DEVELOPMENT OF BEAM LOSS MONITOR FOR THE SPRING-8 STORAGE RING

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Abstract

A beam loss monitor using PIN photodiodes has been developed. To check its performance, we installed it at an in-vacuum insertion device, a chamber for irradiation experiments and the injection section in the SPring-8 storage ring. Information on the beam loss at these points will be useful for examining demagnetization of permanent magnets of insertion devices and for studying a mechanism of beam loss. A noise level at these points is however high due to stray synchrotron radiation, an induction voltage generated by pulsed injection magnets, etc. The beam loss signal is then picked up under a high noise condition.

INTRODUCTION

One of the major concerns in the SPring-8 storage ring (SR) is an irradiation-induced damage due to beam loss to the environment surrounding the accelerator. The in-vacuum insertion devices (IDs) of 20 have been utilized in the SPring-8 storage ring (SR). Since demagnetization of permanent magnets can be caused by the irradiation of electron beam [1], beam loss should be monitored around these IDs. In 2003, the melt of a SUS vacuum chamber at the injection section was caused by the electron beam on timing of a beam abort. In order to manifest its mechanism and to confirm a durability of a newly developed vacuum chamber, the electrons of 100 mA have been irradiated into a test material of the chamber by utilizing the beam abort system in the SR [2].

In order to observe turn-by-turn beam loss, to manifest its mechanism, and to handle beam losses, a beam loss monitor for beam diagnostics have been developed with PIN photodiodes and installed inside the tunnel of the SR, while ionization chambers and rem-counters for the radiation safety have been located outside the tunnel. In this paper, the setup of the beam loss monitor and its experimental results are reported.

LOSS MONITOR

PIN photodiodes without a reversed bias voltage was chosen for detecting secondary particles on a beam loss from economical point of view for instalment and maintenance, and from its fast responsibility. As seen in Fig.1, 4 PIN photodiodes (4 PINs) are utilized for detecting the beam loss, and 2 PIN photodiodes (2 PINs) are used for compensating a background noise, which are shielded by an aluminium chassis. Each detector is connected to a shielded 2 pair twist cable, and both the shied of the cable and the chassis are connected to the ground.

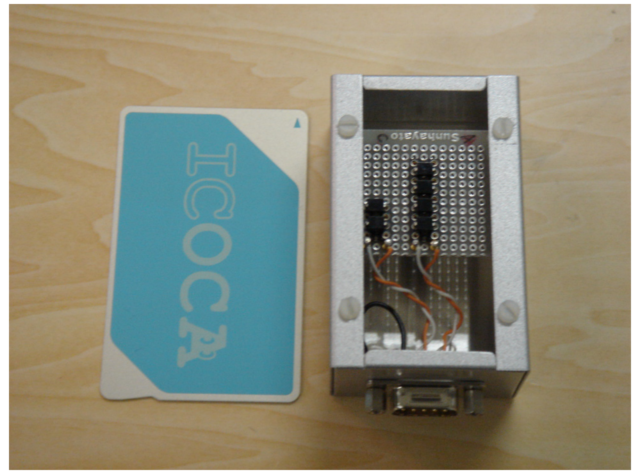

Figure 1: Beam loss monitor.

The loss monitor has been installed to demonstrate its performance near the injection section, a chamber for the irradiation experiment mentioned above (see Fig. 2), and the in-vacuum IDs in the SPring-8 SR.

Figure 2: Setup of beam loss monitor near chamber for irradiation experiment.

In a loss monitor, a signal is also induced by a secondary particle scattered by the synchrotron radiation from crotches and absorbers, and this is defined as the background noise for the beam loss monitor in this paper, because it is independent of the beam loss. The beam loss monitor signal at the injection section is shown in Fig.3(a), in which a filling pattern of electron bunches (11 bunches train times 29) is observed (black line). Almost the same waveform can be observed even when all PIN photodiodes are removed from the chassis. So, it seems that this is dominantly induced by the secondary particles scattered from crotches and absorbers when they hit the chassis and the shield of the cable connected with the ground.

