The 13th Symposium on Accelerator Science and Technology, Suita, Osaka, Japan, October 2001

MEASUREMENTS OF OPTICAL PARAMETERS OF THE STB RING AT LNS

A. Miyamoto, H. Hama, F. Hinode, A. Kurihara, M. Mutoh, M. Nanao, Y. Shibasaki,
K. Shinto, S. Takahashi, and T. Tanaka
Laboratory of Nuclear Science, Tohoku University,
1-2-1 Mikamine, Taihaku, Sendai 982-0826

Abstract

A Stretcher-Booster ring (STB ring) at Laboratory of Nuclear Science (LNS) has recommissioned in these years since beam diagnostic devices were installed. Various optical parameters of the STB ring are now able to be measured, so that we have measured beta functions, chromaticities, dispersion function, and closed-orbit distortion (COD), and compared them with designed value. Furthermore COD has been corrected by using 4 steering magnets, and successfully decreased to within 1 mm from uncorrected one of ~10 mm maximum through the ring.

1 STRETCHER-BOOSTER RING

The STB ring[1,2] at LNS, shown in Figure 1, is a multipurpose electron synchrotron has major two functions, i.e., a stretcher ring converting linac pulsed-beam to quasi cw-beam and a booster-storage ring to supply higher energy beams up to 1.2 GeV. Fundamental designed parameters of the STB ring are shown in Table 1. Lattice structure of the ring is the double-bend achromat consisted of 4 unit cells. Three dispersion-free straight sections are occupied by an injection septum, an RF cavity and a wire septum for slow extraction, and an extraction septum. One remaining straight section is reserved for future projects. An internal target wire for Bremsstrahlung γ-ray production is installed in a bending section for nuclear physics experiments.

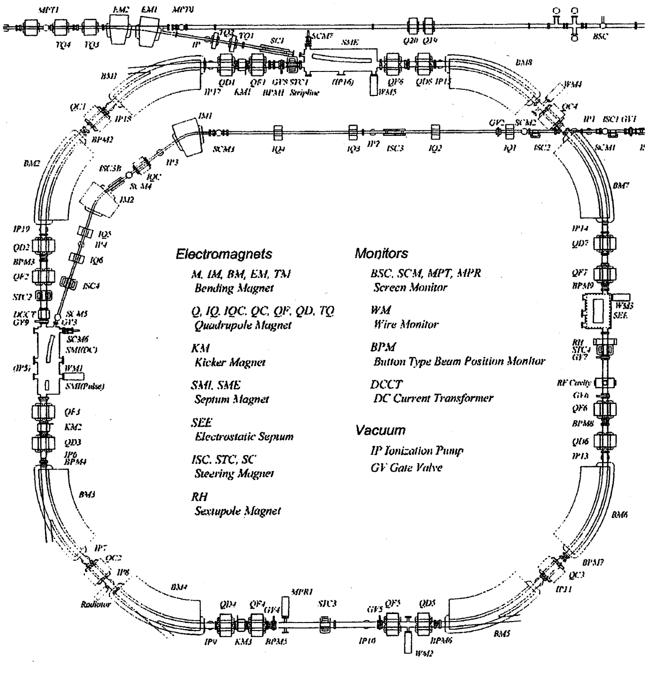

Figure 1: The Stretcher-Booster Ring at LNS.

Table 1: Designed parameters of the STB ring.

Lattice type	Chasman-Green
Superperiodicity	4
Circumference	49.751 m
Maximum energy	1.2 GeV
Injection energy	0.2 GeV (nominal)
Betatron tune	(3.30, 1.20)
Chromaticity	(-5.79, -4.98)
Momentum compaction α	0.0378
RF frequency	500.1 MHz
Harmonics	83

2 MEASUREMENT SYSTEMS

2.1 Tune measurements by a strip-line

A beam duct containing 4 strip-line type electrodes is installed in a straight section of the STB ring. Tune measurements are executed by two beam signals from one pair of electrodes on opposite angle are fed into a 180° hybrid mixer and analyzed by a real time spectrum analyzer. Betatron oscillations are excited by affording external RF dipole field on another pair of diagonal strip-lines. Accordingly betatron tunes in both plane are able to be measured simultaneously. On the other hand using white noise at a certain frequency range near the betatron frequency, RF knockout fields can be produced. Schematic of tune measurements system is shown in Figure 2.

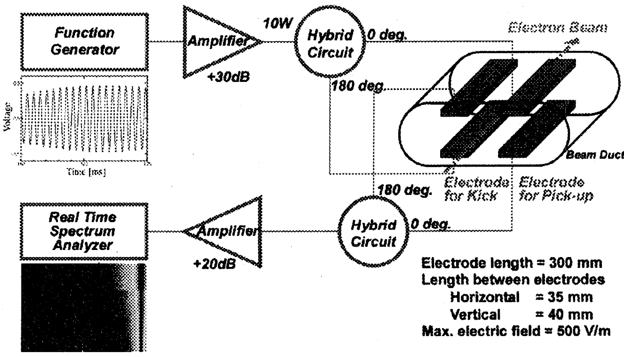

Figure 2: Tune measurement system.

