RESEARCH ON THE DESIGN AND SIMULATION OF THE CSRE STOCHASTIC COOLING SYSTEM

Hu Xuejing, Yuan Youjin, Zhang Xiaohu, Jia Huan
IMP, Lanzhou, 730000, China

Abstract

The beam extracted from CSRm is injected into the CSRe, and then the secondary beam with large momentum spread and large emittance is produced at the internal target area. This paper is designed to optimize the lattice of CSRe in order to satisfy the requirement of stochastic cooling system. Particle tracking method is used and simulation on transverse and longitudinal stochastic cooling is made on the basis of the designed lattice. The results indicate that stochastic cooling is suitable for the beam cooling with larger momentum spread or larger emittance.

THE SIGNIFICANCE OF STOCHASTIC COOLING ON CSRE

CSRe is a system which is used to cooling, deceleration and high resolution target experiment. The circulating beam from the CSRm is making target experiment at the CSRe continuously, and the beam is supplemented every running circle, then quasi-continuous running mode is realized. After target collision, the secondary beam with large momentum spread or emittance is produced. If we only use the electron cooling, the cooling time is much longer than the time with stochastic pre-cooling. Therefore, electron cooling combined with stochastic pre-cooling can reduce the cooling time effectively, which provides advantageous conditions for high effective experiments.

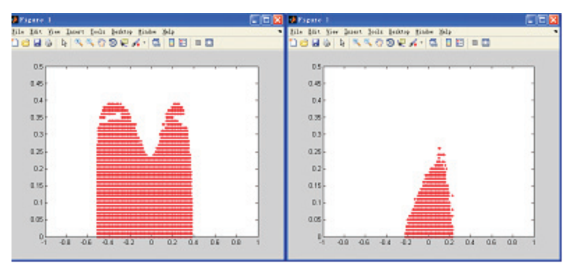
The Institute of modern physics is carrying on mass measurement experiment on HIRFL-CSR at present, and the high requirement of the beam is a new challenge to the CSR system. The success of the mass measurement experiment means a milestone in the mass standardization area. Therefore, how to get the beam cooled in the shortest time is an urgent problem presently.

Stochastic cooling is the most suitable to cool beam with large momentum spread and emittance. So building a stochastic cooling system on CSRe has important significance.

DESIGN AND RESULTS OF LATTICE FOR CSRE STOCHASTIC COOLING SYSTEM

The lattice of the CSRe storage ring is consisted of four same deflection sections. The two straight sections are used to lay the electron cooling equipment and internal target equipment respectively. CSRe is symmetrical along the short axis, and the whole lattice is consisted of triplet type and doublet type. The dipole of CSRe uses C type, in order to make it easy to inject beam and lay pickups. As there is no spare space for placement of stochastic cooling equipment, pickups and kickers are installed into the dipole or quadrupole.

As Fig. 1 shows, Fig. 1a and Fig. 1b are the dynamic aperture of CSRe without and with sextupole. According to the contrast, the area of dynamic aperture can be reduced by use of sextupole. Figure 2 shows the twiss parameters of CSRe. Among which, Dx=13.8m at the target section, Dx=0.0m at the electron cooling section. β max=25m both in X and Y direction. Figure 3 is the distribution of working tune with and without sextupole. The red points in linear array is the working tune without sextupole and blue points with sextupole. By comparison we can get results that working points can be narrowed in a smaller region by use of sextupole. Figure 4 shows that acceptance of the CSRe is nearly 20 pi*mm*mrad with sextupole.



(a)without sextupole (b)with sextupole

Figure 1: Dynamic aperture of CSRe.

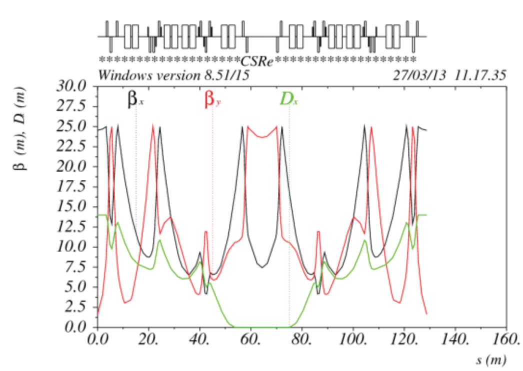


Figure 2: Twiss parameters of CSRe.

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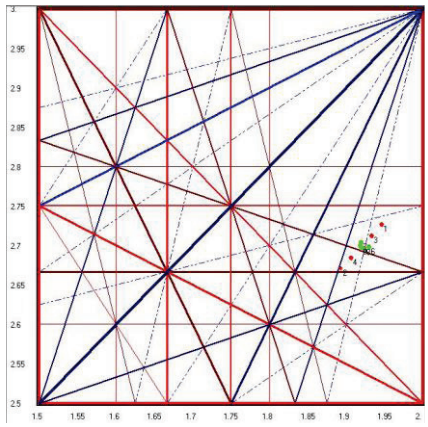

Figure 3: Distribution of working tune of CSRe.