In addition, the excitation of the injection bump magnet also induces an nonnegligible noise as shown in Fig. 3(b) (black line), which is also independent of the PIN photodiodes.

In order to remove these noises independent of the PIN photodiodes, the signal of the 2 PINs is distracted from that of the 4 PINs, especially at the injection section. The result is shown in Figs. 3, where the background noise becomes smaller after the compensation (red) than that before the compensation (black).

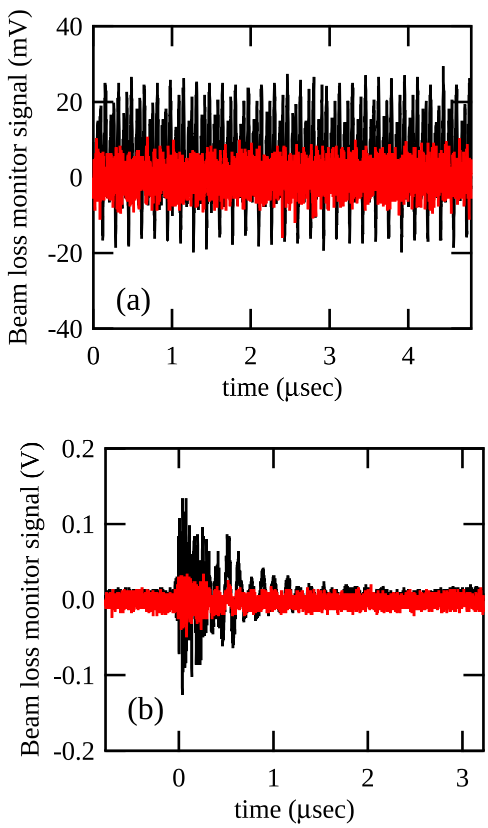

Figure 3: Background noise by (a) Compton scattering and (b) induction voltage from injection bump magnet detected by beam loss monitor, (black) before and (red) after compensation/

INJECTION BEAM LOSS STUDY

Beam loss in the injection period has been examined for R&D of the beam loss monitor.

In the SPring-8 SR, two types of the beam injection scheme are adopted: nominal injection and top-up one, respectively. In the former, a bunch is directly injected from the synchrotron through the beam transport line (SSBT) at that time. On the other hand, for the top-up injection, the tails of bunch in the horizontal direction are removed by the slits at the SSBT, and the remained core of about 0.03 mA is injected into the SR. The trajectory of injected bunches for the top-up injection is closer to the stored beam orbit than that for the nominal, because of the difference of the beam size.

The RMS of the loss monitor signal for 1 µsec after the injection is shown in Fig. 4, in which “no beam” in the horizontal axis means that the beam was not stored in the SR, the beam was not injected, and only the injection bump magnets were turned on. It seems that the beam loss signal of the top-up injection is higher than that of the nominal one though the bunch current of the former is lower than the latter. It is now under studying.

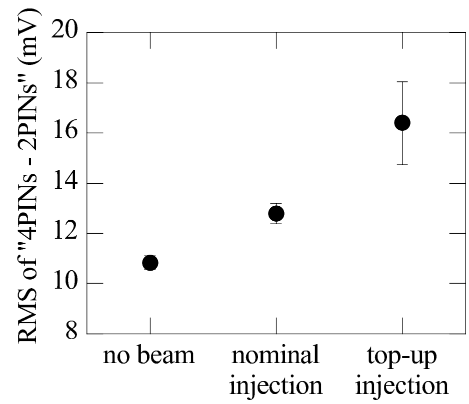

Figure 4: RMS of the loss monitor signal for 1 µsec after the injection.

A signal of the loss monitor in the nominal injection is shown in Fig.5, where a piece of material for the vacuum chamber was set for the irradiation experiment, so that this piece took a part of a scraper. Bam loss dependent on the chromaticity was observed. In the case of (ξ_x, ξ_y) = (8, 8), where ξ_x and ξ_y are the horizontal and vertical chromaticity, respectively, the beam loss was continuously induced turn-by-turn in comparison with the case of (2, 2).

