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The Tohoku University Stretcher-Booster Ring

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Abstract

The Tohoku University Stretcher-Booster Ring Project was approved this year. This ring plays three roles: the pulse beam stretcher, the booster and the storage ring for the internal target nuclear experiment. It has four 3.1 m long straight sections and its circumference is 50 m. The maximum energy is 300 MeV as the stretcher and 1.2 GeV as the booster.

I. INTRODUCTION

In the 1970's, the intermediate energy electromagnetic nuclear physics had made the compelling needs for new high intensity continuous electron beam accelerators. Several laboratories in the world had actively studied design alternatives with the objective of constructing accelerators which can meet the needs of future research program. Some of which have been realized as the MAMI, Mainz microtron, the pulse stretcher rings with existing linacs at Saskatchewan, Bates and NIKHEF, and the entirely new superconducting linac at CEBAF. We have proposed the pulse stretcher ring projects since 1978.[1]-[7] A prototype 150 MeV stretcher ring (SSTR) [8] was constructed in 1981 and has been used for coincidence experiments for 14 years. The Tohoku University Stretcher-Booster Ring was approved this year and will be completed in 1997.

II. GENERAL DESCRIPTION

The stretcher-booster ring (STB) plays three roles: the pulse stretcher ring mode which accepts pulsed beam from the 300 MeV Linac and delivers external continuous beam for the nuclear coincidence experiments, the booster ring mode which accelerates electrons up to 1.2 GeV and injects them into another storage ring by fast extraction, and the storage ring mode which holds the beam at 1.2 GeV for internal target nuclear experiments.

Pulsed electron beam from electron linacs is not suitable for the coincidence experiments, and then we need a pulse stretcher which stretches pulsed beam to continuous one. The energy of electrons extracted from a stretcher is the same as the injected energy, 300 MeV in this ring

For the booster and internal target modes, the injected electrons are accelerated using an RF cavity up to 1.2 GeV within 0.4 second. Since the storage ring is dedicated to synchrotron radiation and electrons are injected at the maximum energy, we can expect the high stability of the electron orbital motion. Except the period of injection to the storage ring, the STB may be used for the nuclear experiments simultaneously. The vacuum system of the storage ring will be isolated using a thin foil or differential pumping system, we can use gases for the internal targets in the STB.

Figure 1 shows the layout of the STB. The circumference of the STB is 49.75 m and it has four 3.1 m long straight sections which are used for the injection, the extraction, the internal target experiment and the RF acceleration. Parameters of the STB are listed in Table 1.

The beam is extracted fast by using kicker magnets for the booster mode and is done slowly using the third integer

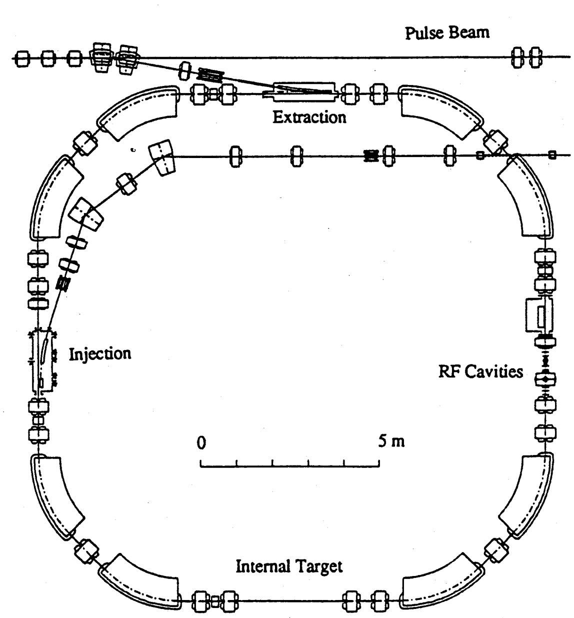

Figure 1. The layout of the STB.

resonance ($\nu_x = 3.33$) for the stretcher mode. The later case that the electron energy should be kept constant by RF acceleration is so-called "achromatic extraction." The STB has two RF acceleration systems, a 2856 MHz system is for the stretcher mode and a 500 MHz system for the booster and the internal target modes. No RF system is needed for stretcher mode operation under 250 MeV and electrons are extracted by means of "monochromatic extraction".

Table 1. Parameters of the STB.

Machine Parameters	
Circumference	49.7512 m
Lattice	DBA
Super Period	4
Betatron Tune	$\nu_x = 3.300$
	$\nu_y = 1.200$
Momentum Compaction Factor	$\alpha = 0.037767$
Chromaticity	$\xi_x = -5.7861$
	$\xi_y = -4.9791$
RF Frequency	500.1/2856.24 MHz
Beam Parameters	
Stretcher mode	
Energy	300 MeV
Energy Loss per Rev.	$U_0 = 2.39\times10^{-4}$ MeV
Energy Width	$\Delta E/E = 1.209\times10^{-4}$
Damping Time	$\tau_x = 7.921\times10^{-1}$ sec
	$\tau_y = 7.131\times10^{-1}$ sec
	$\tau_s = 3.396\times10^{-1}$ sec
Emittance	$\varepsilon_x = 8.585\times10^{-9}$ m·rad
Booster Mode	
Energy	1.2 GeV
Energy Loss per Rev.	$U_0 = 6.11\times10^{-2}$ MeV
Energy Width	$\Delta E/E = 5.8\times10^{-4}$
Damping Time	$\tau_x = 7.23\times10^{-4}$ sec
	$\tau_y = 6.51\times10^{-4}$ sec
	$\tau_s = 3.10\times10^{-4}$ sec
Emittance	$\varepsilon_x = 1.717\times10^{-7}$ m·rad

