BEAM LOSS INVESTIGATION NEAR THE PULSE BENDING MAGNET OF KEKB INJECTOR LINAC

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Abstract

A KEKB Linac delivers an electron beam of 8 GeV to a KEKB high-energy ring (HER) and a positron beam of 3.5 GeV to a KEKB low-energy ring (LER). Furthermore, electron beams of 2.5 GeV and 3 GeV are supplied to the PF and the PF-AR, respectively. The KEKB Linac is operated to deliver the beams to HER, LER, and PF every 20 msec. Beam loss is investigated by optical fiber and thermoluminescent dosimeter (TLD).

INTRODUCTION

The pulse magnet (BP_58_1) installed downstream from the linac controls the beam distribution to 4 storage rings. The measured data of beam position monitor (BPM) show that the charge quantity of the PF beam decreases before and behind this magnet. The beam loss was investigated using an optical fiber, and the results show that the beam loss occurs in the straight section of the BP_58_1 lower stream. In order to prevent radiation damage to the ceramic chamber inside the magnet, a collimator is located just before the magnet. A branch duct is also present immediately after the magnet. We investigated the beam loss inside the magnet and measure the magnet circumference. Under present operating conditions, we found almost no beam loss in the collimator but very large beam loss in the branch duct of the magnet.

The doses of radiation in various places under operation are measured in TLDs, and these are compared with the optical fiber loss monitor's data [1]. Considerable beam loss occurs near the branch duct. The duct of the ~100-m PF beam line at lower streams of a pulse bending magnet and the residual radioactivity of the flange are observed. Under present operating conditions, it appeared that the beam loss had occurred in the past although there was almost no beam loss in the collimator.

We found that the optical fiber loss monitor is very useful to detect beam loss. Since an optical fiber is a nonmagnetic material, it can observe the beam loss even inside a magnet. Since the information on a beam loss is acquired for every pulse in real time, the beam loss occurring in a single shot can be observed. If one optical fiber is laid to the beam line, the extent and location of the beam loss can be observed with an oscilloscope.

BEAM LOSS MEASUREMENT BY OPTICAL FIBER

The electron/positron beams are distributed to the various rings at the end of the linac (the so-called "third switch yard"), as shown in Fig.1. Concerning the PF-ring beam injection, the beam line from BP_58_1 to a partition door (the boundary between the linac and the PF ring) is 95 m in length. The beam charge decrease is observed from the BPM located downstream of BP_58_1. Since the beam loss monitors are not available, it is not well understood whether this beam charge decrease comes from actual beam loss or calibration error in the BPMs. In order to investigate these problems, the optical fiber with a 400-μm-diameter core was installed in this section. Two optical fibers fixed to both the right and left of the duct were laid from the upper stream of BP_58_1 to a partition. Fig. 2 shows the results of beam loss

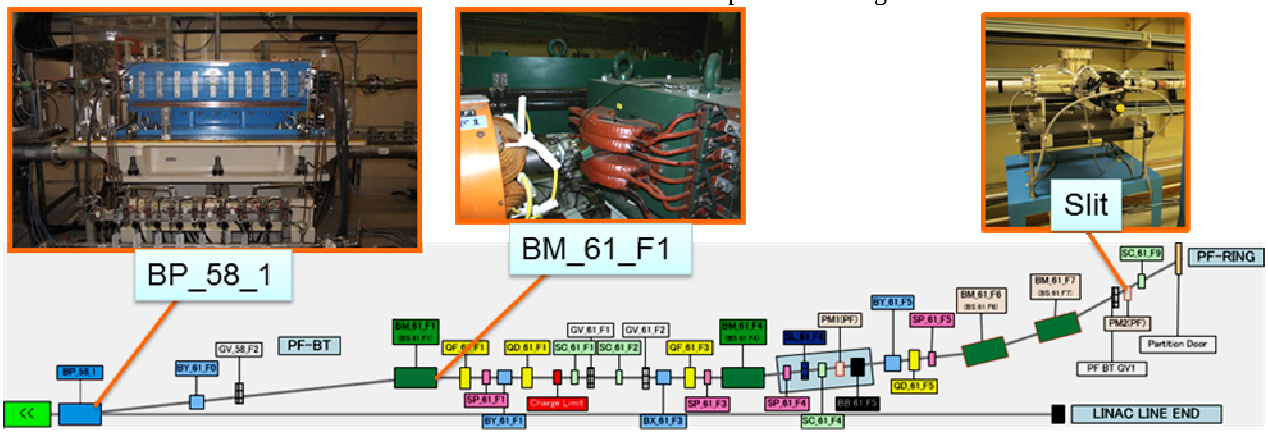

Figure 1: Layout of PF beam line in the third switching yard. The blue square represents the pulse bending magnet (BP_58_1); green, the bending magnet; yellow, the quadrupole magnet; light blue, the steering magnet; pink, the beam position monitor; light green, the screen monitor; red, the charge limit; and black, the beam stopper. Photographs of BP_58_1 and slit are also shown.