2.2 Beam position monitor

The STB ring has 9 beam position monitor (BPM) of button-type electrodes for measurement of beam orbit. BPM-2 and 7 are installed in bending sections and others are in straight sections. The BPM system is composed of signal pickup parts with 4 electrodes, RF amplifiers with multiplexer (BERGOZ Beam Position Monitor), ADC (YOKOGAWA WE7000) to digitize signals and personal computer to calculate the beam position.

3 COD CORRECTION BY STEERING MAGNETS

The ring is equipped with 4 steering magnets at each straight section for COD correction. The COD correction has been done by using a χ-square fitting employing measured transfer matrices of steering magnets to derive excitation currents of them. Deference of COD between before and after correction is shown in Figure 3. Though the maximum deviation of the beam position from the central orbit has reaches more than 10 mm before correction, it was successfully decrease to about less than 1 mm.

BPM-2 and 7 at path length of 17.943 m and 42.819 m are placed in the dispersive sections. Beam positions at this section depend on the RF frequency. However we have not convinced the center frequency experimentally. Consequently, beam positions at BPM-2 and 7 were excluded in the fitting procedure for the COD correction.

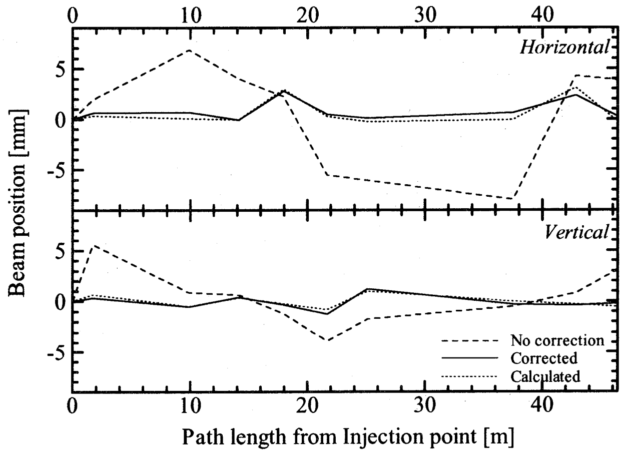

Figure 3: Comparison of the COD between with and without correction. Calculated beam orbits using the transfer matrix are also shown.

4 MEASUREMENTS OF OPTICAL PARAMETERS OF STB RING

4.1 Beta function

By changing the excitation currents of quadrupole families (QF and QD), averaged beta functions in one unit cell of the STB ring were derive from tune shifts measured by real time spectrum analyzer. Figure 4 shows measured horizontal and vertical beta functions, and solid and dashed lines are calculated one from the designed lattice.

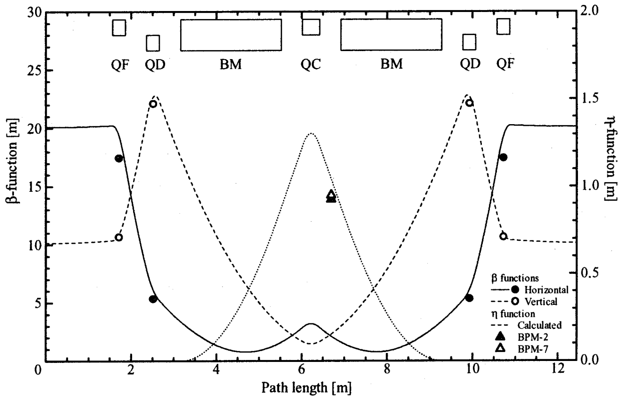

Figure 4: Measured beta functions and dispersion function in one unit cell of the STB ring. Closed and open circles denote measured horizontal and vertical beta functions, respectively. Lines are the calculated lattice functions. Closed and opened triangles show the measured dispersion functions at BPM-2 and 7.

4.2 Dispersion function

Dispersion functions at 9 positions where BPMs are installed are deduced from measured orbit displacements depending on momentum deviation. The beam momentum was changed by varying the RF frequency, in which a calculated value of momentum compaction factor was employed. Measured dispersion functions at BPM-2,7 and designed value are shown by a line in Figure 4. The others at dispersion-free straight sections are less than 10 cm as shown in Table 2.

Table 2: Measured dispersion functions at dispersion-free straight sections.

