The Tohoku University Stretcher-Booster Ring

Masayuki Oyamada and Working Group
Laboratory of Nuclear Science, Tohoku University
Mikamine, Taihaku-ku, Sendai 982, Japan

Abstract

The Tohoku University Stretcher-Booster Ring is proposed. This ring plays three roles: the pulse beam stretcher, the booster and the storage ring for the internal target nuclear experiment. It has four 2.9 m long straight sections and its circumference is 49 m. The maximum energy is 300 MeV as the stretcher and 1.2 GeV for as 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 Saskachewan, Bates and NIKHEF, and the entirely new superconducting linac at CEBAF. We have proposed the pulse stretcher ring projects since 1978.[1]-[6] A prototype 150 MeV stretcher ring (SSTR) [7] was constructed in 1981 and has been used for coincidence experiments for 12 years. We propose a new realistic stretcher ring in the existing experimental room.

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 contineous 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 proposal.

For the booster and internal target modes, the injected electrons are accelerated using an RF cavity up to 1.2 GeV during 0.5 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, STB may be used for the nuclear experiments simultaneously. The vacuum sytem of the storage ring is isolated using a thin foil or differential pumping system, we can use gases for the internal targets in the STB.

A high injection and extraction efficiency is required for the stretcher mode since the injection and extraction are repeated at 300 cycles per second. The rather long straight section is necessary for the injection and extraction systems to keep their performances and the configurations and strength of the magnets would be subject to restriction somewhat. Another long straight section is needed for the internal target spectrometer and it is important that the size of stored beam is small at this point. Thus STB has been designed under the conditions mentioned above.

Figure 1 shows the layout of STB. The circumference of STB is 49.13 m and it has four 2.9 m long straight sections which are used for the injection, the extraction, the internal target and the RF acceleration. The straight section for the internal target system and the opposite section would be 4.5 m long by rearranging quadrupoles. Parameters of 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 resonance (ν_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." STB has two RF acceleration systems, a 2856 MHz system is for the stretcher mode and a 476 MHz system for the booster and the internal target modes.

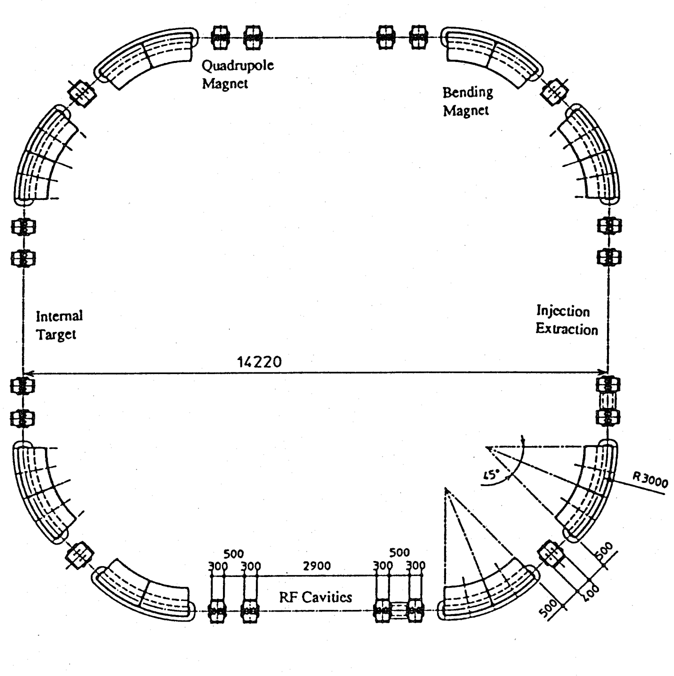

Figure 1. The layout of STB.

Table 1. Parameters of the STB.

Machine Parameters	
Circumference	49.13 m
Lattice	DBA
Super Period	4
Betatron Tune	$\nu_x = 3.326$
	$\nu_y = 1.200$
Momentum Compaction Factor	$\alpha = 0.03815$
Chromaticity	$\xi_x = -6.099$
	$\xi_y = -4.8158$
RF Frequency	476/2856 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	$\tau_x = 7.921\times10^{-4}$ sec
	$\tau_y = 7.131\times10^{-4}$ sec
	$\tau_s = 3.396\times10^{-4}$ 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	$\tau_x = 7.16\times10^{-1}$ sec
	$\tau_y = 6.45\times10^{-1}$ sec
	$\tau_s = 3.07\times10^{-1}$ sec
Emittance	$\varepsilon_x = 1.978\times10^{-7}$ m·rad

III. STRUCTURE OF STR

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 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 flux of bending magnets is 1.33 T at 1.2 GeV. Table 2 shows parameters of a quarter lattice of STB. Also Figure 2 shows betatron and dispersion functions of a quarter part of STB.

Table 2. A quarter lattice of STB

Configuration

$O_1 - O_2$ - QF - O_3 - QD - O_3 - BM - O_3 - QFC - O_3 - BM - O_3 - QD - O_3 - QF - $O_2 - O_1$

Drift Space	
O_1	1.25 m
O_2	0.20 m
O_3	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
	QFC = 0.4 m
Bore Radius	R = 0.05 m
Focus (horizontal)	QF $k = 2.0617\ m^{-2}$
	QFC $k = 2.737\ m^{-2}$
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
	$k = 10\ m^{-3}$

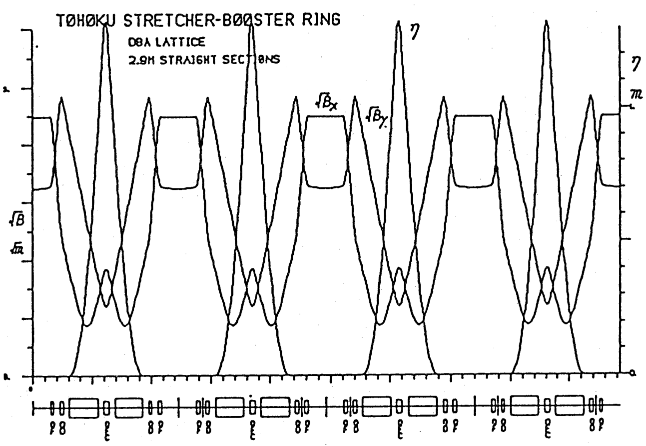

Figure 2. Betatron and Dispersion functions of STB.

IV. RF SYSTEM

Two types of RF system are installed in STR. One is 476 MHz system for the booster ring and internal target modes and the other is 2856 MHz system for stretcher ring mode. Parameters of RF system are listed in Table 3.

For the booster ring and internal target modes, the 476 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. This frequency is one sixth of the linac operating frequency (2856 MHz) and synchronous operation of STR with Linac is possible. 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 a rapid change. We adopt cavities with very low shunt impedance and with input couplers of very large coupling constant (β=15). Then the voltage and phase of accelerating field are kept within small fluctuation.

Table 3. Parameters of the RF system.

	Booster Mode	**Stretcher Mode**
Maximum Energy	1.2 GeV	300 MeV
Maximum Current	100 mA	300 mA
RF Frequency	476 MHz	2856 MHz
Harmonic Number	78	468
Shunt Impedance	5 MΩ	0.25 MΩ
Over-voltage Factor	6.0	11
Acceleration Voltage	367 kV	30.0 kV
Quantum Lifetime	38 hours	
Synchronous Phase	80.4°	89.54°
Synchrotron Freq.	59.5 kHz	102 kHz
Klystron Output	100 kW	50 kW
Wall Loss	27 kW	90W
Number of Cavities	1	2

VI. REFERENCES

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