Lattice Design of the SRRC 1.3 GeV Storage Ring

C.S. Hsue*, C.C. Kuo, J.C. Lee, and M.H. Wang
Synchrotron Radiation Research Center
No. 1 R&D Rd. VI, Hsinchu Science-Based Industrial Park
Hsinchu, Taiwan, R.O.C.
*Department of Physics, National Tsing Hua University
Hsinchu, Taiwan, R.O.C.

Abstract

We present the magnet lattice of the SRRC 1.3 GeV low emittance synchrotron light source. The lattice consists of six identical cells. Each cell has a Triple-Bend-Achromat (TBA) arc and a 6-m dispersion free long straight section. Quadrupole triplets between achromat arc and long straight section are employed for tune and beta matching. The ring circumference is 120 m. Bending magnets in the arc are with vertically focusing gradient components. Such combined function magnets can reduce vertical beta function and hence vertical aperture is small. The emittance is 1.92×10^{-8} m-rad at 1.3 GeV. Two families of sextupoles are used for chromaticity correction and good dynamic aperture can be achieved.

1. Introduction

A synchrotron radiation facility is under construction at SRRC in Taiwan, R.O.C. The lattice of the storage ring is optimized to be a dedicated low emittance, high brightness light source in the VUV and soft x-ray region. Long straight sections are reserved for the installation of undulator and wiggler magnets, injection elements, and accelerating RF cavities. The nominal beam energy is 1.3 GeV. In this paper, we describe the linear lattice and the beam dynamic aperture in the presence of the sextupole magnets for chromaticity correction.

2. Linear Lattice

The design criteria for the SRRC storage ring are as follows:

(a) The nominal energy is 1.3 GeV and the emittance is less than 2.0×10^{-8} m-rad at 1.3 GeV.
(b) The ring circumference is around 120 m.
(c) Long dispersion free straight sections are required for the installation of the insertion devices and the acceleration RF cavities.
(d) The lattice should be insensitive to various magnetic field errors, and magnet misalignments.
(e) The lattice should be simple and flexible.
(f) Long beam lifetime.

After design studies of several lattices, including FODO, Chasman-Green, and TBA structures, a TBA lattice was chosen as the working lattice which meets the requirements listed above. The lattice structure is similar to the ALS lattice.[1]

The lattice has 6-fold symmetry. Each cell consists of an achromat arc and a 6-m long dispersion free long straight section. The achromat arc is formed by three bending magnets and two focusing quadrupoles. These quadrupoles are used for achromat matching. The bending magnets are gradient bending magnets with vertically focusing components. The value of the field index is n = 4.52. With such combined function bending magnets, the vertical betatron function can be suppressed and hence requires smaller dipole gap. Horizontal partition function is changed so that the natural emittance becomes smaller. Furthermore, the separation of the betatron function near the bending magnet provides suitable location of sextupoles for chromaticity correction.

Quadrupole triplets are used for betatron matching in the long straight section and also used for tune matching. To have efficient horizontal injection, the horizontal beta value β_x^* at the center of the long straight is constrained around 12 m while the corresponding vertical beta value β_y^* is matched to be about 3 m to accommodate the bunched beam inside the small vertical gaps of the insertion devices. Nominal working point with $\nu_x=7.18$, $\nu_y=4.13$ is selected. This tune point is away from systematic third-order resonances. It also appears that variations of the lattice functions are quite smooth in an ample tune space and the dynamic aperture is comfortably large in this large tune range.

A schematic layout of one of the six identical cells is depicted in Fig. 1. Each cell is mirror symmetry with respect to the center of the middle bend. Table 1 lists the lattice structure and strengths. There are four families of quadrupole and two families of sextupole magnets. The linear lattice functions of each cell are shown in Fig. 2. A summary of the main parameters of the storage ring is given in Table 2.

