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TEST OF NEW BEAM LOSS MONITORS FOR SOLEIL

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Abstract

SOLEIL is currently testing new beam loss monitors to replace its pin-diode based system. The new detectors are made of plastic scintillators associated with photomultiplier and connected to Libera BLM dedicated electronics. This new detector should provide both fast (turn by turn) and slow loss measurement, post mortem capabilities and should be less sensitive to the beam directivity compared to the pin-diodes. Different methods for a relative calibration of the modules are under investigation, either using a photodiode or a cesium radioactive source. Calibration results and first measurements in SOLEIL storage ring are presented.

INTRODUCTION

In the storage ring, the electron beam is subjected 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.

In order to monitor these losses, 36 loss monitors have been installed along the storage ring since the commissioning of SOLEIL in 2006. These monitors consist of two PIN diodes in coincidence [1] used in counting mode (Fig 1). 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.

Figure 1: PIN diode loss monitor in its lead housing installed upstream of the HU640 undulator in the SOLEIL storage ring.

In order to prepare the upgrade of the system, we have decided to test new Beam Loss Monitors (BLMs) based on a scintillator and a photomultiplier.

SYSTEM DESCRIPTION

The new BLM system has to fit the following requirements:

- Allow a relative calibration in between the detectors to enable a comparison of the losses amplitudes around the machine.
- Provide slow and fast losses measurement.

Based on the work conducted by ESRF [2], we have tested BLM modules made of a scintillator (or a quartz Cerenkov radiator) and a photomultiplier. The plastic scintillator is a rod EJ-200 [3] wrapped into high reflectivity aluminum foil to improve photon flux on photosensor input. The photomultiplier is a photosensor module from Hamamatsu (series H10721, models 110, 113 and 210 [4]).
Those two elements are embedded in a compact aluminium housing (Fig.2).

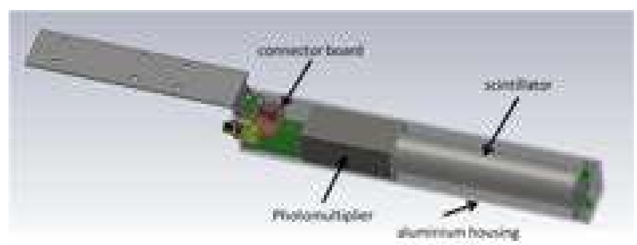

Figure 2: New BLM components and their Al housing.

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 [5].

SYSTEM 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%. Two different calibration methods have been investigated: using a LED or using a cesium source.

Diode

A dedicated housing has been realized to install a diode emitting at 455 nm, i.e. close to the maximum of the photosensor spectral response (250nm to 650 nm). The 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).

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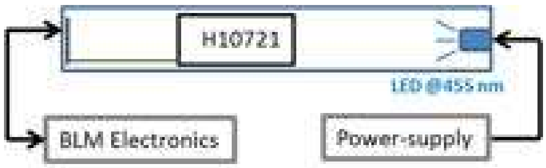

Figure 3: Setup for the calibration with a diode.

While increasing the control voltage, we have measured the gain of the different photosensors. All photosensors have a very similar gain response with respect to the control voltage, see Fig. 4.

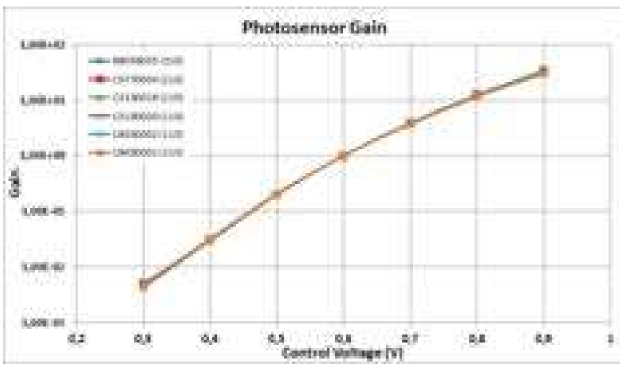

Figure 4: Gain of photomultipliers versus control voltage. Measurements have been normalized by the response value at 0.6V for each photosensor. The dispersion over the average is less than 6%

Relative sensitivity between photosensors has also been measure (for a fixed gain) and is found to be in a good agreement with the data provided by the manufacturer (Fig. 5).

