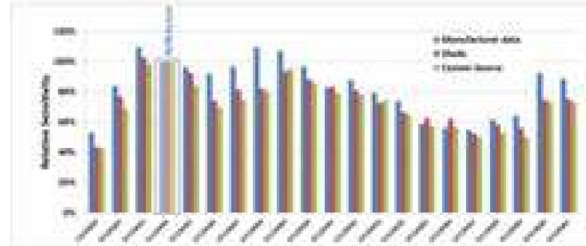

Figure 7: Relative sensitivity of the scintillators with their photosensor measured with the cesium source in laboratory and compared to the diode method and manufacturer data.

Results are in very good agreement with diode based calibration, with less than 7 % error. This error could be explained by the relative yield of the scintillators. This relative yield has been measured on a small sample of them, and has been found up to 5% [2]).

The same measurement was then repeated after BLM installation in the tunnel, using final long cables, and final individual electronics readout (Fig. 8).

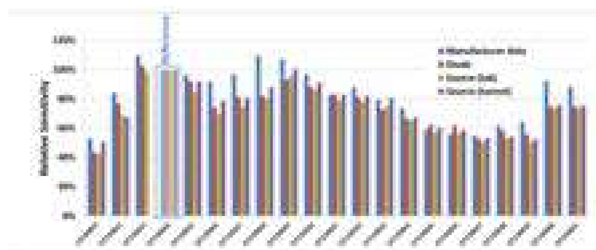

Figure 8: Relative sensitivity of the scintillators with their photosensor measured with the cesium source in the laboratory, in the tunnel and compared to the diode method and manufacturer data.

Here again the agreement with previous measurements is very good. Since this measurement in the tunnel takes into account cable attenuation variations and electronics errors, it has been decided to use those values to compute the final relative calibration. Moreover, this BLM response to the cesium source will be repeated periodically (every year or 2 years) in order to survey an eventual modification of the BLM sensitivity.

Gain Power-Supply Offset

Libera BLM electronics provides also a voltage source to control the gain of the photosensor. It has been found out that there is a few mV offset between different channels. Over 28 voltage sources, the maximum difference between 2 channels is 13 mV (Fig. 9). This (small) gain control offset, induces a 20 % variation on the applied gain value on the photosensor (coming from the photosensor gain response). It has been decided to compensate for this voltage supply offset independently of the detector calibration so that we will not need to redo the measurement with the cesium source in case of modification in

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the couple detector/electronics. This correction is done in the high level application, adding the right offset to the gain voltage set by the user.

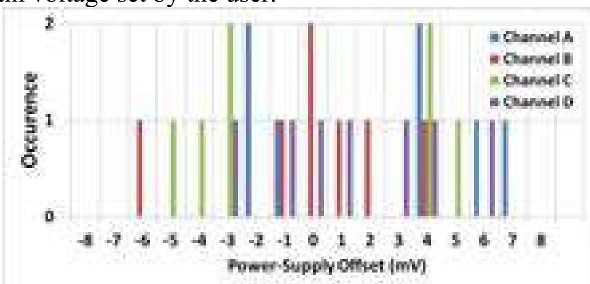

Figure 9: Libera BLM electronics power-supply offsets.

Application of the Calibration

The electronics is able to compensate for the different detector sensitivities that have been measured, and is also automatically correcting for the difference of gain and attenuation settings that are applied [6]. Thanks to this compensation, the loss measurements given by the different detectors can be directly compared even if their settings are not the same.

MEASUREMENTS WITH BEAM

Twenty BLMs have been installed in two cells of the storage ring:

- C01 has been equipped with twelve detectors: six in the straight section (where injection kickers and a vertical scraper are installed) and six in the arc (where an horizontal scraper is installed).
- C04 has been equipped with eight detectors: three in the straight section (where two undulators are installed) and five in the arc.

In the straight sections, BLM are installed on the external side of the machine, whereas in the arcs they are on the internal side. All detectors have the middle of their scintillator intercepting the horizontal beam axis at approximately 30 cm of the vacuum chamber.

In order to damp the synchrotron radiation, a 3 mm lead shielding has been installed around the BLMs (Fig. 10).

Figure 10: One BLM (in white) installed just downstream a bending magnet (internal side) in cell 4.

Fast Losses Measurements

With the vertical scraper slightly inserted, we excite the beam using a vertical stripline and record the beam loss signature for different filling patterns. With a temporal resolution of ~8 ns (limited by ADC sampling rate at 125 MHz), the new BLM system is not able to resolve bunch by bunch losses (2.4 ns spacing). Nevertheless, we can clearly correlate the losses signal to the filling pattern of the storage ring (Fig. 11).

