DESIGN OF DOUBLE STORAGE RINGS AT MUSES

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Abstract

Double storage rings (DSR) will play a role to perform various experiments of collision or merging of radio-isotope beams with ions, electron beams and X-rays produced from an undulator. The experiments will be performed at two crossing points. One is for collision of RI beam with electron with crossing angle 20 mrad. Another is for merging for ion beams with angle of 170 mrad. To perform these expriments with high luminosity, electron beam has two different operation modes. The emittance of 10^{-6} m*rad is prepared for the collison with RI and that of 10^{-8} m*rad is done for production of high brilliant X-ray.

1 INTRODUCTION

The DSR is an experimental colliding rings planned in Radio Isotope Beam Factory at RIKEN[1]. In the DSR a variety of unique experiments are envisaged through the collisions of RI beam with electron beam, collision of RI beam with X-ray produced from undulator and merging of RI (ion) beams. To perform these experiments with high luminosity electron beam is required to have two different operation modes. One is a mode to have emittance of the 10^{-6} m*rad (large emittance mode, L.E.M) at energy of 1 GeV. This mode is used for collision with RI beam. Another is to have emittance of 10^{-8} m*rad (small emittance mode, S.E.M) at 2.5 GeV to produce high brilliant X-ray from the undulator. Ion beam is required to have a large maximum energy of 14.6 Tm (800 MeV/u for A/Z=3) and is operated by third mode (ion mode, I.M).

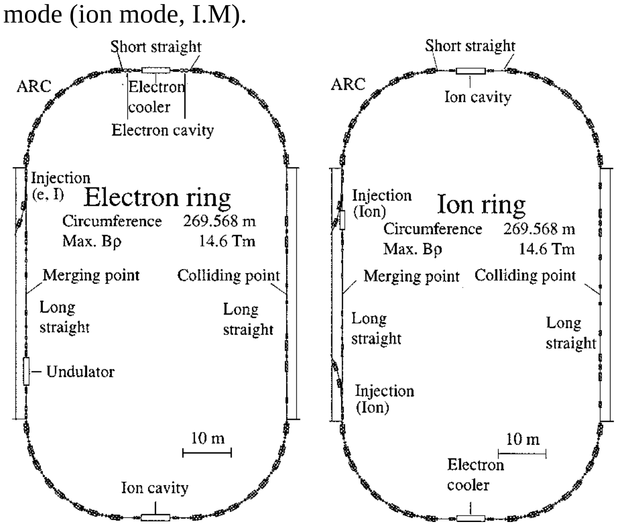

Fig. 1 Two rings in the DSR. 1a is an electron ring and 1b is an ion ring.

The DSR is composed of an electron ring and an ion ring shown in Fig. 1a and b. The electron ring stores not only electron beam but also ion beam for the merging experiment. The ion ring stores only ion beam. The circumference of each ring is 269.568 m which is 8 times larger than that of injector superconducting ring cyclotron. Each ring has four arcs, two long straight sections and two short straight sections.

The arc section is designed to adjust emittance of electron beam. In each long straight section, two rings cross vertically. One crossing point is used for the collision of RI beam with electron beam with collison angle 20 mrad (colliding section). In the colliding section configurations of magnets for the electron and ion ring are different because clearance is small due to small crossing angle. Another crossing point is used for merging of ion beams with merging angle of 170 mrad. (merging section) In the merging section the undulator and insertion devices are also located. Electron beam is injected into the electron ring with multi-turn injection method. Ion beam is inserted into both rings with one turn. Short straight sections are used for an electron cooler and RF cavities. The electron cooler is prepared to supress the beam instabilities and to make a short bunch of ion beam. In the following section, details of each section will be described.

2 DESIGN OF EACH SECTION

2.1 Arc Section

Figure 2 shows configuration of the arc in the DSR for both S.E.M and L.E.M. Small emittance can be produced by making small dispersion in dipole magnet.

