LATTICE OF THE CSR

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Abstract

CSR, a new Cooler-Storage-Ring project, is the post-acceleration system of the Heavy Ion Research Facility in Lanzhou (HIRFL). It consists of a main ring (CSRm) and an experimental ring (CSRe). From the HIRFL cyclotron system the heavy ions will be accumulated, cooled and accelerated in the CSRm, then extracted fast and injected into the CSRe for many internal-target experiments with electron cooling. The experimental ring (CSRe) will be operated with three lattice modes for different experiments. The details of the lattice for the two rings will be described in this paper.

1 INTRODUCTION

HIRFL-CSR, a new accelerator project in Lanzhou[1], is a multi-purpose Cooling Storage Ring system that consists of a main ring (CSRm) and an experimental ring (CSRe), shown in Figure1. The two existing cyclotrons SFC (K=69) and SSC (K=450) of the HIRFL[2] will be used as its injector system. The heavy ion beams with the energy range of 8~30 MeV/u from the HIRFL will be accumulated, cooled and accelerated to the high energy range of 100~400 MeV/u in the main ring (CSRm), and then extracted fast to produce radioactive ion beams (RIB) or highly charged heavy ions. The secondary beams (RIB or highly charged heavy ions) can be accepted and stored by the experimental ring (CSRe) for many internal-target experiments or high precision spectroscopy with beam cooling. On the other hand the beams with the energy range of 100~900MeV/u will also be extracted from CSRm while using slow extraction or fast extraction for many external-target experiments.

Two electron coolers located in the long straight sections of CSRm and CSRe respectively, will be used for beam accumulation and providing high quality beams for internal-target experiments.

2 LATTICE OF THE CSRM

The CSRm layout is a racetrack shape shown in Figure 2, and consists of four identical arc sections. Each arc section consists of four dipoles, two triplets and one doublet. 8 independent variables for quadruple are used.

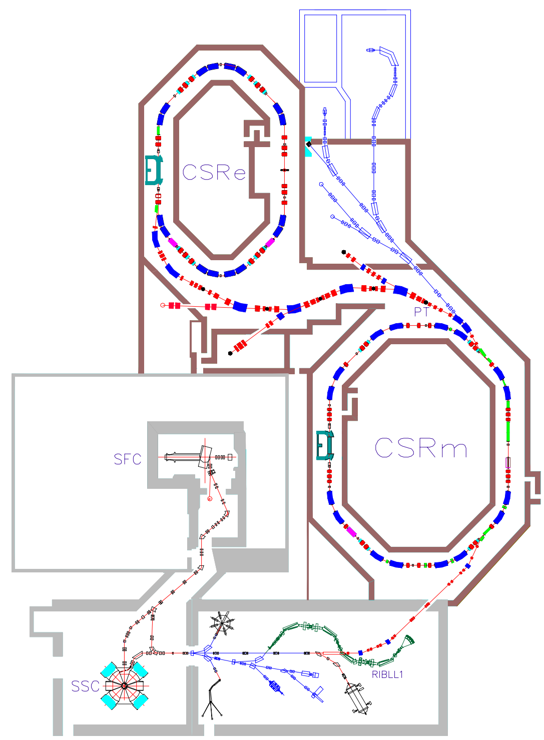

Figure 1: Layout of the HIRFL-CSR complex.

The lattice of each arc section is given as follows,

L_1 L_2

----------FDF--B--B--F-------DF--B--B--F $\frac{1}{2}$ D

Where $2L_1$ is a long-straight section with dispersion free for e-cooler or RF cavities. L_2 is a dispersion drift for beam injection or extraction. Figure 3 is the distribution of the β-functions and the dispersion in the CSRm, Table 1 is the lattice parameters of the CSRm.

In the injection arc-section 3 bump magnets (BP1, BP2, BP3) will be used to move the closed orbit from center to the injection orbit in the horizontal plane, then injection beam will be deflected into the closed orbit by one static-electric septum (ES1) and one magnetic septum (MS1). During multi-turn injection, the field of the 3 bumps will be reduced to zero isochronously, the closed orbit will go back to the center, and the horizontal acceptance (150π mm-mrad) will be filled by injection beam simultaneously. Figure 4 is the injection orbit of the Multiple Multi-turn Injection (MMI).

