Beam Commissioning of Stretcher-Booster Ring in Tohoku University

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Abstract

The 1.2 GeV Stretcher-Booster Ring was constructed at Laboratory of Nuclear Science (LNS) in Tohoku University. This ring has three operational modes; the pulse stretcher mode, the booster mode and the storage mode. Beam commissioning of the ring has been carried out since November, 1997. This report describes the present status of the beam commissioning.

1 Introduction

In 1981, the first pulse stretcher ring (SSTR [1]) was constructed in Tohoku University and had been supplying continuous electron beams for nuclear experiments with the beam energy of 150 MeV. To meet the requirement of the higher energy beam, the construction of the 1.2 GeV Stretcher-Booster Ring (STB [2, 3]) was started in 1995. Since the first beam commissioning of the STB in November, 1997, the beam operation is continued up to now.

The STB has three functions such as the pulse stretcher, the booster and the storage ring. In the pulse stretcher mode, the STB converts a pulsed beam accelerated by a LINAC to a continuous beam, which is utilized for coincidence experiments in nuclear physics. In the booster mode, the beam is ramped up to 1.2 GeV with RF acceleration in 1 second after the beam injection, and then injected to a proposed synchrotron-light facility. In the storage mode, the accelerated 1.2 GeV beam is utilized for internal target experiments and high energy tagged photon experiments.

A schematic layout of the accelerator in LNS is shown in Figure 1. It consists of a 300 MeV S-band LINAC, an injection line, an 1.2 GeV STB ring and transport lines for experiments. In the LINAC, there are 20 accelerating structures, and 5 klystrons feed power to those structures.

The main parameters of the STB are listed in Table 1. The design detail is given by the Reference [3]. The STB ring consists of 8 bending magnets and 20 quadrupole magnets, and has four straight sections of 3.125 m for injection, extraction, RF acceleration and internal target experiments. The circumference is 49.751 m. It is desirable to have a large circumference with respect to an intense extracted beam, however, the whole size was restricted by the limited space in the experimental hall. RF acceleration is done by a single-cell cavity which had been originally used at Photon Factory in KEK. The RF frequency is 500.144 MHz, corresponds to a harmonic number of 83. Vacuum chambers are made of stainless steel to suppress eddy currents on the booster operation. The beam monitor system consists of 5 wire monitors, 9 button-type BPMs, a DCCT and an SR monitor port. The read-out electronics of the BPM uses superheterodyne methods. The BPM can measure the closed orbit for the storage mode, but not used for the stretcher mode. Two wire monitors were replaced by screen profile monitors. In addition to the above monitors, some loss monitors were placed along the beam lines. The STB control system [4] was constructed using personal computers with commercially available application softwares. Programmable Logic Controllers, PLCs, are used as the device controller. In the beam injection line, a beam collimator is installed at the just upstream of injection septum magnets. And also, 3 beam collimators are installed in the transport line, due to eliminate the beam halo. In both beam lines, the beam positions and the shapes are monitored by screen profile monitors. Vacuum chambers are made of aluminum alloy, and whose inner diameters are $\phi 50 \sim 80$ mm.

Table 1
Main parameters of the STB ring.

Circumference	49.7512 $[m]$
Revolution Frequency	6.026 $[MHz]$
Lattice	DBA
Super-periodicity	4
Betatron Frequency	$\nu_x = 3.30$
	$\nu_y = 1.20$
Moment. Comp. Factor	$\alpha = 0.03777$
Chromaticity	$\partial\nu_x/\partial\delta = -5.7861$
	$\partial\nu_y/\partial\delta = -4.9791$
Circulating Beam Current	300 $[mA](max)$
Beam Injection	three-turn injection
Stretcher Mode	
Beam Energy	300 $[MeV](max)$
Rep. Rate	300 $[pps]$
Extracted Beam Current	10 $[\mu A]$
Duty Factor	90%
Beam Extraction	third-integer resonance
Booster-Storage Mode	
Accelerated Beam Energy	1.2 $[GeV]$
Harmonic Number	83
RF Frequency	500.144 $[MHz]$
Radiation Loss / turn	61.2 $[keV]$
Damping Time	$\tau_x = 8.0$ $[msec]$
	$\tau_y = 6.5$ $[msec]$
	$\tau_z = 3.0$ $[msec]$

2 Beam Commissioning

Stretcher Mode

The machine time of the STB has been mainly consumed in the stretcher mode up to now. For the present, the injected beam energy is 200 MeV so as to be relatively easy to operate the LINAC. In the stretcher mode, the ring is operated with a repetition rate of 300 pps.