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measurement at the third switch yard, where the beam is switched from the linac to the PF ring.

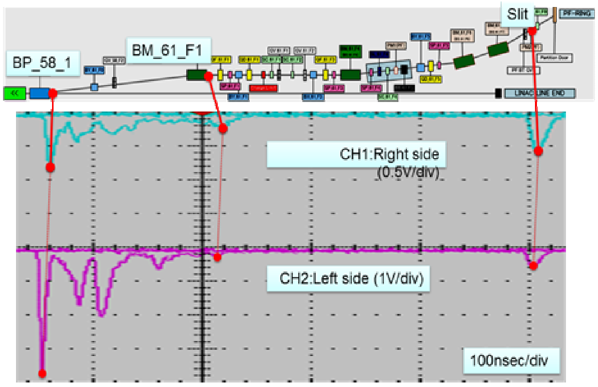

Figure 2: Oscilloscope waveform of 2 optical fibers laid on the duct in parallel, superposed with the layout of the end of the linac.

In Fig. 2 the large beam loss near the downstream of the pulse bending magnet can be observed. Both fibers, left- and right-laid, detect the large beam loss. From this experiment, we found that the beam charge decrease is not the result of BPM miscalibration but real beam loss. Since we laid the fibers in parallel, we can obtain the difference between the left and right sides of the beam effectively. The left-hand side seen from the beam entrance detects a larger signal, which is shown as the red-colored signal in Fig. 3. Our interpretation is that since the low energy electrons in the beam bunch are bent strongly (even in the same bending magnetic field), larger beam losses occur here than on the other side.

BEAM LOSS MEASUREMENT BY TLD

As is known, beam loss is very large in the branch duct of the magnet [1]. However, since the signal of the optical fiber is not calibrated, we cannot estimate the absolute extent of the beam loss. Thus, TLDs were installed in the duct, and the dose of radiation under beam operation was measured. The setting positions of the TLDs and the signal of the optical fiber are shown on top in Fig. 3 [2].

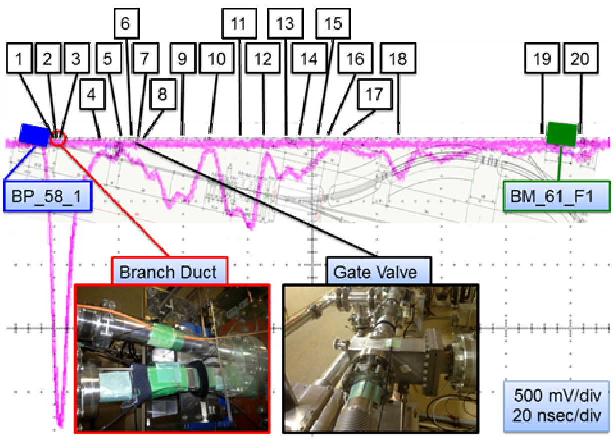

Figure 3: Setting positions of TLDs, and the signal of the optical fiber on top.

The TLD dynamic range is 10 μSv to 10 Sv. Two or more measurements were performed with each beam condition at about 0.3 nC/pulse at the 58_BP_1. The measured doses by TLDs are shown in Fig. 4. TLD-1, TLD-2, and TLD-3 were irradiated for 5 minutes, And TLDs 4-20 were irradiated for 20 minutes. Measurement data were calibrated to 1 minute. As shown in Figs. 3, and 4, the results obtained using the optical fiber show correlation with the results of TLD .

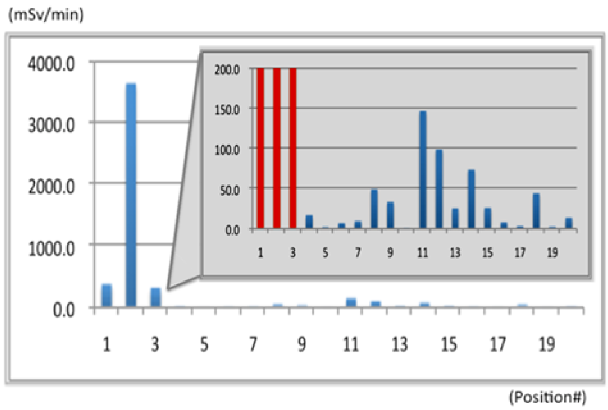

Figure 4: Dose measured by TLDs.

Although measurement of the place of a collimator was also performed, there is no beam loss now. Since the branch duct contains a flange, the optical fiber is separated from the duct by about 2–3 cm in the flange neighborhood.

A photograph showing the TLD in the branch duct is given in Fig. 5.

