BEAM LOSS MONITOR AT THE INS ELECTRON SYNCHROTRON

Y. Hashimoto, K. Kobayashi, H. Masuda, M. Muto, K. Norimura,
H. Okuno, K. Yoshida and K. Watanabe

Institute for Nuclear Study, The University of Tokyo,
Midori-cho 3-2-1, Tanashi-shi, Tokyo 188, Japan

Abstract

We have developed a beam loss monitor which measures the spatial distribution of the beam loss around the synchrotron ring at the time of beam injection and ejection. The monitor consists of 8 scintillation counters placed in the longitudinal direction of each straight section. The loss distributions for each acceleration period are displayed on the oscilloscope. This monitor system is found to be helpful for the adjustment of beam injection and also is useful for understanding of the beam loss background at the beam ejection period.

Introduction

A plan view of the INS 1.3GeV electron synchrotron is shown in Fig.1. The synchrotron ring consists of 8 magnets which are excited by the resonance method at a repetition rate of 21.5Hz. The time sequence of the injection and ejection of the beam is shown in Fig.2.

The beam from the linac is injected into the ring at the energy of 15MeV when the field strength of the ring magnet is 125Gauss. At this injection time, a considerable amount of the beam is lost due to the mismatch between the beam emittance and the ring acceptance and due to the capture loss by the RF acceleration system.

At the final stage of acceleration, RF voltages are reduced gradually and the radius of the beam orbit becomes smaller because of the energy loss due to synchrotron radiation. Then, the beam hits either the internal platinum radiator of 50μ thick for the bremsstrahlung beam (γ1 and γ3) or hits the beryllium absorber of 12mm thick for the electron extraction (γ2) by the Piccioni method. Also, the fast ejection system is available for supplying the beam to the 400MeV storage ring for a synchrotron light source. The beam spill time can be prolonged up to 10msec, which corresponds to the duty cycle of 20%. The characteristic features of these beam ejection system is that the beam can be shared by the various beam channels simultaneously. At the beam ejection stage, a large amount of the beam is lost around the synchrotron ring, since both the conversion efficiency at the internal radiator and the extraction efficiency are not high. Therefore it is important to know the beam loss distribution around the ring for the fine tuning of the experimental conditions.

For these purposes, we have developed a beam loss monitor, which can display the spatial distribution of the beam loss around the ring. The beam loss can be sampled at any time during the acceleration period. In the following, we describe the monitoring system and its performance together with the results of its practical use.

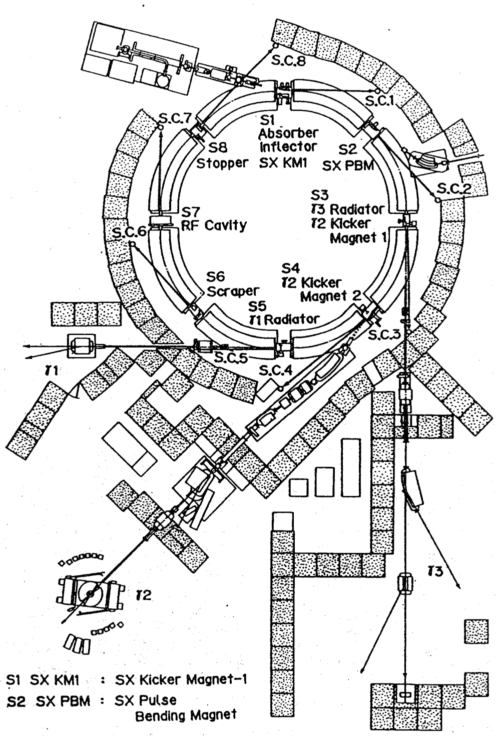

Fig.1 Plan view of the INS electron synchrotron.

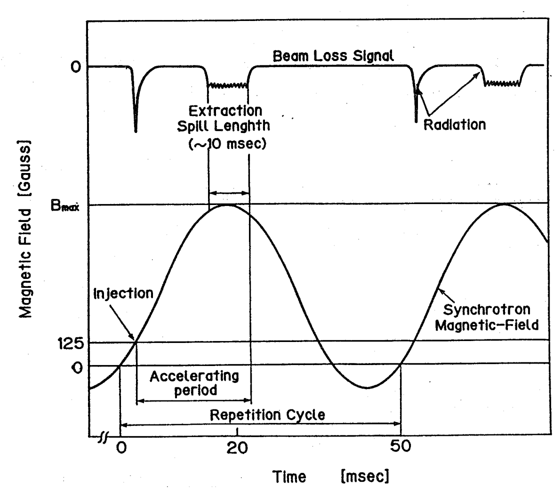

Fig.2 Time sequence of the beam injection and ejection.

Beam-Loss Monitoring System

Scintillation Counter

Since we need a fast time responce, we use plastic scintillation counters. A plastic scintillator of 15 mm in diameter and 2 mm in thickness is attached directly on the head of the 1/2-inch photomultiplier XP1110. The gain of each counter is adusted by changing the applied voltage and the gain calibration is made by use of the β-ray source.

