DESIGN OF BOOSTER SYNCHROTRON FOR MUSES

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Abstract

The Booster Synchrotron Ring (BSR) is a part of Multi-USe Experimental Storage rings (MUSES). BSR functions exclusively for the acceleration of ion and electron beams. The maximum accelerating energy is, for example, to be 3 GeV for proton; 1.45 GeV /nucleon for light ions of q/A=1/2; 800 MeV/nucleon for heavy ions of q/A=1/3. Electron beam is accelerated to 2.5 GeV from the injection energy 300 MeV. The accelerated ion and electron beams will be fast extracted and injected into the Double Storage Rings (DSR) by one turn injection. As another operation mode, ion beams will be slowly extracted for the experiments. In this paper, results of lattice study and injection and extraction procedures of the BSR are presented.

1 LATTICE REQUIREMENTS AND CONSTRAINS

The lattice structure is to be as compact as possible. Basically FODO structure is used, and we adopt a racetrack type to accommodate two long straight sections. They are used for the devices for fast and slow extraction of ion and electron beams and RF cavities.

The circumference of BSR is 179.716m which is 32/6 times the SRC extraction radius, and the maximum magnetic rigidity is 14.6Tm. Those values are determined by a requirement that heavy ions with q/A=1/3 are accelerated up to the energy of 800 MeV/nucleon. Transition γ was set to be as high as 4.22, being satisfactory value for beam stability.

2 BSR LATTICE DESCRIPTION

As shown in Fig.1, the BSR consists of two arc sections and two long straight sections. Each arc section is mirror symmetrical system, and there are two bending cells. Each bending cell is a dispersion suppresser arc, and consists of four FODO cells because this number of cells is specified to raise γ_t sufficiently large. The dispersion in the straight sections outside the arc section is zero. The length of a dipole magnet of 1.911 m is determined by the circumference specification. The maximum magnetic field of a dipole (1.5 T) is determined by required maximum rigidity of 14.6 Tm. The lattice is specified for eight families of quadrupoles; QF1 and QD1, QF4 and QD4 in the arcs, QF2 and QD2, QF3 and QD3 in the long straight sections. The structure of one FODO cell and short straight section in the arc are given as follows.

$$\mathrm{cel}=\mathrm{QF1}\,\underline{d_1}\,\mathrm{B}\,\underline{d_2}\,\mathrm{QD1}\,\underline{d_1}\,\mathrm{B}\,\underline{d_2}$$

$$\mathrm{str2}=\mathrm{QF4}\,\underline{d_3}\,\mathrm{QD4}\,\underline{d_s}\,\mathrm{QD4}\,\underline{d_3}\,\mathrm{QF4}$$

Then, the lattice of each arc section (60.365 m) is

arc=(cel,cel.cel,cel,str2,-cel,-cel,-cel,-cel)

In this structure, d1 (d2) is 0.925 m (0.475 m) drift space which are used for sextupole magnets for chromaticity correction and kicker magnets for COD correction.

The two long straight sections are mirror symmetry structure. The lattice of each section (23.876 m) is

$$\mathrm{str1}=\underline{d_s}\,\mathrm{QF2}\,\underline{d_3}\,\mathrm{QD2}\,\underline{d_s}\,\mathrm{QD3}\,\underline{d_3}\,\mathrm{QF3}\,\underline{d_3}\,\mathrm{QD3}\,\underline{d_s}\,\mathrm{QD2}\,\underline{d_3}\,\mathrm{QF2}\,\underline{d_s}$$

where, d_S is a free space with a length of 4.276 m which is used for RF cavities, injection kickers or other device.

Then, the whole lattice of BSR is described as follows.

BSR=(arc,str1,arc,str1)

Tune values are chosen from the tune diagram shown in Fig.2. The parameters of the lattice are summarized in Table 1. The β and dispersion functions are shown in Fig.3. Transition γ is 4.643 and the peak dispersion is 3.730 m. The peak β function are 14.028 m in horizontal direction and 15.089 m in vertical direction. The calculation is performed using the MAD program.