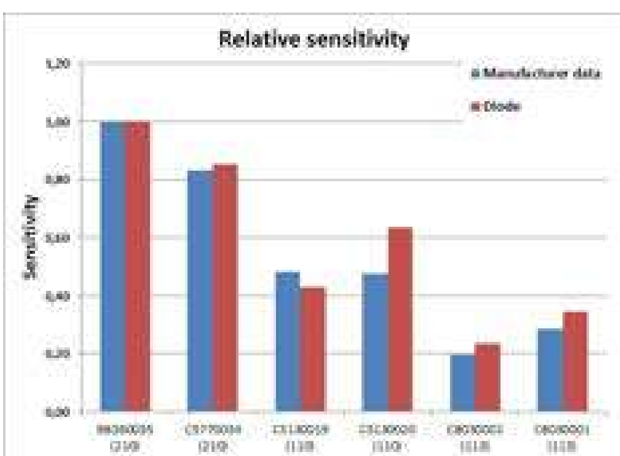

Figure 5: Relative photosensor sensitivity measured with the diode and compared with the manufacturer data (also measured with a diode).

Source

The calibration measurement with the diode qualifies only the photosensor whereas the use of a gamma source would characterize the scintillator together with the photosensor. A cesium source has been used and placed directly on the side of the BLM housing (Fig. 6).

To determine the best position of the source in order to maximize the incident flux in the scintillator, the source position with respect to the BLM has been scanned.

Figure 6: Source based calibration setup.

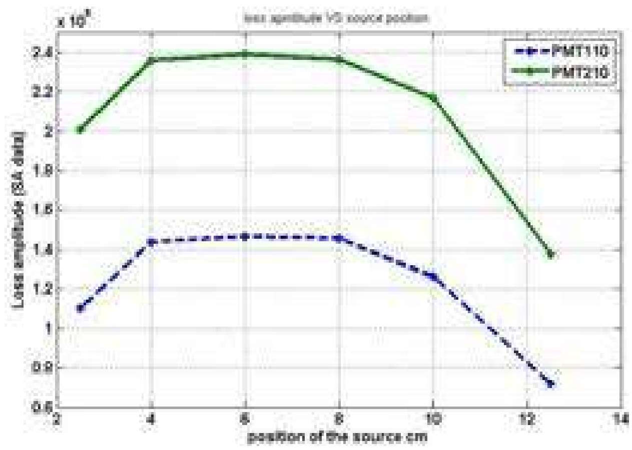

Figure 7: Loss amplitude in function of the cesium source position for a control voltage of 0.8V with PMT 110 (blue) and PMT210 (green).

As presented in Fig. 7, the maximum flux was measured for the source placed between 4 and 8 cm from the top of the housing, corresponding to the middle part of the scintillator.

Keeping the source at the same position and using the same photosensor (control voltage at 0.7V), the relative yield of the scintillators was measured. The dispersion between scintillators is small, below 5 % (Fig. 8).

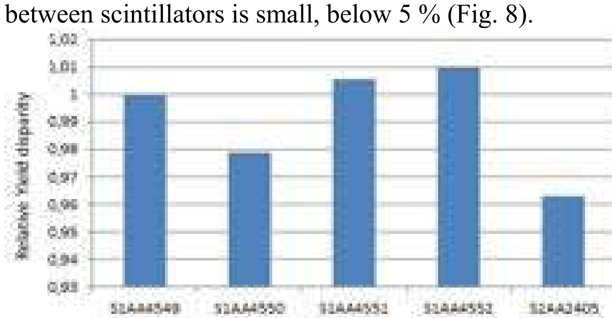

Figure 8: EJ-200 scintillator relative yield disparity.

Then, still with the source at a fixed position and using always the same scintillator, the relative sensitivity of the photosensor has been measured again with this calibration method (Fig. 9).

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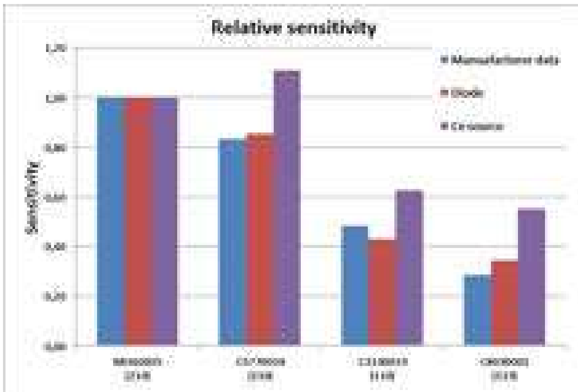

Figure 9: Comparison of the relative sensitivity for the two calibration methods.