Eight counters are placed at the longitudinal extention of each straight section. Since various apparatuses for beam injection and for beam ejection are contained in the straight section as shown in Fig 1, the beam aparting from the central orbit might hit these apparatuses firstly. As a result, high energy photons are radiated in the longitudinal direction of the straight section.

Before setting counters at the desirable position, we surveyed the loss distribution in the vertical direction and in the azimuthal direction. Since various shielding materials (lead blocks and paraffin) are placed close to the ring, the vertical position with the maximum intensity is not necessarily on the median plane of the ring. After these measurements, we positioned counters at 20cm above the median plane at the radius of 7m. The azimuthal counter position is shown in Fig.1

A typical example of the output signal is sketched in Fig.2, where a sharp spike corresponding to the injection and a broad spill corresponding to the slow ejection process are illustrated.

Readout Circuit

A block diagram of the readout electronics is shown in Fig.3. Output signals from the counters are sent to the readout circuit placed at the main control room via 50m-long coaxial cables. A signal from each counter is divided into two; one is for sampling at the injection timing and the other is for sampling at the ejection timing. As a result, the beam loss information at both timings is sampled during one acceleration period. The timing of sampling can be adjusted freely by the front panel knob, so that the loss information can be measured at any time.

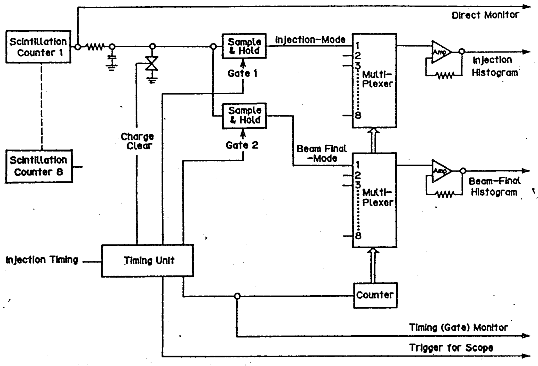

Fig.3 Block diagram of the readout electronics.

Signal voltages thus sampled are held for 50 msec at maximum and read out through multiplexers during the beam-off period of 20 msec. The frequency of the readout clock is chosen to be 1 kHz. For each acceleration period, two histograms representing spatial distributions of the beam loss around the ring at the injection time and at the ejection time are displayed on the oscilloscope Each horizontal step corresponds to the location of the beam loss monitor (S-1, S-2,····, S-8) and vertical scale shows the relative amount of the beam loss.

Use of the Beam-Loss Monitoring System

At Injection

Figure 4(a) shows the beam loss distribution at the time of injection under normal operating conditions, where the maximum energy is 550MeV and the circulating current is about 36mA. All apparatuses in the straight sections are set at the nominal positions The largest beam loss is observed with S.C.8. This is because S.C.8 is placed close to the injection beam line and the inflector in S-1. Since an injection efficiency of the linac beam to the ring is about 2% with the present multi-turn injection method, almost all linac beam is lost at S-1 and S-2. As the energy of the injection beam is 15 MeV, radiations are considered to be scattered uniformly around S-1 and S-2.

Figure 4(b) shows the loss distribution, where injection parameters such as the linac beam energy, the inflector voltage and the injection timing are not correctly adjusted. When the parameters are mismatched, the beam loss at S-1 and S-8 are relatively large and no beam loss at S-3, S-4, S-5, S-6 and S-7. By the adjustment of parameters, the beam loss at S-2 becomes extraordinary large under certain conditions. This means that the injected beam comes to S-2 and is lost at the SX pulse bending magnet (PBM) contained in S-2.

Once the beam starts to circulate the ring, the beam loss at S-2 becomes smaller and those at S-3, S-4 and S-5 become larger. Especially, the loss at S-5 is found to be very sensitive for the search of the beam circulation.

Since the beam loss distribution under the normal operating conditions shows characteristic pattern, we can use this monitoring system for search of injection parameters when the beam does

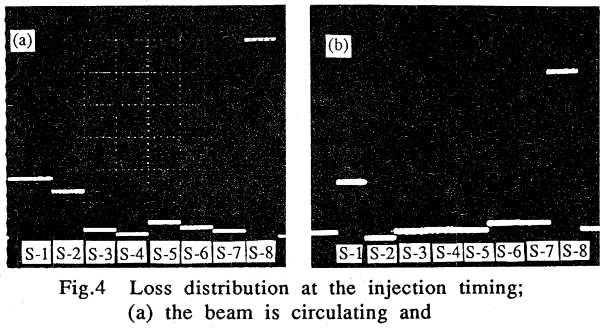

Fig.4 Loss distribution at the injection timing; (a) the beam is circulating and (b) not circulating.

not circulate. From the experience we have learned that the parameter adjustment should be done in such a way that the loss at S-2 is in the reasonable range and the loss at S-3, S-4 and S-5 should be observed. Once a small amount of signals appear at S-5, the fine tuning of parameters for increasing the circulating current is not difficult.

