CURRENT STATUS OF A STRETCHER-BOOSTER RING AT TOHOKU UNIVERSITY

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Abstract

A 1.2 GeV Stretcher-Booster Ring (STB ring) has been routinely utilized for experiments of nuclear physics at Laboratory of Nuclear Science (LNS), Tohoku University. The STB ring was designed and constructed to have functions of a pulse beam stretcher and a booster-storage ring. In the stretcher-mode operation, the STB ring converts pulsed beam produced by a linac to the quasi cw-beam at a lower energy region from 150 to 200MeV. In this issue we mainly report the status of the stretcher-mode operation.

1 INTRODUCTION

A coincidence experiment for the nuclear physics requires a continuous-electron beam in order to suppress the accidental coincidence. On the other hand, higher energy beam is also useful for some purposes such as an internal target experiment even if the beam can't be extracted from a ring. The STB ring was constructed to supply such beams. It is also supposed to be an injector for a planned future light source. Since the first beam commissioning of the STB ring in 1997, the machine study has been continued at intervals of the machine time for the nuclear physics. The detail of the booster-storage mode operation is given in a reference [1].

The facility layout is shown in Fig.1. An injector S-band linac consisted with 20 accelerating structures provides multi-bunch beam with a long-pulse duration of 1 ~ 3 μs. The linac has been operated for multi-purpose use with high repetition rate up to 300 Hz, e.g., the lower energy beam than 50 MeV is able to branch off and often used for radioisotope production. Though the unloaded maximum energy is 300 MeV, a beam energy of 200 MeV is normally employed for the injection into the STB ring because of sufficient beam current. The beam energy is analysed at a dispersive section in the transport line and selected to be within certain width (typically ± 1.5 %). In the stretcher-mode operation, the quasi cw-beam extracted from the STB ring is transported to a couple of experimental stations.

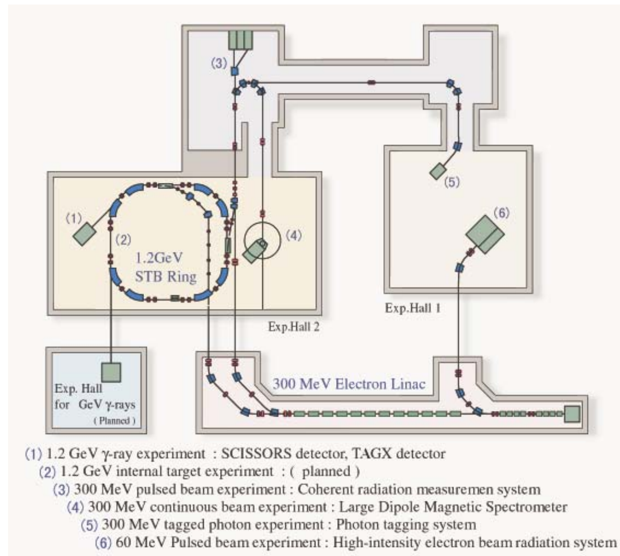


Figure 1: Facility layout.

2 THE STB RING

2.1 Basic Parameters

Main parameters and current status of the STB ring relevant to the stretcher-mode operation are given in Table 1.

Table 1: Parameters and status of the STB ring

Lattice type	Chasman-Green
Superperiodicity	4
Circumference	49.75 m
Injection energy	0.2 GeV (nominal)
Betatron tune	(3.31, 1.20) $^{*)}$(@ 0.2 GeV)
Chromaticity	(~ -5.78, ~ -4.97)$^{*)}$
Momentum compaction α	0.0376$^{*)}$
Dispersion	< 10 cm$^{*)}$
x-y coupling coefficient	0.005$^{*)}$
Beam current at injection	~ 100 mA$^{*)}$ (@ 0.2 GeV)
Repetition rate	300 pps (max)
Extracted beam current	~ 1 μA$^{*)}$
Duty factor	> 90 %$^{*)}$

$^{*)}$Measured value

Lattice structure of the ring is the simplest double-bend achromat consisted of 4 cells. An injection septum, an RF cavity and a wire septum for slow extraction, and an extraction septum occupy three dispersion-free straight sections, respectively. Remaining one is reserved for future project. The betatron tune has been chosen to be an adequate value (3.31~3.32, 1.20) for the operated beam energy (200~150 MeV). The natural chromaticity was measured to be (-5.5, -4.7).

