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APPLICATION OF FIBER BEAM LOSS MONITORING SYSTEM (FBLM) AND SCINTILLATOR BEAM LOSS MONITORING SYSTEM (SBLM) AT HEPS*

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Abstract

The High Energy Photon Source (HEPS) is a fourth-generation light source with a beam energy of 6 GeV currently under development by the Institute of High Energy Physics. The Beam Loss Monitor (BLM) system is designed for monitoring beam losses during machine commissioning. Two types of beam loss monitors have been installed in both the booster and storage ring. This paper introduces the principles and composition of these two BLMs, as well as their application in commissioning.

INTRODUCTION

The High Energy Photon Source (HEPS) constructed by the Institute of High Energy Physics (IHEP) with a beam energy of 6 GeV is doing commissioning. Beam Loss Monitor (BLM) systems are important part of the accelerators diagnostics. They are used during normal operation to identify and locate beam losses. To protect the HEPS commissioning, new Beam Loss Monitor (BLM) systems have been developed, installed and operated in HEPS. There are two types of BLMs at HEPS, including a fiber-optic beam loss monitor system (FBLM) for the booster and a scintillator beam loss monitor (SBLM) system for the storage ring. The design, installation and commissioning results are reported in this paper.

FBLMS IN THE HEPS BOOSTER

At HEPS booster, FBLMs are applicated. FBLMs are sensitive enough to record multiple large losses. There are three main components for the FBLMs, including optical fiber, Photo Multiplier Tube (PMT) and electronics.

Optical Fibers

Fiber play a role of sensor. To allow sufficient probability to detect secondary particles caused by beam losses, larger core diameter is preferred. The specification for the fibers are described in Table 1.

Table 1: Fiber Specification

Type	Core Diameter	Core/Cladding Material
HCP-M600T	600 μm	Pure Silica/ Hard Polymer

PMT and Electronics

PMT as data collector captures the light from Cherenkov radiation. The cathode spectral response for the PMT

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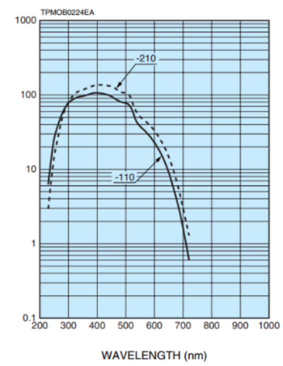

Figure 1: Cathode sensitivity for PMT.

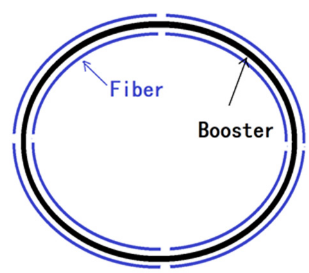

Figure 2: Schematic view of the optical fiber installation (blue line).

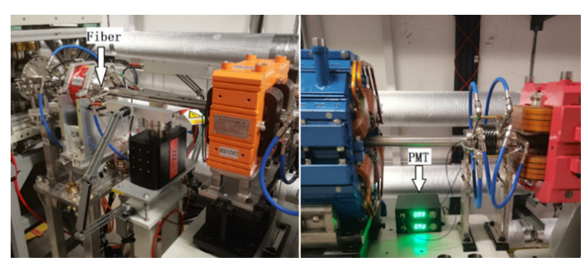

Figure 3: FBLM installed in the HEPS booster.

H10720-110 is shown in Fig. 1. The electronics is self-developed ADC with a maximum sampling rate of 500 Hz.

System Installation

The HEPS booster is 450 meters length. Figure 2 shows the schematic view of the optical fiber installation. 8 fibers are installed inside and outside the booster ring, each with a length of 110 meters, covering the entire booster. The fiber and PMT installed alongside the booster's vacuum pipe are shown in Fig. 3. For each fiber, two PMTs are connected to the fiber at both upstream side and downstream

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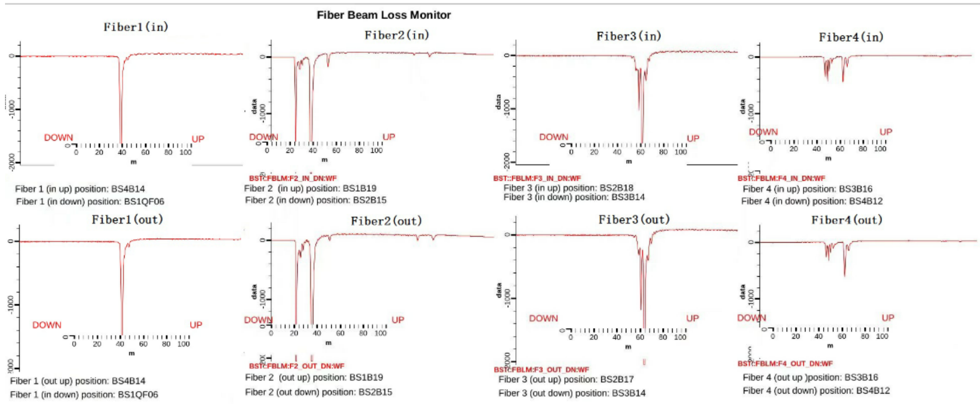

Figure 4: Beam loss signals captured by eight fibers at early stage of commissioning.