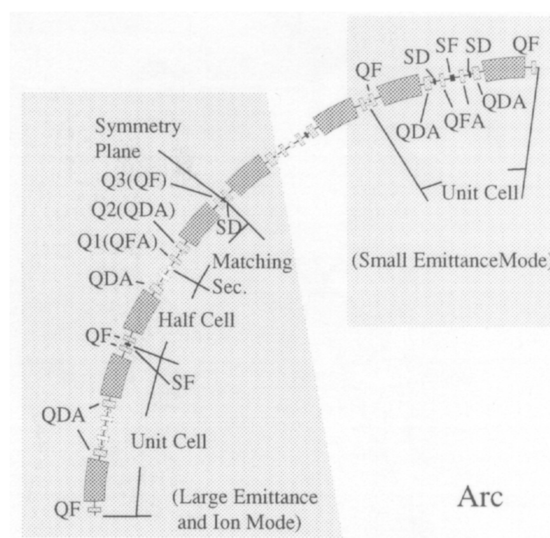

Fig. 2 Compositon of the arc section.

For the S.E.M the arc consists of four unit cells with Double Bend Achromat (DBA) structure. The DBA structure is achieved by the quadrupole magnets for focus (QFA) and those for defocus (QDA). The other quadrupole magnets (QF) are used to fulfill a periodic condition of the cell. Fig. 3 shows β and dispersion functions of the cell. Beta functions fulfill the periodic condition. From the result that dispersion is 0 outside the dipole magnets, one can see that DBA structure is achieved in the cell. The horizontal emittance is almost decided by the cell because there are no horizontal bending magnet except for arcs. The obtained value of horizontal emittance is 13.9 nm*rad at 2.5 GeV. The value is small enough for the S.E.M.

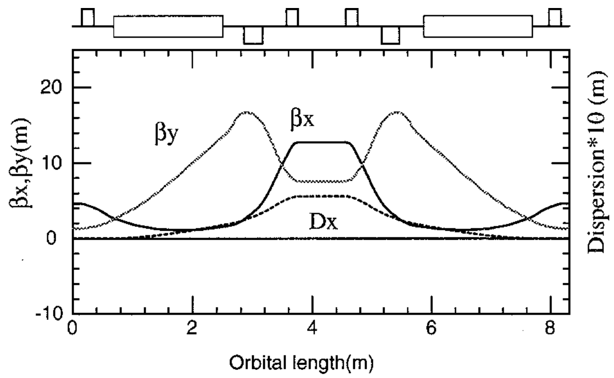

Fig. 3 β and dispersion functions in the unit cell for S.E.M.

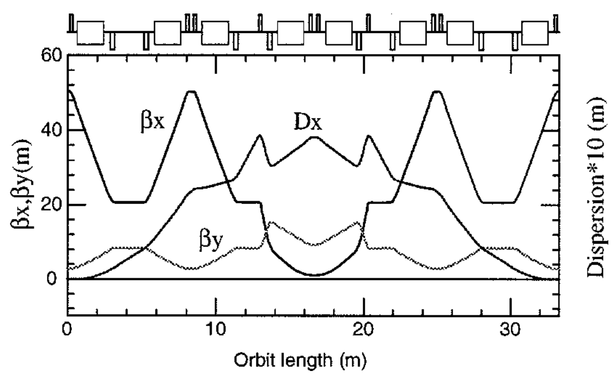

Fig. 4 β and dispersion functions in the arc for L.E.M.

For the L.E.M, emittance is made large by abandoning DBA structure and making large dispersion in dipole magnet. As shown in Fig. 2 the center of the arc is a symmetry plane of β and dispersion functions. The half arc consists of an unit cell, a half cell and a matching section. In the unit and half cell the QFA's are not used to enlarge dispersion in the dipole magnets. In the matching section three quadrupole magnets (Q1, Q2 and Q3) are adjusted to make the symmetry plane at the center of the arc. Figure 4 shows β and dispersion functions of the arc for this mode. Both functions have symmetry plane at the center and a region out of the arc is dispersion free. The obtained value of emittance is 0.76 μm*rad, which fulfills requirements.