To match the injection beam parameter to those

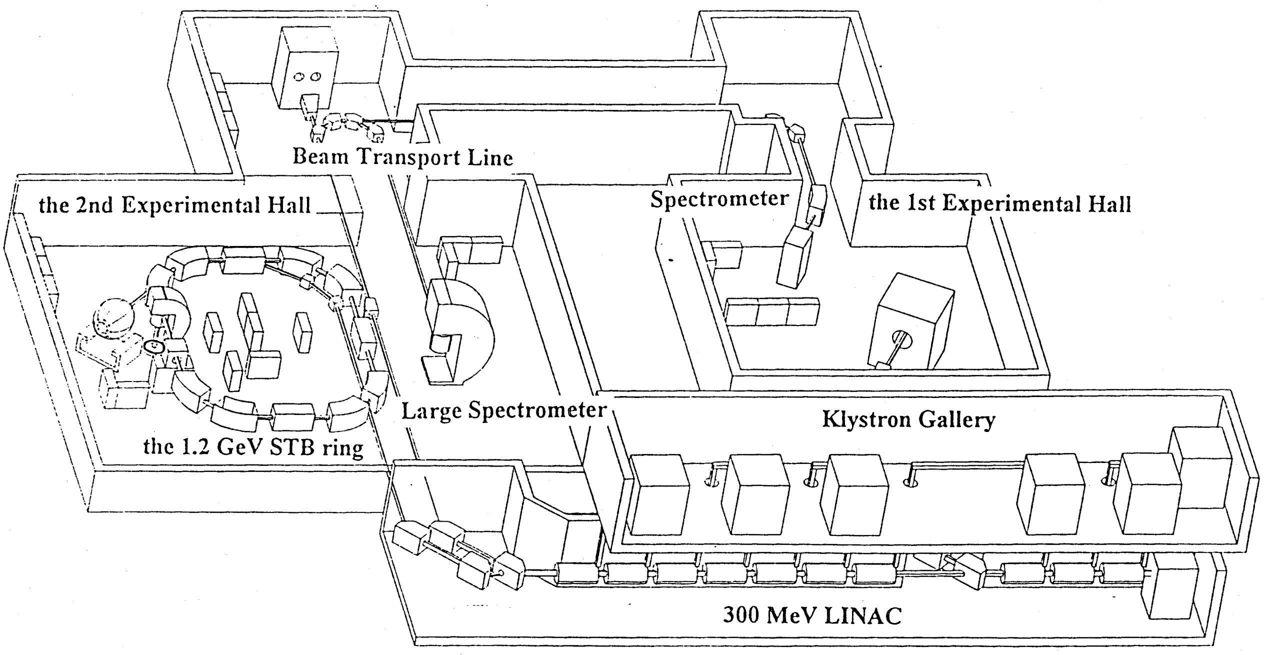

Fig. 1 A schematic layout of the accelerator at LNS in Tohoku University.

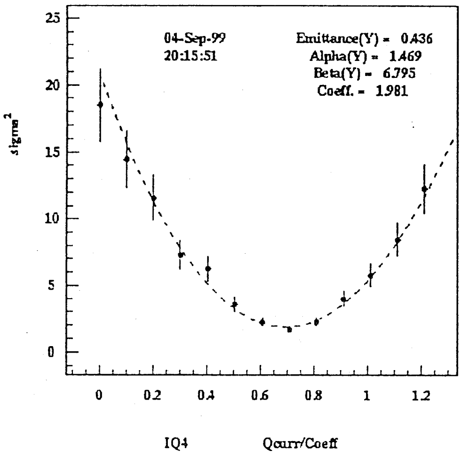

Fig. 2 An example of the parabola fitting to determine the beam parameters.

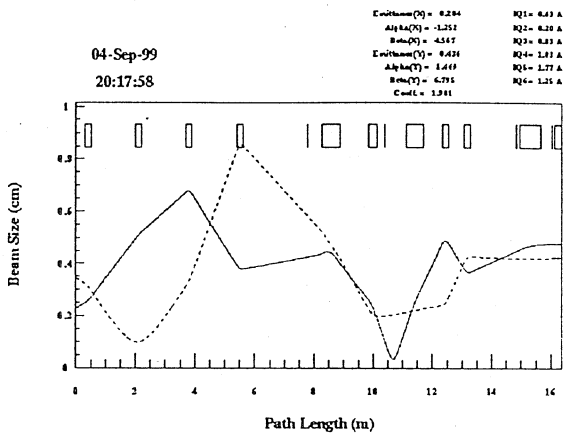

Fig. 3 An example of the fitted result after the injection matching.