At Ejection

The beam loss distribution at the ejection period depends largely on the locations of the internal radiators and the absorber. Three remote-control positioning systems are provided for the platinum radiators at S-3 (γ3) and S-5 (γ1) and for the beryllium absorber at S-1 (γ2 electron). By adjusting these positions, the experimental areas supplied with the bremsstrahlung beam or the electron beam are selected. At certain conditions, the beams can be supplied for both areas simultaneously.

Histograms are taken at the beam energy of 550MeV and the circulating beam current of 37 mA. The S-5 radiator is removed throughout these measurements. Figure 5(a) shows the histogram when the S-1 absorber and the S-3 radiator are set at normal positions at -26mm from the central orbit. The beam loss is scattered in various parts around the ring. Relatively large loss is observed at S-1, S-2, S-3, S-6 and S-8. In these straight sections, the Be absorber(S-1) , SX-PBM(S-2), the Pt radiator(S-3), the Cu scraper of 3 mm thick(S-6) and the Cu stopper of 13 mm thick(S-8) are placed close to the central orbit. At the final stage of acceleration, the radius of the circulating beam shrinks due to the synchrotron radiation loss and a part of the beam hits the internal material placed at the closest position to the central orbit. When the radiator/absorber thickness is not large enough to stop the electron beam, considerable amount of the beam will continue to travel in the ring and further hit the material in the straight section.

Figure 5(b) shows the results when both the S-1 absorber and the S-3 radiator are moved away from the central orbit. In this case, the first material which the beam hits is the S-8 stopper. Since this stopper is thick enough to convert almost all the electron beam into the electromagnetic shower, the beam loss concentrates only on S-8.

When the synchrotoron is operated at low energies ($E \leq 600$ MeV), it is difficult to prolong the beam spill time, especially in the period when the magnetic field is decreasing. For example, a typical beam loss signal at E = 550MeV is shown in Fig. 6(a), where two different shapes are observedat the ejection timing. We tried to prolong the first spill as long as possible, but the beam can not be ejected after at the certain timing. This is because the beam orbit radius can not be shrunk after this timing since the decreasing rate of the magnetic field becomes larger compared to the beam energy loss due to synchrotron radiation. Therefore, the beam orbit radius starts to increase and finally hit the outside material closest to the central orbit. Figure 6(b) shows the beam loss distribution at the timing after the critical point. The result is completely different from that for the normal beam spill sshown in Fig.5(a). The large beam loss is observed at S-2, where the SX-PBM for the fast beam ejection is placed. This means that the outside aperture of the beam orbit is difined by this magnet.

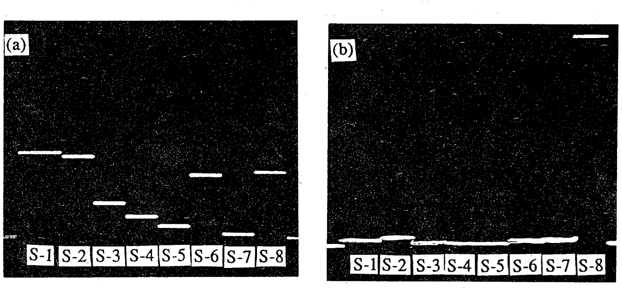

Fig.5 Loss distribution at the ejection timing;
(a) the S-1 absorber and the S-3 radiator are set at norminal positions,
(b)both are removed.

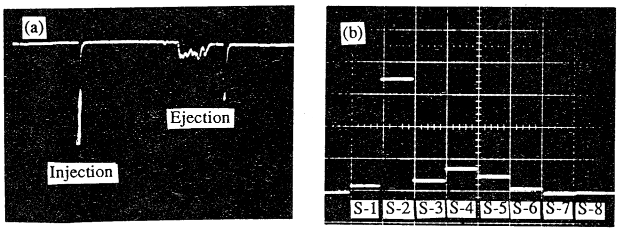

Fig. 6 (a) Output signal from the beam monitor at E = 550MeV operation.
(b) The loss distribution at the timing after the maximum point of the magnetic field.

Conclusion

We have installed the beam loss monitoring system around the synchrotorn ring, which measures the spatial distribution of the beam loss at the injection and ejection timing. It is found that the beam loss distribution shows a characteristic structures depending on the operational conditions.

At injection, this monitoring system is useful for the adjustment of the injection parameters. Especially, when the beam is completely lost, we can diagnose the possible obstacle in the straight sections. At the ejection, this monitoring system is effective for measuring the background conditions for each experimental area under various absorber-radiator conditions. In addition, with the use of the timing-variable sampling gate, beam loss distributions at any time during the acceleration period can be obtained, which is useful for the beam diagnostics in the synchrotron operation.