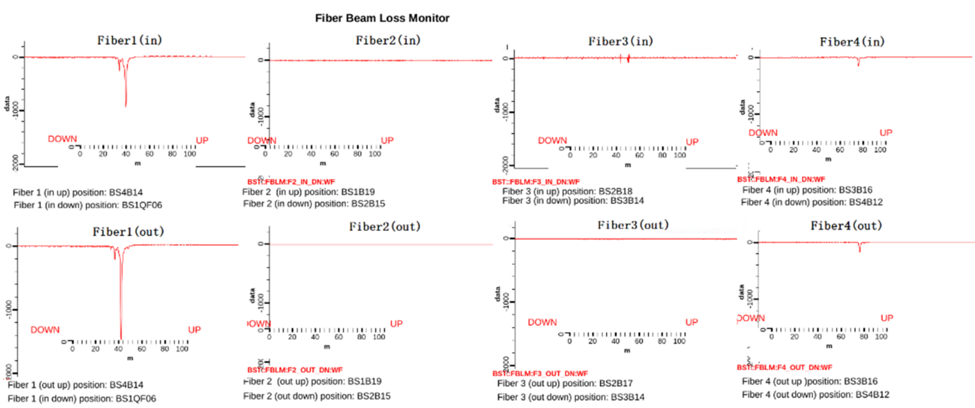

Figure 5: Beam loss signals captured by eight fibers after commissioning for several weeks.

side. The position of the loss can be calculated by measuring the arrival time of the signals measured at both ends of the fiber.

Commissioning Results

The FBLM signals obtained in the early stage of booster commissioning are shown in Fig. 4. The FBLM signals from fibers inside and outside the ring are consistent. Evident beam losses can be observed in all four regions of the booster. By locating the beam loss, in region 1, beam loss is caused by beam injection and in region 2-4, beam losses mainly occur at locations where the β function or dispersion function are relatively large.

Figure 5 shows that after the commissioning for several weeks, there are no significant beam losses in region 2-4. The beam orbit optimization is effective.

SBLM IN THE HEPS STORAGERING

The HEPS storage ring (SR) has a circumference of 1300 m and consists of 48 cells. SBLMs as more sensitive system were applicated for monitoring both the relatively large beam losses during commissioning and small turn-by-turn losses during operation [1]. SBLM consists of a plastic scintillator coupling with a PMT as detector, and electronics to readout the detectors.

Scintillator and PMT

The scintillator employed is a EJ-200 rod (100 mm length, 22 mm diameter), wrapped into a high reflectivity aluminium foil to improve the photon flux towards the PMT. The maximum emission wavelength is 425 nm.

The selected PMT is a Hamamatsu H10721-110 as mentioned above, with a cathode sensitivity centred in the scintillator emission wavelength.

The scintillator and PMT are coupled and enclosed in a metallic casing (Fig. 6).

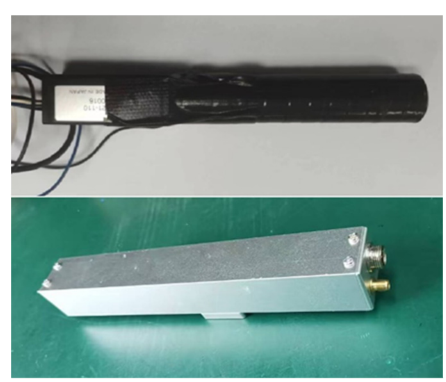

Figure 6: PMT-scintillator system without and with the metallic.

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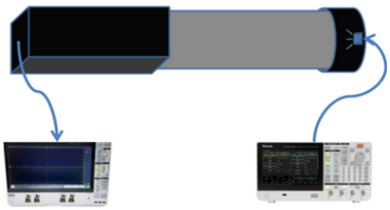

Figure 7: PMT calibration with LED.

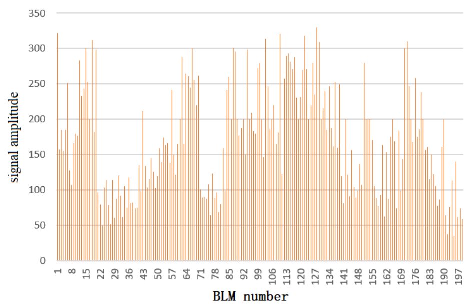

Figure 8: PMT sensitivity measured with blue LED.

Electronics

Depending on the requirements, a commercial open source hardware–RedPitaya which has 14-bit ADC, 65 MHz bandwidth and 125 MHz sample rate is chosen to complete the data acquisition. More details of the electronics can be found in Y. Zhao et al. [2]

PMTs Calibration

From manufacturing, the relative sensitivity of PMTs is quite different. In order to compare the losses amplitude measured by different BLMs, the PMTs should be calibrated. A dedicated housing has been 3D printed to install a LED which can emit 455 nm blue light. The output flux of the LED can be adjusted with a signal generator. The PMT is connected to oscilloscope and a dedicated power-supply for data acquisition and gain control, as shown in Fig. 7. The signal amplitudes are measured with the LED on and the PMT gain of 0.7 V (Fig. 8). Then the PMT gain is adjusted in order to ensure that different PMTs can output the same signal amplitudes.