of the STB ring, six quadrupole magnets are used in the injection line. First, beam profiles observed by CCD cameras are automatically processed by a personal computer in order to get horizontal and vertical beam sizes [5]. Such beam sizes are measured with varying the strength of an adequate quadrupole magnet, and fitted with a parabola. The emittance and Twiss parameters of the injected beam are determined using three sets of parabola parameters obtained with varying three quadrupole magnets. Then the strength of the quadrupole magnets are optimized to match the injected beam to the ring. Figures 2 and 3 show an example of such a measurement. This procedure is executed manually for the present, however, it will be sophisticated so as to reach to easier operation. The injected beam orbit is adjusted by two septum magnets and three kicker magnets. These kicker magnets must be also adjusted with respect to their timing taking into account of the time-of-flight of the injected beam between them, so as to inject the beam through three turns of the ring with a suitable betatron oscillation amplitude for beam extraction. For the horizontal tune measurement, the radiation from a wire monitor inserted in the ring to disturb the circulating beam is detected by a beam loss monitor which consists of a plastic scintillator and a photomultiplier. For the vertical tune measurement, the synchrotron radiation is monitored by a photomultiplier with a horizontal slit. In the latter case, the beam orbit is distorted in the injection line, so that the amplitude of the betatron oscillation is large enough. Both signals

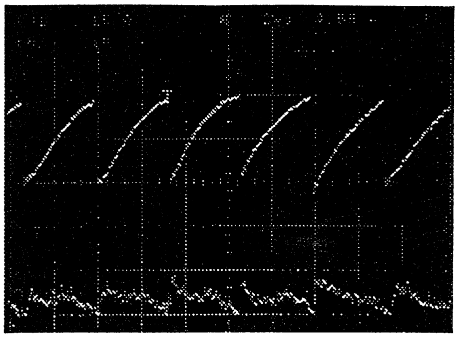

Fig. 4 An example of the beam operation in the stretcher mode, upper: the circulating beam current measured by DCCT (10 mA/div.), lower: the extracted beam observed by a spill monitor placed near the spectrometer.

are recorded in an oscilloscope, and then transformed to the spectrum by a personal computer. This tentative tune monitor system is not enough to measure the tunes stably and should be improved. At the present, the maximum circulating beam current is about 80 mA at the injection. However, the current is usually reduced to 20 ~ 30 mA (preliminary), by a proces to stabilize the beam condition as described below.

Beam extraction from the ring is accomplished by inducing a third-integer resonance in the horizontal plane. The pulse stretcher must keep the intensity of the extracted current constant during the extraction time. This demand is satisfied by monochromatic extraction under 250 MeV. Achromatic extraction will be also used over 250 MeV in the next stage. In the monochromatic extraction, the energy spread of the injected beam is chosen to be equal to the energy loss that occurs between two successive injections, and the chromaticity of the ring is adjusted by a sextupole magnet so that the resonance condition occurs at the lowest energy of the injected beam. Thus the lowest energy part of the stored beam is extracted first, and then finally the highest part is extracted just before the next injection starts. Figure 4 shows the example of the stored current (DCCT) and the extracted beam observed by a spill monitor placed near the spectrometer. Extracted continuous beam current is around 1.2 μA with duty factor of 70 ~ 80 %.

Booster Mode

Since it had been succeeded to accelerate the beam up to 1.2 GeV in the last year, enough machine time had not been assigned for the booster mode by some reasons. One reason was caused by a tuning work on the power supply for bending magnets. In the past months, the magnetic field was ramped up with a ramping time of 6 seconds. The power supply has been recently remodeled, so that the ramping time has become 1 second as designed. Thus the machine study with the booster mode will be restarted soon. According to the preliminary results of the machine study, the stored beam current is about 5 mA after the acceleration up to 1.2 GeV.

Discussion

There have been a lot of problems in the STB operation up to now. Above all, the problems of radiation shield and beam stabilization are serious. In the early time of the beam commissioning, many instruments, such as power supplies and those controllers, monitor control system etc., were placed near the STB ring in the experimental hall. As the circulating beam current increased, magnet power sources and beam monitors were sometimes interrupted from a normal operation due to a heavy radiation. Although a lot of concrete shield blocks were placed, such efforts did not bring critical effect. In the middle of this year, many modules of the control system were moved out from the experimental hall, so that the frequency of the failure in control was reduced. However, many electronics devices are still placed in the experimental hall, we have to cope with the radiation problem.

Another serious problem is an unstable beam feature in the stretcher mode. At the 300 pps operation, six kinds of pulses, which are repeated with 50 pps, are observed in several places. For example, the DCCT signal shows a different time structure and beam current for each of six successive pulses. Such difference is not observed at the 50 pps operation. It seems to be caused by the LINAC. When the LINAC is carefully tuned, the difference of six pulses becomes small, as shown in Figure 4. But this operation reduces the circulating beam current in general. This phenomenon, the so-called hexacolor beam, is discussed in elsewhere [6].

3 Conclusion

The beam commissioning of the 1.2 GeV Stretcher-Booster Ring has been carried out at LNS in Tohoku University. Up to now, the machine time of the STB has been mainly consumed in the stretcher mode with continuing some remodeling work. An extracted continuous beam current is around 1.2 μA with a duty factor of 70 ~ 80 %. The beam commissioning for the booster mode with ramping time of 1 second will be started soon.

References

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