2.2 Extraction Scheme

In the stretcher-mode operation, the STB is operated at where the resonance condition occurs at the lowest energy part of the injected beam. Since no external RF power feeds into an RF cavity, betatron tune approaches a third-integer resonance due to synchrotron radiation loss. A part of circulating beam, which has large amplitude, is then cut out of by a wire septum, and finally the circulating beam is continuously extracted from the ring. Figure 2 shows a schematic diagram of the beam extraction. A square shows an injected beam, which has a certain energy (tune) spread and betatron oscillation amplitude. The energy spread of the injected beam has to be adjusted exactly to the same amount of the radiation loss for one injection period. A sextupole magnet controls the amount of extracted beam as the solid lines. Phase space distribution of the injected beam directly affects the beam size and the time structure of extracted beam because of no radiation damping. Therefore a phase space matching is also carefully adjusted as well as the betatron amplitude.

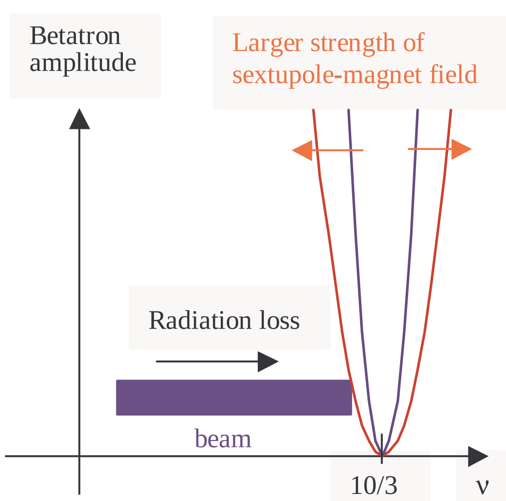


Figure 2: Schematic diagram of beam extraction.

Figure 3 shows a tracking simulation of horizontal phase space distribution at the wire septum position. In the simulation, the energy spread and the emittance of injected beam are supposed to be 0.05% and 300 nmrad, respectively.

Figure 4 shows a time distribution of extracted beam under the same condition of figure 3. Circulating beam current is also shown in this figure. In spite of the very narrow energy spread, finite emittance makes a finite time spread of the extracted beam. The same time distributions are also compared with a measurement. The measurement shows a wider spread than the simulation due to beam jitter, which will be described in the next section.

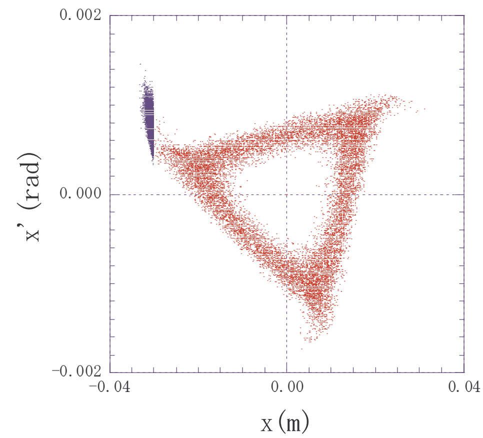


Figure 3: Horizontal phase space distribution at a wire septum. The extracted beam (x<-0.03m) is also shown.

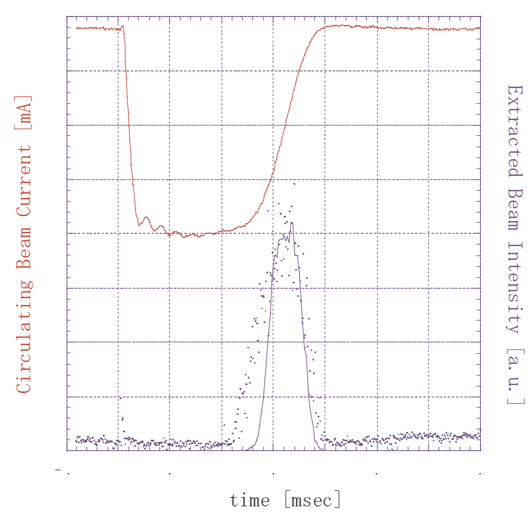


Figure 4: Time distribution of extracted beam. Solid line: tracking simulation, Plot: measured by spill monitor, Upper line: ring current measured by DCCT.

3 CURRENT STATUS

To satisfy requirements of low beam background and high duty factor, betatron amplitude and energy spread of the injected beam have to be carefully tuned as well as the operating point. Moreover, because the injector linac is operated with a higher repetition rate (300 pps), the beam loss in the ring frequently causes serious radiation damage on many electronics devices in the experimental hall.