Location

In order to cover all the storage ring, and obtain a consistent loss pattern, 4 detectors have been installed in each of the 48 HEPS cell, for a total of 201 BLMs (Including 9 movable BLMs). The position of the BLMs in each cell in storage ring is presented in Fig. 9. In each cell, one BLM is located on the inner side of straight section, the other 3 BLMs (Fig. 10) are located on the inner side part of

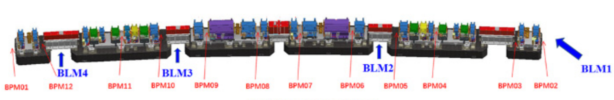

Figure 9: Distribution of BLMs in a cell for HEPS.

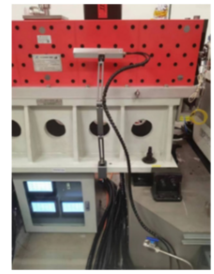

Figure 10: BLM on the inner side of bending magnets.

bending magnets: since all sources of particle losses are driven by an energy loss, particles with lower energy entering in a bending magnet will be bent more, and will more likely crash on the vacuum chamber, creating an electromagnetic shower [1].

SBLM System Operation

The SBLM system has been put in operation at HEPS. The SBLM system can measure slow losses during operation as well as turn by turn fast losses which are useful during the early stage of commissioning [3]. A software application has been developed to monitor the loss distribution.

Slow Loss Measurement

The interface (Fig. 11) can show the real-time beam loss status with a refresh rate of 1 Hz, while the interface (Fig. 12) can display the accumulated beam loss status for the previous hour. Beam loss data are stored and available for reference. Commissioning staff can utilize the beam loss data for beam orbit correction and optimization.

Fast Loss Measurement

The interface in Fig. 13 can show turn by turn loss data of different BLMs. The turn by turn data in Fig. 14 were taken during the early stage of commissioning (BLM4 in cell 3). Data show that the beam can circulate in the storage

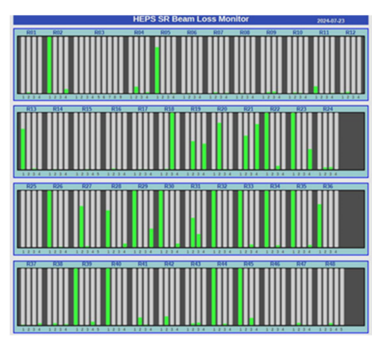

Figure 11: Real-time beam loss status of the SR.

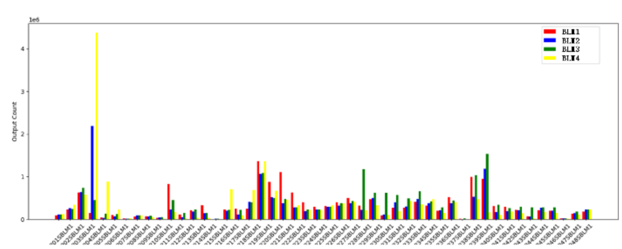

Figure 12: Accumulated beam loss status for the past hour.

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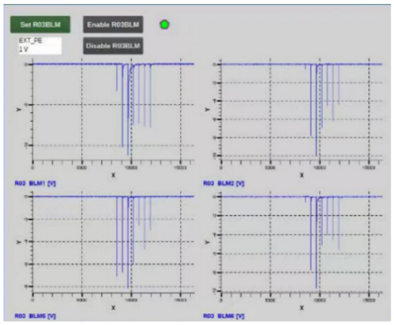

Figure 13: Turn by turn data of different BLMs.

ring for 4 turns and about 100 turns respectively. The turn by turn BLM data can complement the data from BPM.

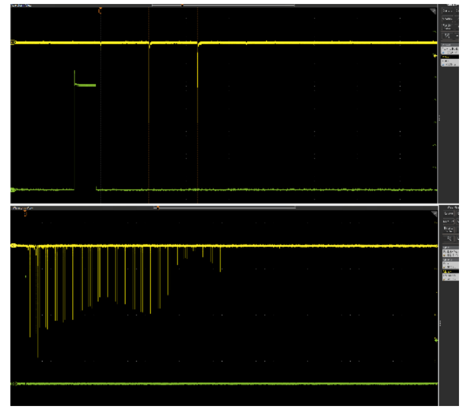

Figure 14: Turn by turn data during the early stage of commissioning.

SUMMARY

FBLMs and SBLMs are now operational to detect the losses at the HEPS booster and storage ring. The components, installation and operation have been present in this paper. At booster, FBLMs are sensitive enough to record and locate multiple large losses. At storage ring, SBLMs are more sensitive, and can measure not only slow losses but also turn by turn fast losses. Both the FBLMs and SBLMs are stable and reliable, can meet the requirements of commissioning staff.

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