BPM No.	Dispersion [m]
1	-0.012
3	-0.027
4	-0.012
5	-0.097
6	-0.042
8	-0.057
9	-0.087

4.3 Chromaticity

Since the stretcher mode of the STB ring works by employing the tune shift due to synchrotron radiation loss without the RF capture, fine adjustment of instantaneous tunes for the injected beam is crucial for proper operation. Tunes at just after the beam injection was found to be observed by the real time spectrum analyzer (TEKTRONIX 3026) as shown in Figure 5. The beam energy and its width at the injection are able to be selected by a high precision energy analyzer consisted with achromatic double-bend magnets and a slit. Figure 6 shows measured tunes as a function of the beam energy and fitted results for chromaticities. Deduced values of the horizontal and vertical chromaticities are -5.86 ± 0.04 and -4.77 ± 0.04, respectively, which are in good agreement with the designed value. This method seems to have better accuracy because uncertainty of measured tune comes from only an error of the magnetic field of the energy analyzer. In the analysis for chromaticity, the error of beam energy (~10 keV) is estimated from stability of analyzer magnets and uncertainty in measurements of magnetic field using NMR method. In addition, the error of measured tunes (0.00052) is includes resolution of the real time spectrum analyzer (3.125 kHz).

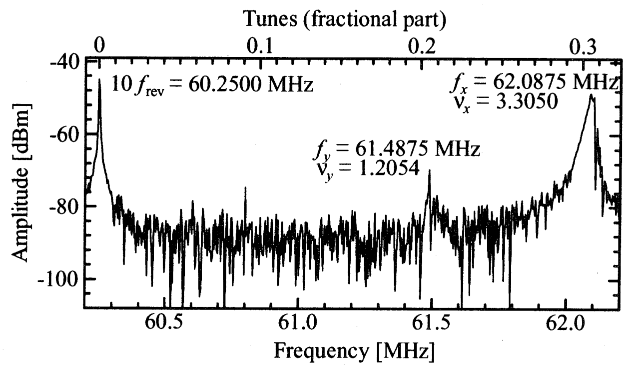

Figure 5: Betatron tunes just after beam injection measured by the real time spectrum analyzer.

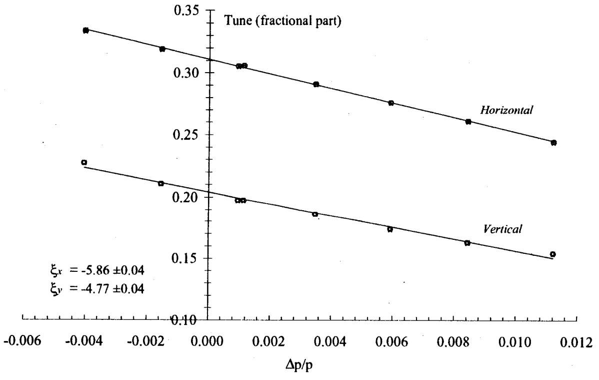

Figure 6: Horizontal and vertical tunes plotted as a function of the energy of injected beam. Solid lines are fitted by the least squares method.

4.4 Momentum compaction factor α

Momentum compaction factor α was also derived from measurements of momentum dependence of revolution frequency by using the real time spectrum analyzer, in which the 31st harmonics of the revolution frequency was chosen to obtain higher frequency resolution. Better to obtain changes of beam energy at the moment chromaticity is measured. A result of measurement is shown in Figure 7, and the deduced momentum compaction factor is 0.0376 ± 0.0023, which agrees very well with the calculated one. This error is determined in the same way of the chromaticity measurement.

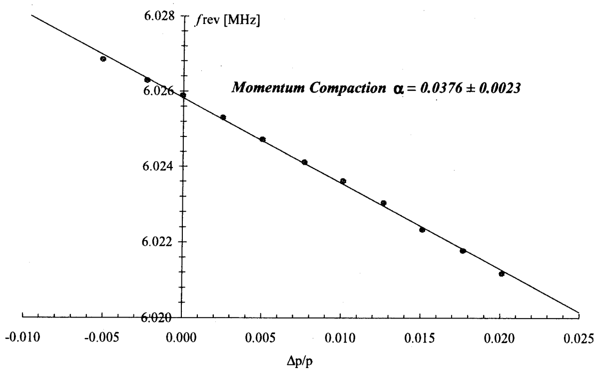

Figure 7: Momentum dependence of the revolution frequency. Only the first order momentum compaction α is taken account in the fit.

5 CONCLUSION

The measured optical parameters of the STB ring are summarized in Table 3, and are compared with the calculation. It can be concluded that the designed optics is mostly accomplished. That is surely very significant to extract higher performance of the accelerator. Further precise measurement of the ring optics such as local beta functions and higher order effects is going to be carried out.

Table 3: Measured optical parameters of the STB ring and designed ones.

Optical parameters		Measured	Designed
β @ QF [m]	*x*	17.43	19.36
	y	10.64	10.91
β @ QD [m]	*x*	5.32	6.13
	y	22.09	22.68
Dispersion [m]	*x*	0.93, 0.95	1.04
Chromaticity	*x*	-5.86(4)	-5.79
	y	-4.77(4)	-4.98
Momentum compaction α		0.0376(23)	0.0378

REFERENCES

[1] F. Hinode et al., Proceedings of the 12th Symposium on Accelerator Science and Technology, Wako, Japan, (1999) 177.

[2] H. Hama et al., Proceedings of the 18th International Conference on High Energy Accelerators, Tsukuba, (2001) to be published.