III. STRUCTURE OF THE STB

The STB lattice has a DBA (Double Bend Achromat) structure and consists of eight bending magnets, twenty quadrupole magnets, a modulated quadrupole and a modulated sextupole. Laminated iron plates are used for all STB magnets. The bending radius of the magnets is 3 m in order to install the STB in the existing experimental room which is 16 m wide, and to realize a long straight section for the internal target system. The magnetic field of bending magnets is 1.33 T at 1.2 GeV. Electrons are injected inside of the ring and the injection beam line from the linac crosses STB orbit. The outside extraction line meets the pulse beam line from the linac. Table 2 shows parameters of a quarter lattice of the STB. Also Figure 2 shows betatron and dispersion functions of a half part of the STB.

Table 2. A quarter lattice of the STB

Configuration

O_1 - QF - O_2 - QD - O_2 - BM - O_2 - QC - O_2 - BM - O_2 - QD - O_2 - QF - O_1

Drift Space	
O_1	1.5625 m
O_2	0.50 m
Bending Magnet	
Bending Angle	45°
Bending Radius	3 m
Length	2.355 m
Edge Angle	0°
Quadrupole Magnet QM	
Length	QF = QD = 0.3 m
	QC = 0.4 m
Bore Radius	R = 0.05 m
Focus (horizontal)	QF $k = 2.0617\ m^{-2}$
	QC $k = 2.737\ m^{-2}$
Defocus (horizontal)	QD $k = -2.2287\ m^{-2}$
Modulated Quadrupole Magnet PQM	
Length	0.1 m
Bore Radius	0.05 m
	$k = 0.2\ m^{-2}$
Modulated Sextupole Magnet PSX	
Length	0.1 m
Bore Radius	0.06 m
	$k = 10\ m^{-3}$

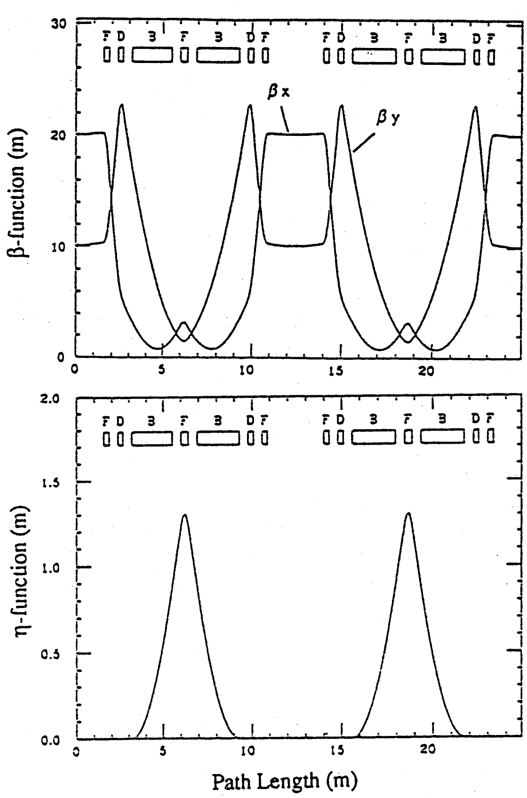

Figure 2. Betatron and dispersion functions of the STB.

IV. RF SYSTEM

Two types of RF system are installed in the STB. One is 500 MHz system for the booster ring and internal target modes and the other is 2856 MHz system for the stretcher ring mode. Parameters of RF system are listed in Table 3.

For the booster ring and internal target modes, the 500 MHz system is chosen since a high power RF source is required for acceleration up to 1.2 GeV. Devices around 500 MHz are commonly used at many accelerator facilities and are available at reasonable price. The cavity is a single cell with two nose cones which has been optimized at KEK and its shunt impedance is 5 MΩ. A 100 kW klystron is adopted to accelerate and to compensate the synchrotron radiation energy loss in the bending magnets as well as the energy loss for higher order mode excitation.

The 2856 MHz system is installed for the stretcher mode to accept all the electrons from the linac without spill. In this mode, the stored current jumps up from zero to 300 mA within 0.5 μsec. and falls down linearly to zero until the next injection. This scheme is repeated at 300 cycles per second. Because it is difficult to control RF voltage and phase according with such rapid change, we adopt a cavity with very low shunt impedance and with input coupler of very large coupling constant (β=15). Then the voltage and phase of accelerating field are kept within small fluctuation.

V. CONCLUSION

All components of the STB, except RF system and magnet power supplies for booster operation, will be installed next spring, and we will start commissioning for stretcher mode operation.

The Tohoku 1.5 GeV low emittance storage ring proposal is under investigation, and it shall hopefully follow completion of the STB. The STB will provide electrons to the storage ring.

Table 3. Parameters of the RF system.

	Booster Mode	**Stretcher Mode**
Maximum Energy	1.2 GeV	300 MeV
Maximum Current	300 mA	300 mA
RF Frequency	500.1 MHz	2856.24 MHz
Harmonic Number	83	474
Shunt Impedance	5 MΩ	0.25 MΩ
Over-voltage Factor	6.0	12
Acceleration Voltage	367 kV	2.87 kV
Quantum Lifetime	38 hours	
Synchronous Phase	80.4°	85.2°
Synchrotron Freq.	59.5 kHz	197 kHz
Klystron Output	100 kW	500 W
Wall Loss	27 kW	32.9W
Number of Cavities	1	1

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