ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-TUPRI100

PRESENT STATUS OF THE CHERENKOV BEAM LOSS MONITOR AT SACLA*

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Abstract

Since 2011, high power X-ray lasers have been delivered stably to the users at SACLA, the SPring-8 Angstrom compact free electron laser, and the upgrades have been performing to obtain the high quality of the laser continuously. Optical fibre based Cherenkov beam loss monitors have been successfully operated from the commissioning phase. This monitor covers the undulator section of beam lines and the electron beam transporting tunnel from SACLA to SPring-8. This monitor is made good use of not only beam transport but also detection of the small beam loss such as electron halos hitting the magnets of undulator. In this presentation, we will report the present status of the Cherenkov beam loss monitor and its usage experience.

OVERVIEW

Cherenkov beam loss monitor is successfully operating since the commissioning phase of SACLA (SPring-8 Angstrom Compact free-electron LAser) [1] in 2011. Figure 1 shows an overview of the Cherenkov beam loss monitor system of SACLA. The monitor consists of a pair of a photomultiplier tube and optical fibre of 230 m in length. Two detectors with different gains are used in order to ensure a wide dynamic range. Further, the large core (400 microns in diameter) step index optical fibre (Fujikura SC400/440 or SC400/500) is installed along the beam duct in order to provide sufficient sensitivity [2]. The upstream end of the optical fibre is connected to the photomultiplier tube (Hamamatsu Photonics, H6780-02 or H10721-20) outside of the undulator hall. The photomultiplier tube is installed in a power supply circuit, which is possible to adjust the gain and status monitoring from the control room via the FL-net. The detector signal is converted by the digitizer (CAEN V1729A, 2 GS/s, 14 bit) for each shot and recorded into the database. It is possible to verify the position and the magnitude of the beam loss in real time by using this data

Position of beam loss can be determined from the time difference between the detector signal and the timing signal of the accelerator. In addition, the calibration of the position was carried out using more than one screen monitor in BL3.

Currently, in addition to the undulator section of BL1 and BL3, this monitor is installed along the XSBT (XFEL to Synchrotron Beam transport Tunnel) for transporting the electron beam to SPring-8 from SACLA.

MEASUREMENT

Beam loss has not been almost observed in undulator section in normal operation, because of the orbit of electron beam is fixed precisely by a feedback system [3]. However, if one of the klystron of the main linac has stopped, the accelerated electron beam causes the beam loss at the dogleg such as the chicane. In such case, the beam loss can be detected by difference between the two CT monitors [4] and the extraction of the electron beam stopped by the machine protection system (MPS) in SACLA. However, the difference of two CT monitors is difficult to detect the beam loss which is less than 10 pC. Therefore the beam loss monitor is necessary in order to detect the beam loss position and it's amplitude in a wide range.

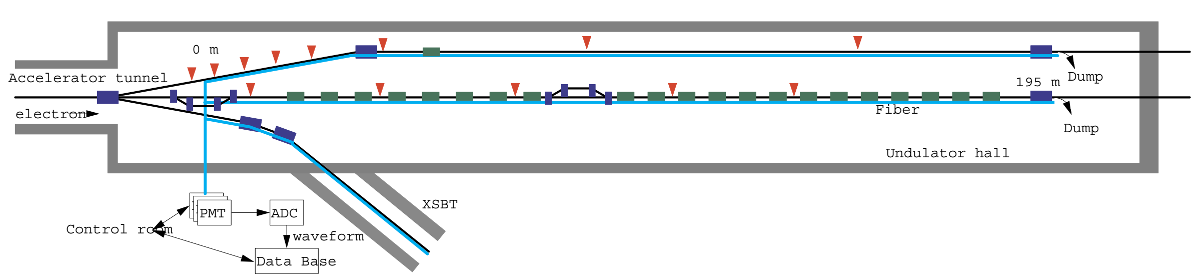

Figure 1: Schematic view of the Cherenkov beam loss monitor system in SACLA. Aqua blue lines indicate the optical fibres for the beam loss monitors. Green boxes, blue boxes and red triangles indicate the undulators, the bending magnets and the screen monitors.