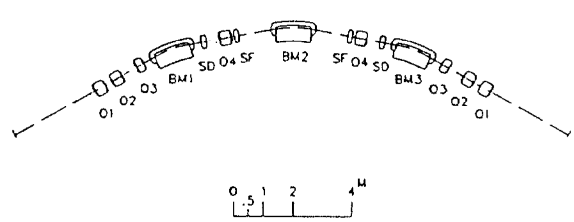

Fig. 1: A schematic layout of one cell of the SRRC lattice.

Table 1 : Lattice parameters of a half-cell of the SRRC storage ring.

Element	Length(m)	Strength
D0(1/2)	3.0	
Q1	0.35	1.50815 m^{-2}
D1	0.30	
Q2	0.35	-2.85966 m^{-2}
D2	0.595	
Q3	0.24	1.15592 m^{-2}
D3	0.435	
B	1.22	1.24 T, n=4.52

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D4	0.37	
SD	0.10	85.1 m^{-3}
D5	0.55	
Q4	0.35	-2.73087 m^{-2}
D6	0.15	
SF	0.10	-69.1 m^{-3}
D7	1.28	
B(1/2)	0.61	1.24 T, n=4.52

Table 2: A summary of the main parameters of the SRRC storage ring.

Nominal energy	1.3 GeV
Circumference	120 m
Natural emittance	1.92×10^{-8} m-rad
RF frequency	500 MHz
Injection energy	1.3 GeV
Harmonic number	200
Horizontal betatron tune	7.18
Vertical betatron tune	4.13
Momentum compaction	0.00678

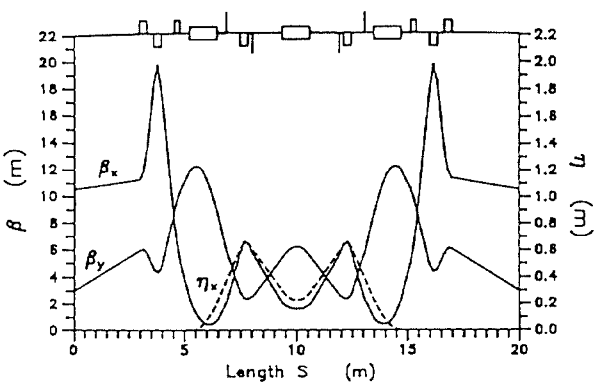

Fig. 2: Lattice functions of the SRRC storage ring.

3.Chromaticity Correction and Dynamic Aperture

The natural chromaticity of a low emittance lattice is usually very high and needs to be corrected to a slightly positive value so as to avoid the so-called head-tail instability. Two families of sextupoles located at proper positions as shown in Fig. 1 are used to correct chromaticity. The integrated sextupole field strength is 8.51 and 6.91 m^{-2} for SD and SF, respectively. The dynamic aperture due to these non-linear fields was obtained using accelerator design codes such as PATRICIA, RACETRACK, MAD, BETA, etc.[2,3,4,5] The results are in good agreement with each other. Fig. 3 shows the dynamic aperture of 1000-turn tracking results from RACETRACK.

Tune shift with momentum deviations reveals the energy acceptance from the tracking point of view and is given in Fig 4. It is found that the energy acceptance of the storage ring is determined by the RF capture of the accelerating system of 500 MHz and 1 MV. The tune variation with respect to the betatron amplitude is the dominating factor in determining the stable amplitude region which is called dynamic aperture. Fig. 5 and 6 show the tune shift versus amplitude. The stable region is larger than 30 mm in the long straight middle. Horizontal phase space trajectories of 3 particles with three different initial betatron amplitudes are shown in Fig. 7. The phase space ellipse for the larger amplitude outside the stable region has large deformation and, hence, particles are lost. Within the stable region the trajectories have small deformations.