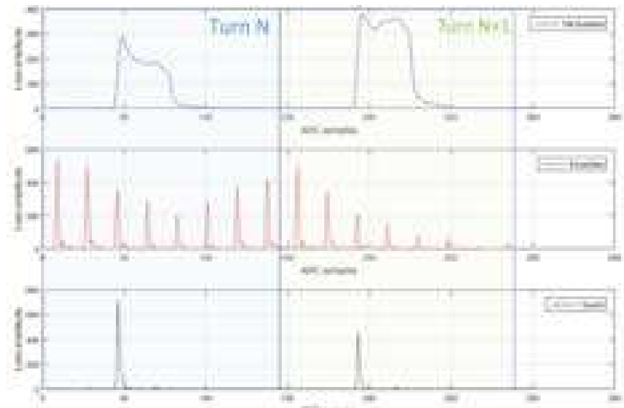

Figure 11: Losses measurement (ADC data) for 104 consecutive bunches (top), 8 bunches (middle) and single bunch (bottom) recorded on the BLM located in front of the vertical scraper for two consecutive turns.

To observe the losses at injection, we use data decimated at turn by turn rate. From an empty storage ring, we inject 104 bunches and trigger the beam loss monitors at the same time. Losses occur during the first ~50 turns and are concentrated in the injection section and in particular in front of the vertical scraper (Fig. 12a). By switching off the RF cavities before injecting, the BLMs show that the injected particles are lost between turns 80 and 140. As expected in this situation of spiralling trajectory, the BLMs located just downstream the horizontal scraper are the ones showing the highest amplitude (Fig 12b).

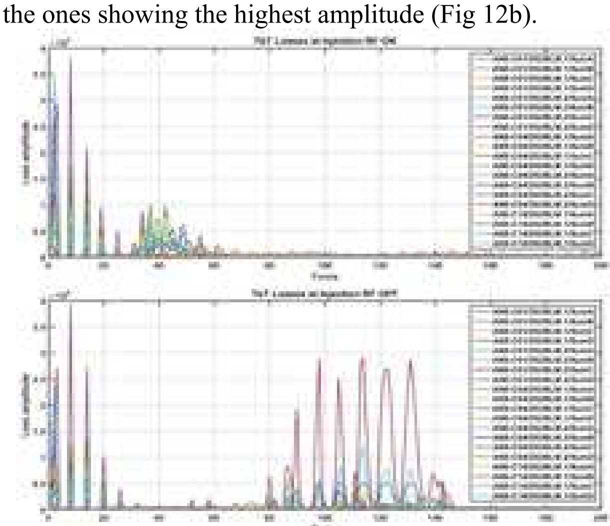

Figure 12: a and b losses measurement (turn by turn data) at injection with RF ON (top) and OFF (bottom).

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Beam losses at injection also show a periodic pattern. Complementary measurements confirmed that this periodicity is the one of the horizontal tune. By measuring the losses at injection for different horizontal tune configurations we were able to see the period of the losses shifting accordingly (Fig. 13).

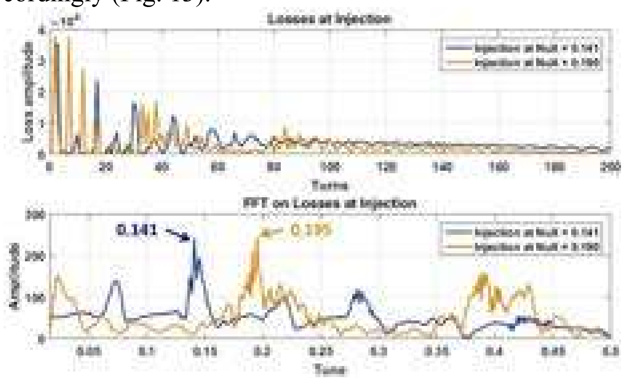

Figure 13: Turn by turn losses at injection for horizontal tune set at 0.141 (blue) and 0.190 (orange) recorded on the BLM facing the vertical scraper (top). Taking the Fourier transform of the losses gives a maximum at the horizontal tune of the machine.

Slow Losses Measurements

When configured in slow (high impedance) mode, BLMs are able to follow very small losses variations. In Fig. 14, we can see the very good correlation between the losses (measured on the detector in front of the vertical scraper at nominal position) and the beam lifetime while moving one after the other the different insertion devices of the storage ring.

Figure 14: Correlation between losses measurement in slow mode and the beam lifetime.

CONCLUSION

A new BLM system, based on plastic scintillators coupled with photosensors, has been installed on two cells of SOLEIL storage ring. Two different calibration methods (with a LED or with a cesium source) have been used and their results compared to the manufacturer data. Both methods are in good agreement and the cesium source based calibration will be used as reference and repeated periodically to survey monitors ageing.

Compared to the current loss monitoring system in operation at SOLEIL, this new BLM system shows better sensitivity, lower directivity (by design) and enables measures of slow as well as fast losses (with a temporal resolution better than one turn). The next step will be the deployment of additional BLMs in all the other cells of the storage ring (4 monitors per cell in average).

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