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Beam loss during tuning of the accelerator

Scattering of the electron by the screen monitor is the main reason of the beam loss during the accelerator tuning. Figure 2 shows the one of the example. In this case, the electron beam is tuned using the screen monitors. Beam loss can be seen to detect from the position of the screen. Thus, in the case of fig. 2, lost electrons in BL1 is about 0.1 nC by using the difference between the two CT monitors.

From this result, we can easily define the beam loss position in real time.

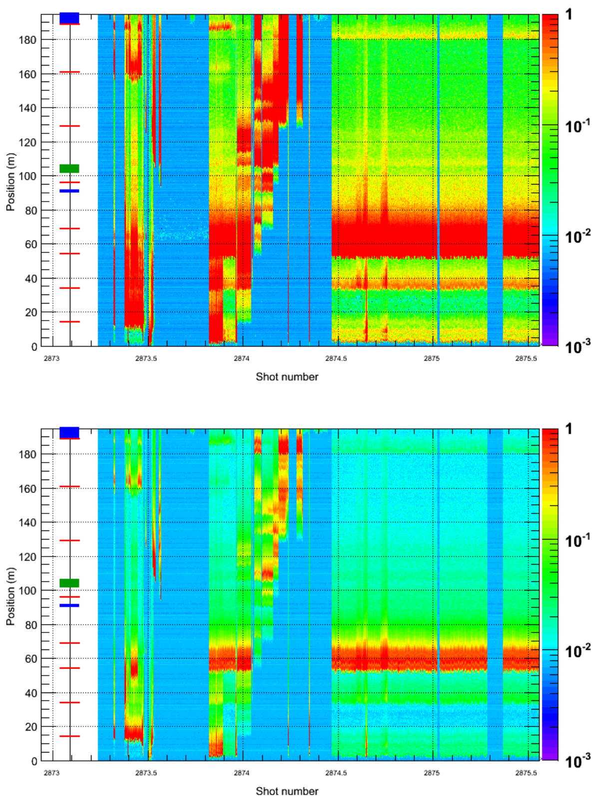

Figure 2: The signal from the high gain (upper) and low gain beam loss monitor (lower) in accelerator tuning. The magnitude of the monitor signal (color scale in voltage) as a function of the shot number (horizontal axis) and the position of the beam loss (vertical axis). Red line, blue box and grenn box indicate the screen monitor, the undulator and the bending magnet.

Beam loss in the test experiment of the beam halo monitor

Figure 3 shows a beam loss when testing the beam halo monitor in BL1. The beam halo monitor located at 165 m.

The beam halo monitor consists of two diamond detector [5]. Diamond detectors (0.3 mm in thickness) with RF finger (BeCu with a thickness of 0.3 mm) are mounted upper and lower of the beam axis.

Usually, the halo monitor never inserted to the beam core. In order to measure the sensitivity of the halo monitor, the halo monitor inserted to the beam core with changing the charge of the electron beam during this experiment.

All electrons in the bunch passed through the halo monitor and a part of the electron beam losing between the halo monitor and the bending magnet for the beam dump could be detect by the beam loss monitor. The total beam charge of hitting the halo monitor is measured approximately 0.32 pC by using the calibrated BPM monitor at this time.

This result means that this detector can measure the very small beam loss over 200 m. Moreover, this result is consistent with our estimation [2].