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For the CSRm fast and slow beam extractions should be done. In the extraction arc-section 5 kicker modes will be used for the fast extraction, and two static-electric septum, two fast quadruples, two families of sextuple and 6 in-dipole coils used for the slow extraction of 1/3 order resonance. The two extractions will use one channel, and the final elements of the extraction are two magnetic septum (MS1, MS2).

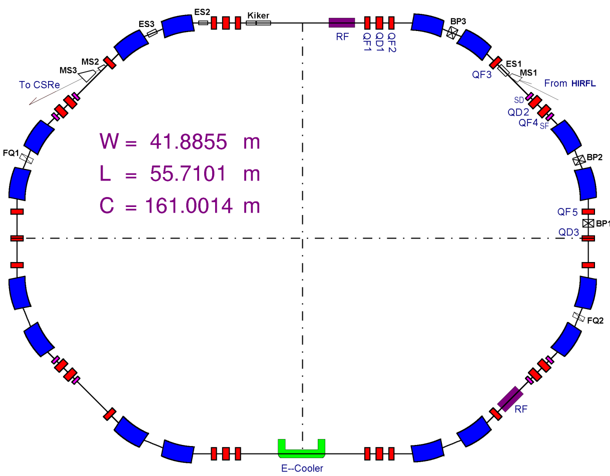

Figure 2: Lattice layout of the CSRm.

For beam injection and extraction the special vacuum chambers will be adopt to get large horizontal space.

In CSRm 16 in-dipole coils, 2 double-direction correctors, 9 vertical correctors will be used for the global closed orbit correction.

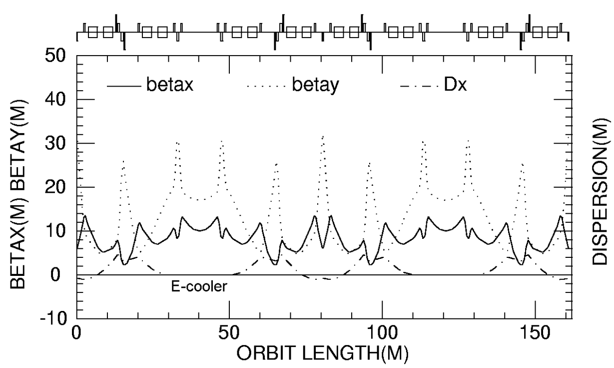

Figure: 3 Distribution of the Twiss functions in CSRm.

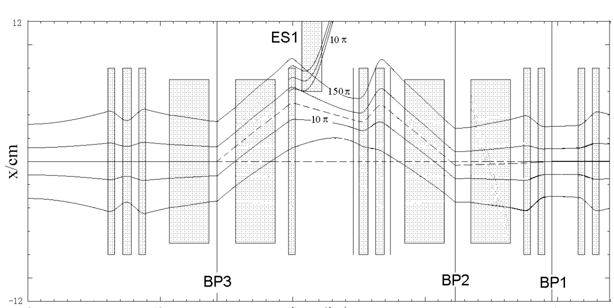

Figure 4: Injection orbit of the MMI in CSRm.

Table 1: Lattice parameters CSRm

Transition gamma	γ_{tr} = 5.168
Betatron tune values	Qx / Qy = 2.63 / 2.61
Natural chromaticity	Q'_x / Q'_y = -3.05 / -5.34
Max. β-Amplitude	β_x/β_y=10.4/17.5 m (Dipole)
	β_x/β_y=13.5/32.2m (Quadruple)
Max. Dispersion	$D_{max}(x)$=3.2 m (Dipole, β_x=10.4m)
	$D_{max}(x)$ = 4.6m (Quad., β_x=8.0 m)
Injection section	β_x=10.0 m, D_x = 4.0 m (Septum)
	β_x=11.9 m, D_x = 3.9 m (Quadruple)
E-cooler section	β_x/β_y = 10.0/17.0 m , D_x = 0
RF station section	β_x/β_y = 10.0/6.4 m , D_x = 4.0