The calibration with the cesium source gives different results compared to the calibration with the diode. This may be due to the fact that with the source, the scintillator is emitting in a broader spectrum (400 to 500 nm) compared to the diode (with dispersion in the response of the photosensors on this range).

FIRST TESTS WITH BEAM

Four BLMs have been installed in the injection section of the SOLEIL storage ring, just behind the vertical scraper in order to be able to modulate the amount of losses and number of particles showered on the monitors (Fig 10).

Figure 10: four BLMs installed behind the vertical scraper in the injection section of SOLEIL storage ring.

The four BLMs have different configurations in terms of detector (plastic scintillator or Cerenkov radiator), in terms of photosensor type but also in terms of lead thickness around the scintillator. The aim was to compare different BLM setups. The Cerenkov radiators have the advantage of being insensitive to X-rays, which is not the case of plastic scintillators, but they produce smaller photon flux. Plastic scintillators need a thick lead shielding to be blinded from synchrotron radiation.

Losses Versus Scraper Gap

Among the four BLMs, the closest one with respect to the storage ring vacuum chamber is used as a reference and its configuration remained unchanged during all acquisitions (PMT type 210, 2 mm lead shielding and gain voltage = 0.6V). For the other detectors, we measure the amplitude of the signal detected for different gain voltages and thicknesses (0, 1, 2 or 3mm) of the lead shielding (Fig.11).

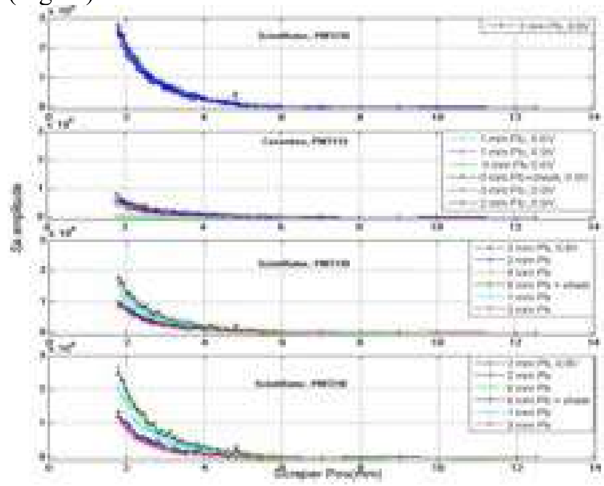

Figure 11: Loss amplitude vs scraper position for different shield thicknesses.

The signals from the two external BLMs, when operated in the same configuration, show that the distribution of lost particles is not the same on all BLMs. (the closest to the vacuum chamber measured twice the amplitude of the farthest).

It also clearly appears that, as expected, the Cerenkov radiator is far less sensitive than the plastic scintillator (by a factor ~60), and will not be retain for next tests. As expected, the sensitivity of PMT 110 is lower to PMT 210, but it is enough for our needs.

Lifetime and Losses Correlation

The physical vertical acceptance of the storage ring is regularly checked by measuring the variation of the beam lifetime versus the vertical scraper position. This acceptance is defined as the vertical aperture of the scraper for which a change of slope in the lifetime is observed.

This measurement usually takes one hour since the lifetime measurement requires integration time. Using the BLMs installed at the scraper location, the same measurement could be performed with a better resolution and within a few minutes only. (Fig. 12).

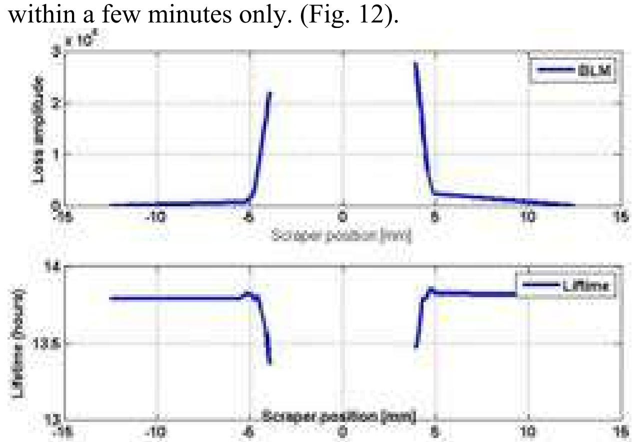

Figure 12: Physical vertical acceptance measurement of the storage ring using BLMs (top) or lifetime (bottom).