A lower beam current is sometimes required for some beam user. In such operation, the repetition rate of 100 pps is applied instead of 300 pps. Figure 5 shows a typical example of a circulating and an extracted beam current during a user beam time. Those are observed by a DCCT and a spill monitor. The spill monitor consists of a plastic scintillator and a PMT, and it was placed at the downstream of a beam target. In this figure, it is found that the flatness of extracted beam intensity is rather vitiated. This is mainly caused by a tune shift due to the ripple of magnet power supplies. According to a tune measurement for the stored beam, it had been clearly observed that the tunes varied with a cycle of 50 pps [1]. In the stretcher operation, the horizontal tune has to be stably controlled in the order of 0.001. However, the amount of this horizontal tune shift was measured to be about 0.01. As a result, the extracted beam has a time jitter in pulse to pulse, as shown in figure 4. An improvement of the stability of magnet power supplies will be proceeded.

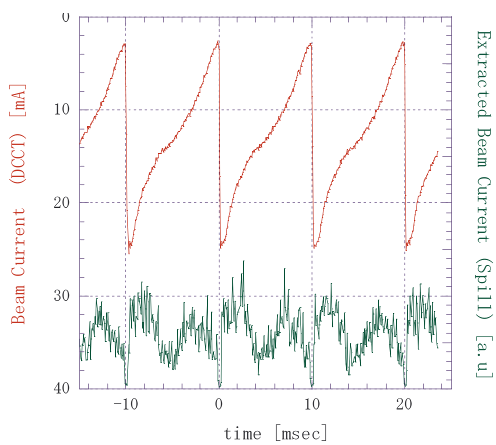
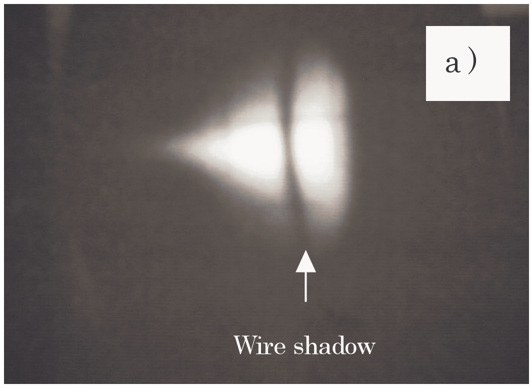


Figure 5: Time distribution of extracted beam for 100 pps operation. A ring current is also shown (upper line).

There is one more serious problem, which is a distortion of extracted beam size due to an insufficient field uniformity of the extraction septum magnet (SME). The SME was designed to generate a field flux density of 0.4 T over the length of 1.5 m in order to extract a 1.2 GeV beam. The extracted beam has a large size more than 10 mm in horizontal plane at the entrance of SME. According to a field calculation by POISSON code, there is 3.5% decrease of the field density with respect to the maximum density at 10 mm displacement, where the higher order component is significant. The extracted beam suffers the distorted field over 1.5 m in the SME, so that the extracted beam profile is much distorted as shown in figure 6-a). A tracking simulation, which includes higher order components of the SME field, is also shown in figure 6-b). In the observation, a vertical wire placed at the entrance of SME is inserted in order to intersect the extracted beam. The simulation result well reproduces the observed profile including the wire shadow. At the present, we proceed the revised design of the SME to improve the field uniformity.



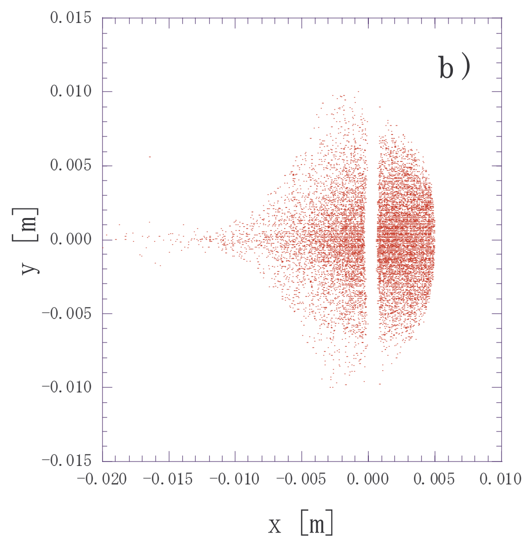


Figure 6: Profile of extracted beam.
a): measured, b):tracking simulation

4 SUMMARY

The STB ring has been routinely utilized for experiments of nuclear physics at LNS, Tohoku University. As the progress of machine study, the performance of the STB has been improving in these years. At the present, the STB supplies the continuous beam of 1 μA in ordinary operation. We proceed some improvements with respect to; the stability of the magnet power supplies, the field uniformity of the extraction septum magnet, etc. We will also continue the study of beam dynamics in a circular accelerator toward the higher performance.

REFERENCES

[1] H. Hama, et. al., “Current Status of a 1.2 GeV Booster Electron Synchrotron and Implementation for Nuclear Study at Tohoku University”,. Proc. 18th International Conf. On High Energy Accelerators (HEACC2001), Tsukuba, March 2001.