For the I.M the composition of the arc is the same as that of the L.E.M. However, since magnetic rigidity of ion beam is much larger than that of L.E.M, focusing powers of quadrupole magnets are adjusted to be weaker than those of the L.E.M. The tendency of the β and dispersion functions are similar. The region out of the arc is also dispersion free in the mode.

2.2 Colliding Section

Figure 5 shows a configuration of the magnet in this section. The crossing angle is chosen as small as possible to get large luminosity. In Fig. 5 path of the electron beam is shown by black arrows and that of the ion beam is shown by white arrows. The electron beam goes to the colliding point with parallel to horizontal plane using two dipole magnets with bending angle 15°. The ion beam goes to the point with angle of 20 mrad (1.145°) after bending down with 10° and bending up with 8.855°.

The small β values of the both beams at colliding point are also chosen in order to get high luminosity. The β values of the electron beam for both horizontal and vertical direction are 0.02 m and those of the ion beam are 0.1 m[3]. To get small β values a quadrupole doublet (QD1) is located at a distance of 1.5 m from the colliding point. The ion beam also passes through the doublet. Since focusing power of the doublet is small for the ion beam additional quadrupole doublet (QDI2) is located at rather long distance from the crossing point. The long distance (7.5 m) is to keep clearance from the beam-line of the electron. The other quadrupole magnets are used to match the emittance of each beam.

The calculated β and dispersion functions of electron and ion beams are shown in Fig. 6 and 7 respectively. In the calculation the central orbit of the ion beam in the quadrupole doublet is assumed to be in the center of the QD1 and QD1'. The maximum β values of the electron beam are 113 m for horizontal direction and 750 m for vertical. The small β value of horizontal direction comparing with that of vertical one is required to prepare large acceptance for electron beam to be inserted by multiturn horizontally. For the ion beam the maximum β values are 1223 m (35 mm in beam size) for horizontal and 970 m for vertical. The large β for the ion mode is due to long distance between the QDI2 and the crossing point.

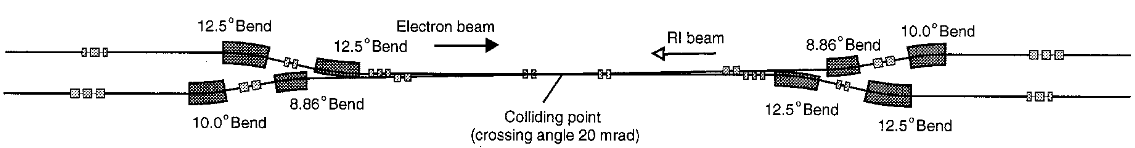

Fig. 5 Side view of the colliding section.

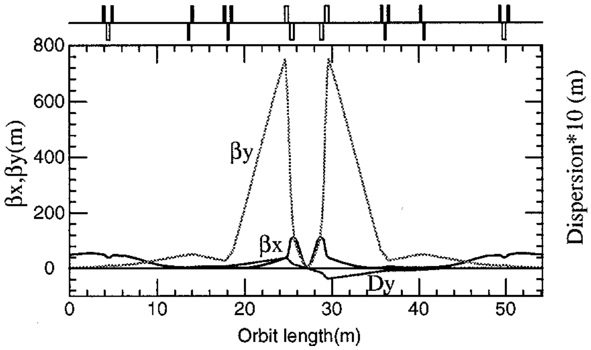

Fig. 6 β and dispersion functions in the colliding section of the electron ring.