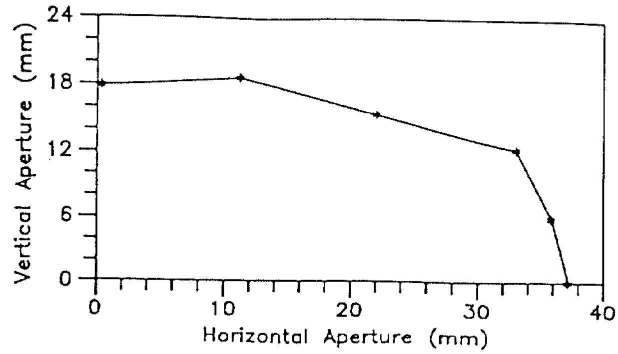

Fig. 3: Dynamic aperture of the SRRC lattice with 1000-turn tracking results from RACETRACK.

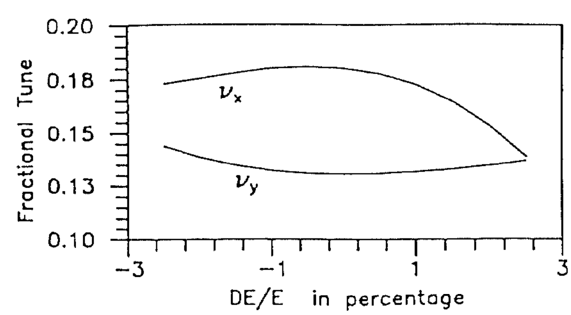

Fig. 4: Tune shift versus momentum deviation.

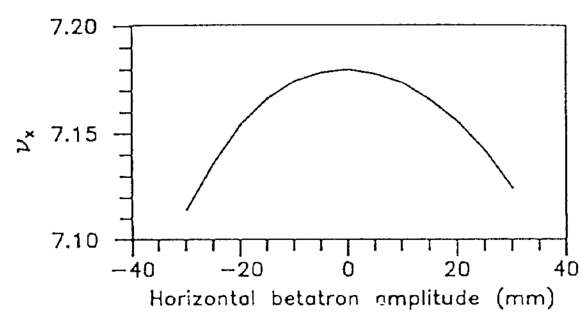

Fig. 5: Horizontal tune variation as a function of horizontal betatron amplitude.

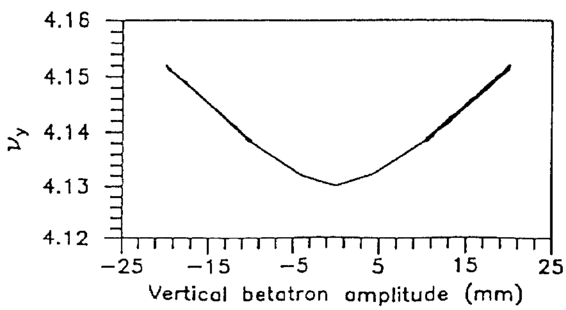

Fig. 6: Vertical tune variation with vertical betatron amplitude.

4. Discussion

The emittance of the SRRC lattice we have described is about 4 times the theoretical minimum value, 5.3×10^{-9} m-rad. However, the lattice is rather relaxed and reliable in terms of the magnetic field errors and magnet misalignment described in another paper presented in the Conference.[6]

5. Acknowledgement

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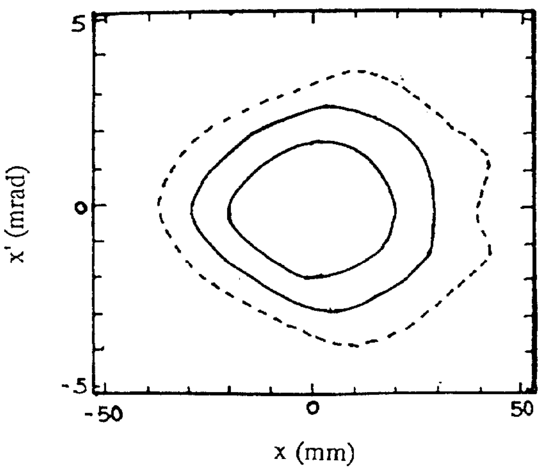

Fig. 7: Horizontal phase space trajectories of three different particles with three different initial amplitudes.

6. References

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