2 LATTICE OF THE CSRE

The layout of CSRe is shown in Figure 5. It is a race-track shape and consists of two quasi-symmetric parts. One is the internal target part and another is the e-cooler part. Each part is a symmetric system and consists of two identical arc sections. Each arc section consists of four dipoles, two triplets or one triplet and one doublet. 11 independent variables for quadruple are used in the CSRe. The lattice of the half ring is given as follows,

L_T L_R L_R L_C

-----FD-F--B-B---FD-F-B-B--B-B-F-DF---B-B--FD----

Where $2L_T$ and $2L_C$ are the long straight sections with dispersion free for internal target and e-cooler. L_R is the dispersion drift for RF cavities.

In CSRe three lattice modes will be adopt for different requirements. The first one is the internal-target mode with small β-amplitude in target point and the large transverse acceptance (A_h=150πmm mrad, A_v=75πmm mrad) for internal-target experiments. The second one is the normal mode with a large momentum acceptance of $\Delta P/P$ = 2.6% used for high-precision mass spectroscopy. The third one is the isochronous mode with a small transition γ_{tr} that equals the energy γ of beam in order to measure the mass of those short-life-time RIB [3].

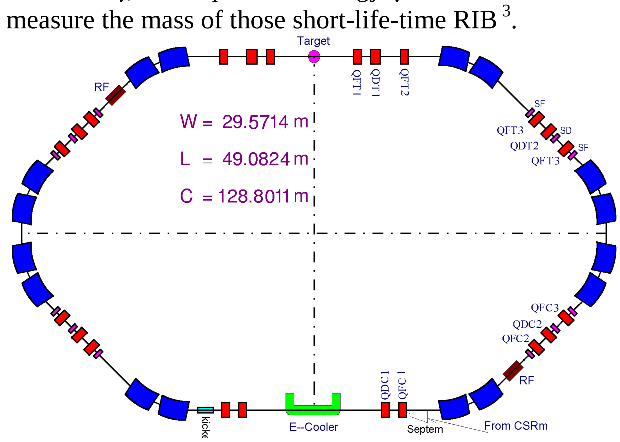

Figure 5: Lattice layout of CSRe.

Table 2 is the lattice parameters of the CSRe for the three lattice modes, and Figure 6, Figure 7, Figure 8 are the distribution of the β-functions and the dispersion for those modes.

Table 2: Lattice parameters of CSRe.

	Internal-target mode	Normal mode	Isochronous mode
Transition gamma	γ_{tr} = 2.457	γ_{tr} = 2.629	γ_{tr} = 1.395
Betatron tune values	Qx / Qy = 2.53 / 2.57	Qx / Qy = 2.53 / 2.57	Qx / Qy = 1.695 / 2.72
Natural chromaticity	Q'_x / Q'_y = -3.70 / -3.55	Q'_x / Q'_y = -3.10 / -3.74	Q'_x / Q'_y = -1.57 / -3.25
Max. β-Amplitude	β_x/β_y =25.7/8.7 m (Dipole) β_x/β_y =43.0/20.4 m (Quadruple)	β_x/β_y =17.6/8.2 m (Dipole) β_x/β_y =30.9/22.3 m (Quadruple)	β_x/β_y =28.1/12.2 m (Dipole) β_x/β_y =41.2/36.4 m (Quadruple)
Max. Dispersion	D_{max}(x)=7.9m(Dipole, β_x=14m) D_{max}(x)=9.4m (Quad. , β_x=16m)	D_{max}(x)=6.5 m (Dipole, β_x=13m) D_{max}(x)=7.8m (Quad. , β_x=16m)	D_{max}(x)=18.5m (Dipole, β_x=28m) D_{max}(x)=21.2m(Quad. , β_x=34m)
Injection section	β_x= 30.8 m , D_x = 0 m (Septum) β_x= 31.4 m, D_x =0 m (Quadruple)	β_x= 30.4 m, D_x = 0 m (Septum) β_x= 30.9m, D_x = 0 m (Quadruple)	β_x= 40.8 m , D_x = 0 m (Septum) β_x= 41.2m, D_x = 0 m (Quadruple)
E-cooler section	β_x/β_y = 12.9/16.5 m , D_x = 0	β_x/β_y = 12.5/16.0 m , D_x = 0	β_x/β_y = 2.6/10.5 m , D_x = 0
Target	β_x/β_y = 3.0/1.7 m , D_x = 0	β_x/β_y = 5.4/1.5 m , D_x = 0	β_x/β_y = 20.8/1.0 m , D_x = 17.7m
RF station section	β_x/β_y = 4.0/8.3 m , D_x = 4.6	β_x/β_y = 4.0/8.4 m , D_x = 4.5	β_x/β_y = 19.0/11.5m , D_x = 15.0m