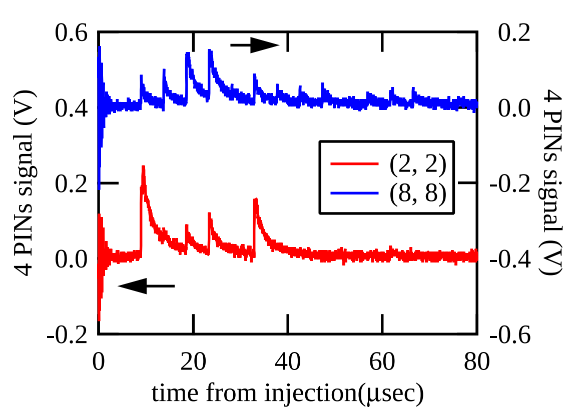

Figure 5: Injection beam loss dependent on chromaticity.

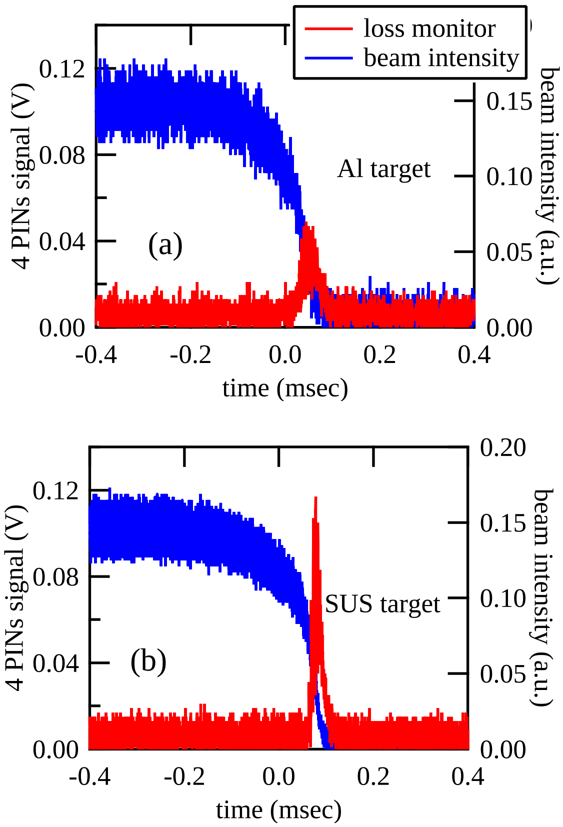

Figure 6: Beam loss signal and beam intensity in irradiation experiments for (a) Al and (b) SUS targets.

IN IRRADIATION EXPERIMENT IN THE SPRING-8 SR

As mentioned above, the irradiation experiment has been performed in the SPring-8 SR. The loss monitor has also been set near the chamber used in this experiment (see Fig.2). The loss monitor signal was measured by changing the test material, Al and SUS. The dependence on the material is clearly shown in Figs. 6. In addition, the signal of the loss monitor started after that the beam intensity became about half. It is thought that the beam was lost at not only this chamber but also the other. It seems that the loss monitor for beam diagnostics is useful to hit circulating electrons on the targets for the irradiation experiment.

SUMMARY

A beam loss monitor using PIN photodiodes has been developed to observe turn-by-turn beam loss, to manifest its mechanism, and to handle beam losses. The cost of one loss monitor is about 20 euro, the size is 50 times 80 times 34 mm, and no reversed bias voltage is required so that the install and maintenance seem to easy. In the injection beam loss study, the beam loss dependent on the chromaticity was measured turn-by-turn. In addition, the signal dependent on the test material was observed in the irradiation experiments.

The loss monitor for beam diagnostics is a useful tool not only from beam dynamical point of view but also for the irradiation experiment by handling the circulating electrons.

One of Authors (Y.S.) would like to thank Dr. Ikeda of KEK for his suggestion about a loss monitor with PIN photodiode.

REFERENCES

[1] T. Bizen, Nucl. Instr. and Meth. A 574, 401 (2006).
[2] M. Oishi et al., SPring-8 internal report, SR06-007, written in Japanese.