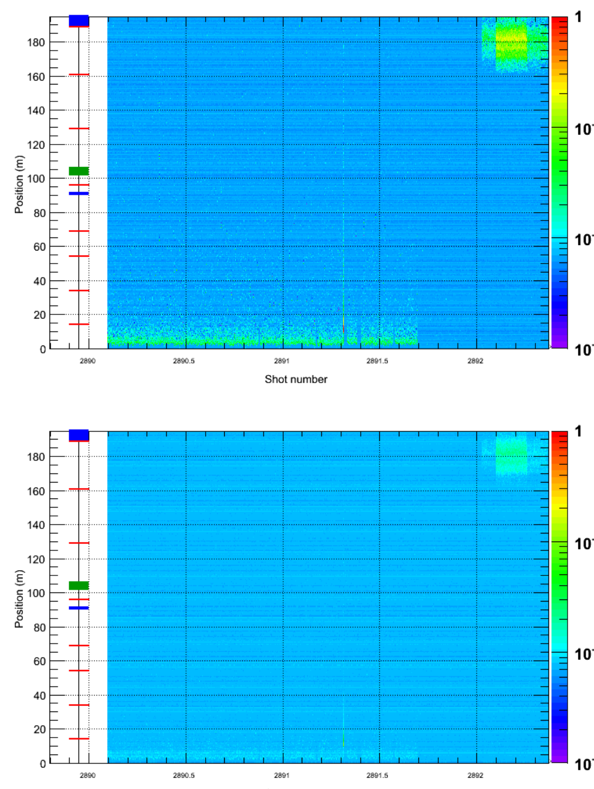

Figure 3: Beam loss in halo monitor experiment. The magnitude of the monitor signal (color scale in voltage) as a function of the shot number (horizontal axis) and the position of the beam loss (vertical axis).

Beam loss in the commissioning of XSBT

Figure 4 shows the signals of the beam loss monitor during the commissioning of XSBT.

There are some bending magnets to bend the electron beam 10 degrees in the vertical direction and 55 degrees in the horizontal direction in XSBT. The screen monitor was used mainly to commissioning.

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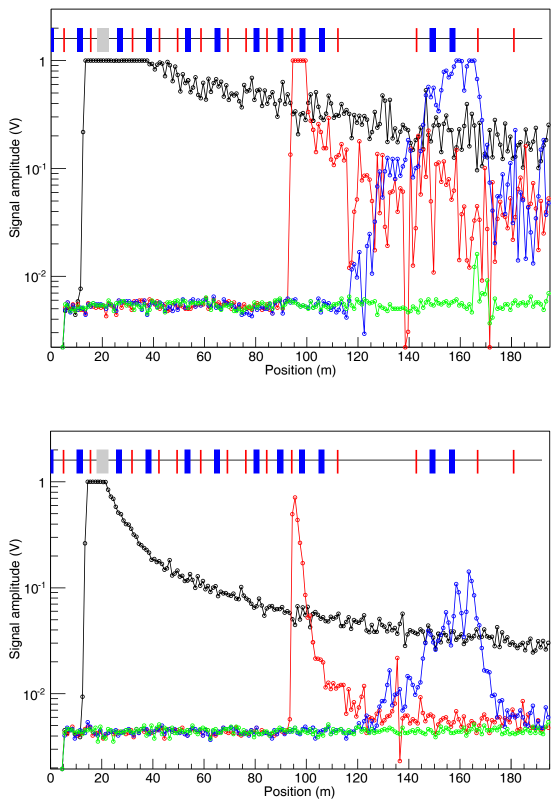

Figure 4: The signals from the high gain (upper) and low gain beam loss monitor (lower) during the commissioning of XSBT. Blue boxes and red lines indicate the bending magnets, the screen monitors respectively. The grey box indicates the shield wall between the undulator hall and XSBT tunnel. Black and red line shows the signal of the beam loss monitor with inserting the screen monitor. Blue and green line shows the beam loss in the progress of the accelerator tuning.

The gain of the upper figure (high gain monitor) is 10 times higher than that of lower figure (low gain monitor). In this case, the signal from the high gain monitor was saturated (black, red and blue line in upper figure) because of the limited dynamic range of the digitizer. However, the high gain monitor was able to detect small beam loss around 165 m which was not able to detect low gain monitor (green line). By using this monitor, it is easy to control the electron beam without any beam loss.

CONCLUSION

In this report the current status of the Cherenkov beam loss monitor operating in SACLA was presented.

Since the commissioning phase of SACLA, this monitor has been successfully working over wide range with high sensitivity.

We plan to extend Cherenkov beam loss monitor to BL2 which will be constructed in this summer.

In preparation for the pulse-by-pulse electron beam operation that is starting in near future, this monitor will be improved in order to give the warning when the beam loss occurs.

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