The injection of the CSRe is located in the zero-dispersion section of the e-cooler in order to accept the large momentum-spread (±1%) beams. The single-turn injection will be adopt by using 4 in-dipole coils, one magnetic septum and 4 modes of kicker, and the injection channel will pass through the fringe field of a dipole and two quadruples. For the three lattice modes the gradient of the doublet quadruple nearly the injection septum should be kept at the same value in order to get the same injection orbit. Figure 9 shows the single-turn injection orbit of CSRe.

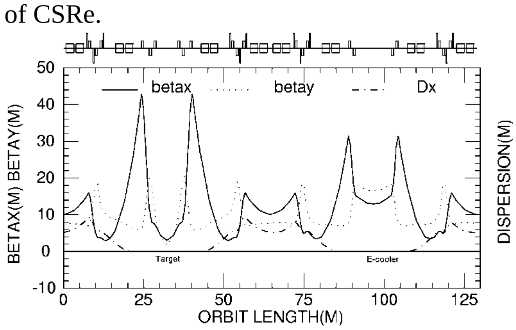

Figure 6: Twiss functions of the internal-target mode.

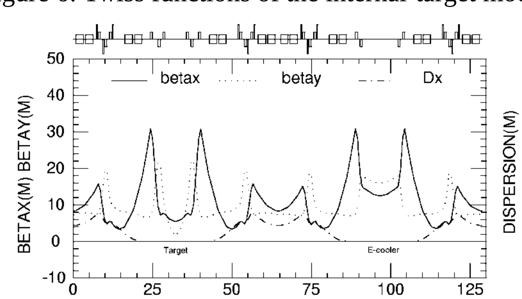

Figure 7: Twiss functions of the normal mode.

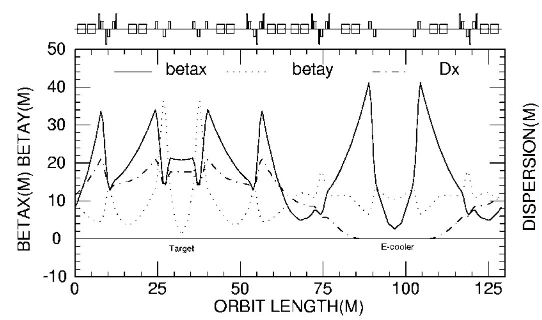

Figure 8: Twiss functions of the isochronous mode.

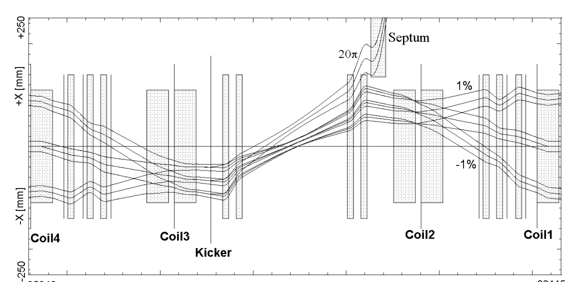

Figure 9: Single-turn injection orbit of CSRe.

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