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BLMs data give better resolution and measurement is performed much faster.

Fast Losses Observation

Without beam in the storage ring, the vertical scraper is inserted. The aim is to lose all the particles injected in the storage ring on the scraper. The BLM electronics is configured in fast detection mode with an input impedance of 50 ohms. In this mode, the temporal resolution of the BLM system (8 ns) shows that the particles are not all lost on the first turn but some of them perform a second or even a third turn (Fig. 13). The temporal structure of the losses is also nicely correlated with the filling pattern of the injected beam (104 bunches or 1 bunch).

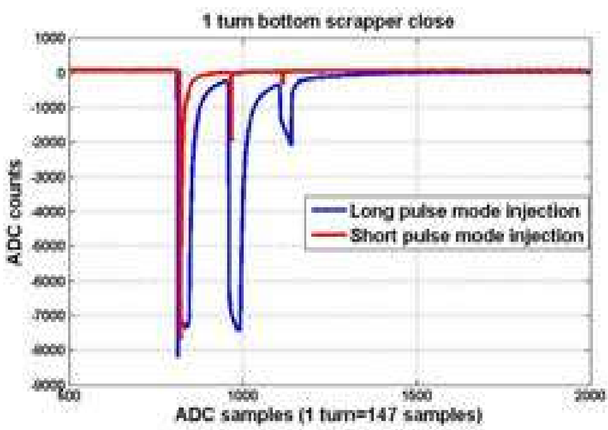

Figure 13: Fast losses versus time using BLMs in two modes of injection: long pulse mode (blue) for trains of 104 bunches and short pulse mode (red) for single bunch when the vertical scraper is inserted in the storage ring.

Post Mortem

The BLM electronics provides a postmortem functionality which freezes the data that were recorded just before (2, 5 ms) a beam loss (Fig. 14). This functionality enables a better understanding of the origin of the loss and the postmortem data can be correlated with the data from other postmortem systems (Beam Position Monitors, bunch by bunch transverse feedback, RF system, etc.).

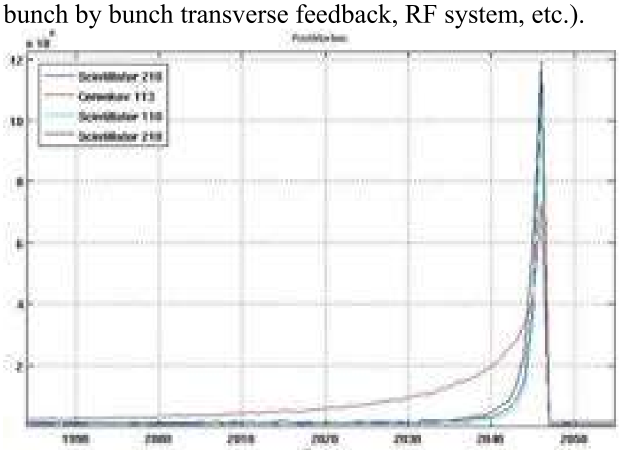

Figure 14: PostMortem data of four BLMs installed behind the scraper in the storage ring (scintillators have a 0.6V gain voltage whereas the Cerenkov has a 1V gain voltage).

CONCLUSION

A new BLM system is currently tested at SOLEIL. The first results are very promising. Two different (laboratory) calibration methods have been tried, using a LED or a cesium source, and measurements with beam are ongoing.

Compared to plastic scintillators, quartz Cerenkov radiators did not give sufficient flux and therefore plastic scintillators with additional lead shielding has been retained for our next tests.

Compared to the current loss monitoring system in operation at SOLEIL, this new BLM system shows better sensitivity, lower directivity (by design) and enables to measure slow as well as fast losses (with a temporal resolution better than one turn).The next step will be the deployment of a large number of BLMs in two sections of the storage ring during the next winter shut down.

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