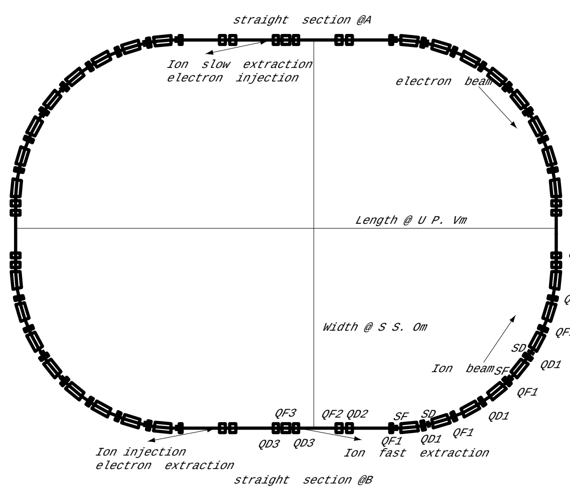

Fig.1 A Layout of BSR

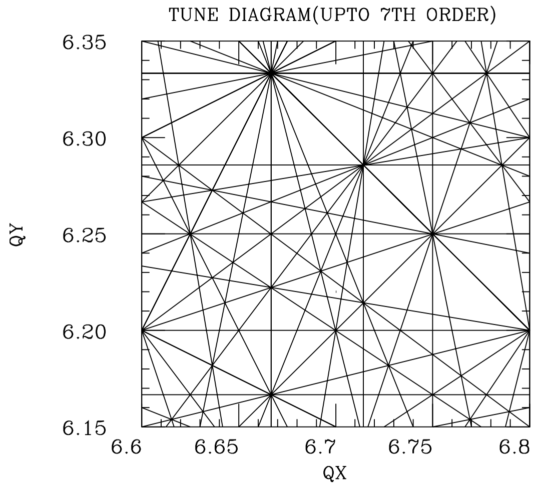

Fig.2 Tune diagram

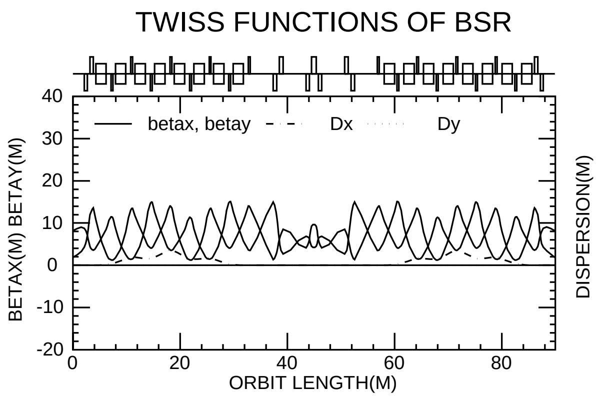

Fig.3 β and dispersion functions along the lattice

Table 1. Lattice Parameter of BSR

Circumference	C=179.7159 m
Average Radius	R=28.603 m
Max. Magnetic Rigidity	Bρ=14.6 Tm
Momentum Compaction	α=0.0437
Transition gamma	γ_t=4.643
Betatron Tune Values	Qx/Qy=6.700/6.220
Natural Chromaticity	Q'x/Q'y=-8.896/-8.321
Max.β Amplitude	βx/βy=14.028m/15.089m
Max.Dispersion	Dx/Dy=3.730m/0.0

3 DYNAMIC APERTURE

The dynamic aperture might be seriously reduced when chromaticity is corrected. The reason for this is due to the low average value of dispersion in a ring, corresponding to high γt. In this lattice, natural chromaticity values are -8.896 (horizontal) and -8.321 (vertical) , and are corrected by two families of sextupoles SF and SD, (focusing and defocusing), associated with their respective qurdrupoles as indicated in Fig.1. Same family's sextupoles in one bending cell, are located π apart in phase in order not to excite the resonance with particular amplitude and phase. The normalized field strengths of sextupoles required to correct chromaticity are relatively large: 9.036 m^{-3} for the SF and -15.000 m^{-3} for the SD. The tracking results of the beam with $\varepsilon_x=125\pi$ mm.mrad, $\varepsilon_y=5\pi$ mm.mrad and fully corrected chromaticity, are shown in Fig.4. The largest initial betatron amplitude for which particles are still on a stable orbit is defined as a dynamic aperture. The above tracking results show that the dynamic aperture of BSR is larger than $\varepsilon_x=125\pi$ mm.mrad and $\varepsilon_y=5\pi$ mm.mrad. Next, we calculate the tracking for the beam with $\varepsilon_x=750\pi$ mm.mrad, $\varepsilon_y=30\pi$ mm.mrad, dp/p=10^{-3} and fully corrected chromaticity when all magnet elements have been misaligned (misalignments are ±100μm and rotations are ±0.1mrad) and field errors (sextupole components of dipole magnets are ±0.1 m^{-3}) introduced randomly. These tracking results shows that the dynamic aperture of BSR is as large as $\varepsilon_x=750\pi$ mm.mrad and $\varepsilon_y=30\pi$ mm.mrad.