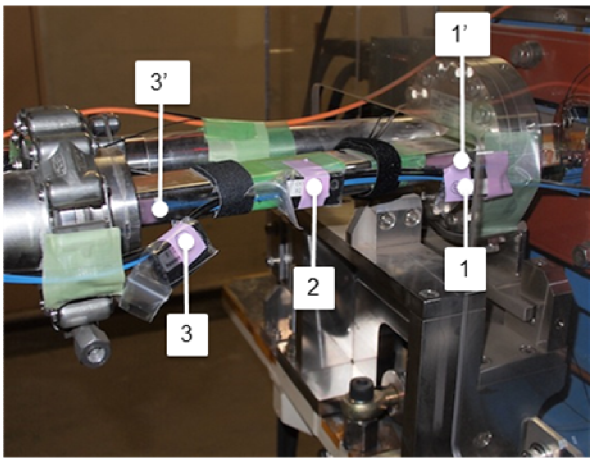

Figure 5: Photograph of optical fiber and TLD in a branch duct.

TLD-2 is in contact with the duct, while TLD-1 and TLD-3 are separated from the duct by about 2–3 cm. Here, TLD-1' and TLD-3' are in contact with the duct. Those comparison tables are shown in Table 1. A large dose decay is observed with the distance from the beam duct. The most effective approach to identifying the beam loss location clearly is to locate the TLDs (using an optical fiber) on the beam duct.

Table 1: Radiation dose measured by TLDs

Position	E_{total} (300 shots)	E_{shot} (mSv/shot)
1	1891	6.30
2	18228	60.76
3	1578	5.29
1’	36050	120.2
3’	12560	41.9

Measurement data are standardized in one shot. If the TLD is separated from the duct, the radiation dose will become about 1/10.

RESIDUAL RADIOACTIVITY MEASUREMENT NEAR THE PULSE BENDING MAGNET

Next, we investigated the relation between the beam loss and residual radioactivity. We measured the residual radioactivity of the duct and the flange about 1 hour after stopping the beam. The measurement results on the surface of a collimator of the 58_BP_1 upper and lower streams are shown in in Figs. 6 and 7, respectively.

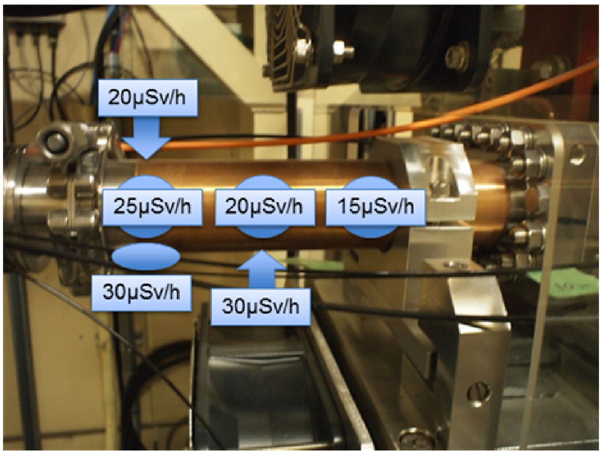

Figure 6: Measurement result on the surface of collimator of the 58_BP_1 upper stream.

We also measured the residual radioactivity from BP_58_1 to a partition door. Almost all the positions of the duct parts from BP_58_1 to BM_61_F1 were 1–3 μSv/h. The flange of the gate valve was 10 μSv/h, and that of the Position-13 neighborhood was 7 μSv/h. Almost all the positions of the duct parts from BM_61_F1 to the partition door were 1–3 μSv/h. The highest dose was 20 μSv/h at the main part in the downstream slit. The flange part before and after the slit was 3 μSv/h, and the duct that was 1 m near the slit lower streams was 1 μSv/h. The duct support stand (aluminum block) of the place was 3 μSv/h.

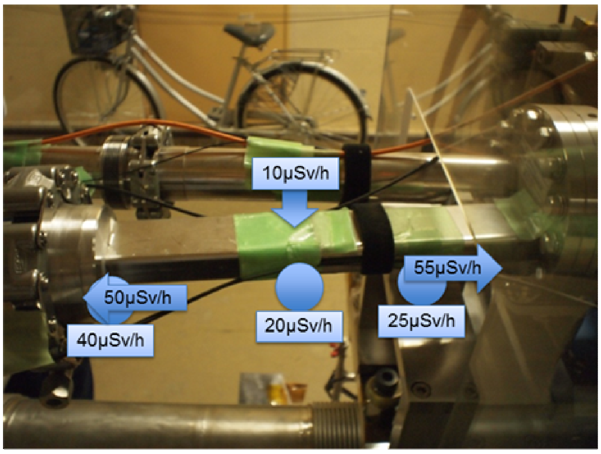

Figure 7: Measurement result on the surface of branch duct of the 58_BP_1 lower stream.

SUMMARY

The observations using the optical fiber were correlated with the results of the TLDs. The radiation dose at the duct surface was considerably different from that at the position separated from the duct. To evaluate the beam loss distribution from the waveform of the observed beam loss, the laying state of the optical fiber has to be considered. It is possible to estimate beam loss from residual radioactivity. However, record of the past beam loss is also included in the measurement result of residual radioactivity.

ACKNOWLEDGMENT

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REFERENCES

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