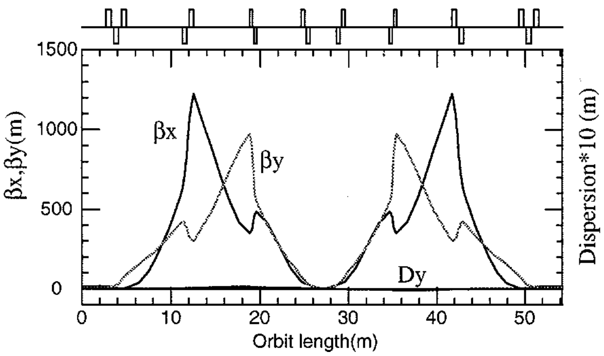

Fig. 7 β and dispersion functions in the colliding section of the ion ring.

2.3 Merging Section

Figure 8 shows a configuration of the magnets for the merging section. The path of the ion beams are shown by two arrows in fig. 8. The crossing angle, 10° is chosen by the requirement of experiments.

Small values of β are also chosen in the mode to get large luminosity. The values of β are 0.6 m for both direction. To get small β value quadrupole doublet is inserted at distance of 3.5 m from the crossing point. To match the emittance several quadrupoles are inserted the section. The configurations of the quadrupole magnets of two beam lines are all the same. The maximum β value in this section is 102 m for horizontal and 58 m for vertical. The small β value in the whole region compared with the that of the colliding section is because the β of crossing point of the merging section is larger than that of the colliding section.

The beam of the undulator is required to be small and pararell for the electron beam of S.E.M. The requirement is fulfilled by inserting of a quadrupole triplet between the arc and the undulator. The obtained β is about 2 m over all the section.

2.4 Short Straight Section

The short straight section is used for the electron cooling of the ion beam. For efficient electron cooling the ion beam should be parallel and have small size. In the section four quadrupole magnets are inserted and make the required beam. The obtained β value is about 7 m over all the section.

3 RING PARAMETERS OF DSR

After the design of each section we calculated the ring parameters for each operation mode. For I.M, two cases are calculated. One is for collision with electron beam (I.M-C). Another is for merging (I.M-M).

The obtained parameters of the four modes are summarized in Table 1. Large chromaticities of L.E.M and I.M-C are originated from large β values and strong filed gradients of quadrupole magnets in the colliding section. That for S.E.M is due to DBA structure of the arc. Natural chromaticity is corrected using sextupoles as shown in Fig. 2.

		S.E.M	L.E.M	I.M-C	I.M-M
Tune	βx	16.105	6.754	6.235	5.637
	βy	9.105	8.163	5.018	5.732
Chromaticity					
	ξx	-29.7	-37.7	-62.7	-11.4
	ξy	-34.7	-90.7	-47.6	-10.3
Transition γ		85.19	4.857	5.071	5.071
Momentum compaction		0.0014	0.042	0.039	0.039
Max. β (m)	βx	24.5	113	1223	102
	βy	51.9	750	970	57.8
β at colliding section (m)	βx*	8.5	0.02	0.1	4.2
	βy*	10.5	0.02	0.1	4.8
β at merging section (m)	βx*	3.9	5.0	10.0	0.6
	βy*	23.4	5.0	10.0	0.6

Table 1 Parameters of the DSR for several modes.

REFERENCES

[1] Yano et al., in these Proceedings.
[2] Wakasugi et al., in these Proceedings.
[3] Katayama et al., proc. of STORI 96, to be published.

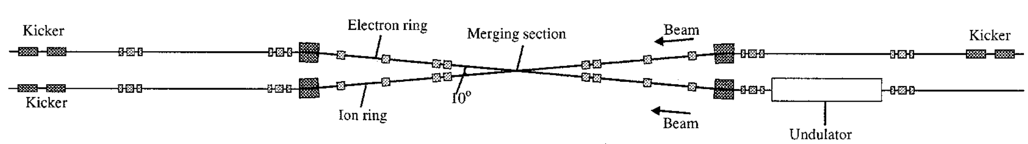

Fig. 8 Side view of the merging section.