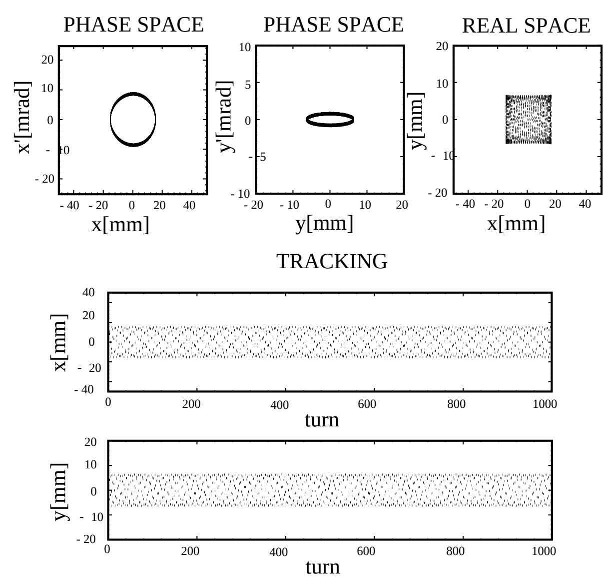

Fig.4 Result of single-particle tracking

Further tracking has to be performed to obtain information about the main sources of dynamic aperture reduction and to estimate the level of multipolar content tolerable in the dipoles.

4 INJECTION AND EXTRACTION

An arrangements of the injection and extraction magnets are shown in Figs 5 and 6. The BSR lattice is designed to be able to operate with two different extraction mode for ion beams; fast extraction and slow extraction.

As seen in Fig.5, an electrostatic septum(ES), four septum magnets(SM1, SM2, SM3, SM4) and three bump magnets(BM1) are used for the electron beam multi-turn injection. These magnets except bump magnets, are used for ion beam slow extraction which is carried out by using third order resonance (ν_{res}=20/3).

As seen in Fig.6, three septum magnets(SM2, SM3, SM5), four bump magnets(BM2) and ten kicker magnets(K1) are used for the ion beam one turn injection. These magnets are also used for electron beam fast extraction. The ion beam from the ACR is injected into the septum magnet SM5 at an angle of with respect to the straight section of the BSR.The ion beam is finally kicked and placed in the reference orbit by the kicker magnets.This kicker magnets are used for ion beam fast extraction. So, kicker magnets must be risen and fallen less than 50 ns.

5 SUMMARY

We have designed the lattice of BSR which satisfies fundamental requirements. This lattice is required to be further investigated in detail for the installation of all the necessary hardwares. Optimization of the lattice of the BSR is under progress.

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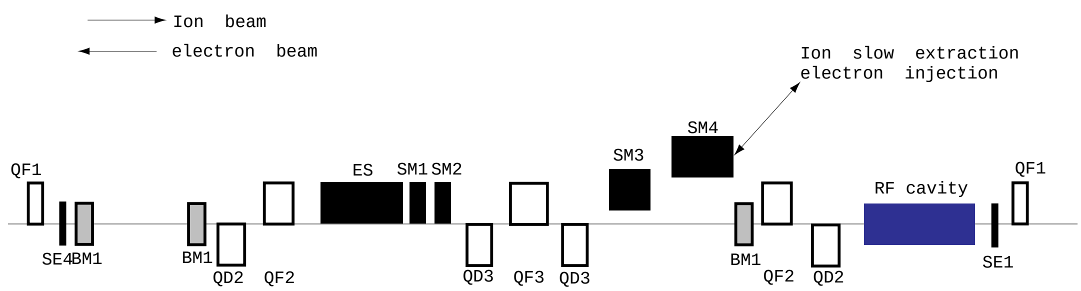

Fig. 5 An arrangement of straight section A

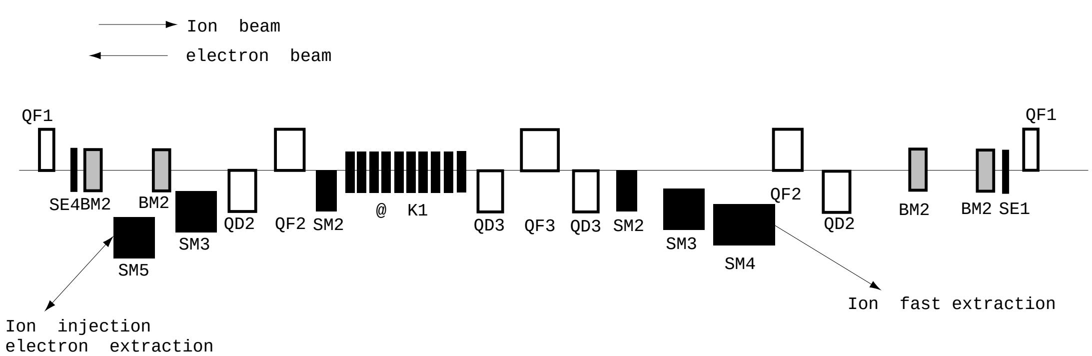

Fig. 6 An arrangement of straight section B