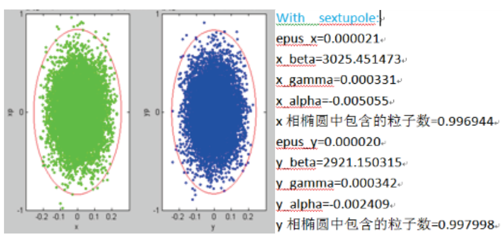

Figure 4: Acceptance of CSRe.

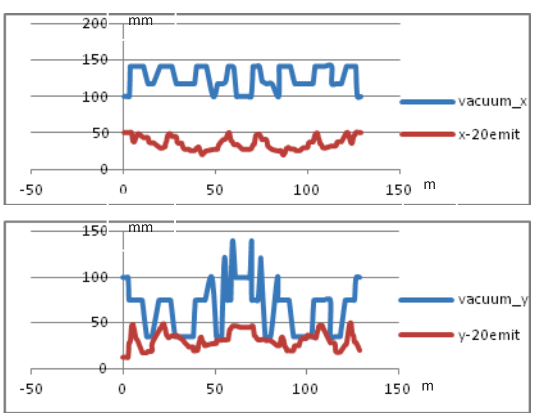

Figure 5: Beam envelope (red: ε =20pi*mm*mrad) and vacuum aperture distribution (blue).

Figure 5 shows the vacuum aperture distribution and the beam envelope with emittance is 20 pi*mm*mrad. As it is clearly indicated that beam envelope is smaller than the real vacuum aperture.

TRANSVERSE AND LONGITUDINAL SIMULATION RESULTS AND ANALYSIS OF STOCHASTIC COOLING SYSTEM ON CSRE

Since there is no spare space for the installation of pickup and kicker on CSRe, pickup and kicker are installed in the dipole or quadrupole. The phase change between pickup and kicker should be (2n+1)*90° (n=0,1,…). After calculation, horizontal phase change between dipole (5) and (8) is 85.32° , and vertical phase change between dipole (6) and (9) is 90.36° , which is suitable for stochastic cooling, as show in Fig 6.

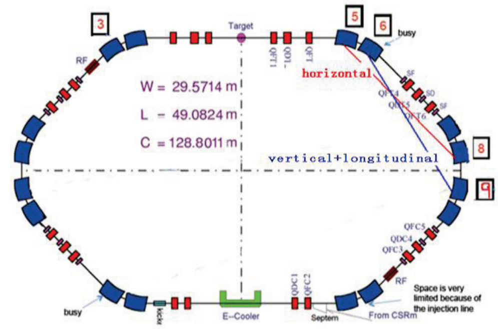

Figure 6: Layout of CSRe stochastic cooling system.

Due to the transverse displacement formula of single particle:

$$x(s)= (\sqrt{\beta(s)*\varepsilon})*\cos(\varphi+\delta)+ Dx(s)*\Delta p/p. \qquad (1)$$

We can know that horizontal displacement is consisted of two components. By calculation, the displacement produced by dispersion is larger than β-function, so we decide to use palmer cooling at this place for longitudinal cooling.

Table 1: Twiss Parameters and Beam Envelope for Stochastic Cooling on CSRe

	horizontal		vertical		longitudinal	
	pickup	kicker	pickup	kicker	pickup	kicker
L/m	10.5–13.1	28.9–31.5	13.4–16.0	32.9–35.5	13.4–16.0	32.9–35.5
β_x/m	14.349	9.353	10.686	6.618	10.686	6.618
β_y/m	3.407	11.415	8.026	6.755	8.026	6.755
D_x/m	8.912	6.347	7.834	6.100	7.834	6.100
A_x/mm	43.4	36.1	36.8	27.7	36.8	27.7
A_y/mm	17.6	36.7	19.7	30.2	19.7	30.2
θ/°	85.32		90.36			

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Table 2: Parameter of CSRe Stochastic Cooling Simulation

Beam energy	300 MeV/u, $6C^{12+}$
Particle number	9790
Sample number	445
Number per sample	22
Initial emittance	200/20 pi*mm*mrad
Initial momentum spread	±0.01/0.003
Momentum cooling method	Palmer Method
Frequency bandwidth	338 MHz
CSRe Circumference	128.801120
Gammat	1.857442
N_{pickup}/N_{kicker}	3/3

The parameters used in the simulation are listed in Table 2. Figure 7, 8 and 9 show the results under the initial condition that emittance is 200 pi*mm*mrad and momentum spread ±0.01. As shown in Fig. 7, Fig 7a, 7b and 7c are the phase space area after 1, 100 and 10000 circles respectively. The green, red and blue correspond to the horizontal, vertical and longitudinal direction. Figure 8 is the change of phase space area during 10000 circles and it is indicated that after 10000 circles, both horizontal and vertical area decreased to 0 and longitudinal decreased to 5.6%. After 300 circles, the particle is no longer reduced. The total loss number is 2704, and the loss rate is 27.04%. The stochastic cooling simulation results under other conditions are listed in Table 3.

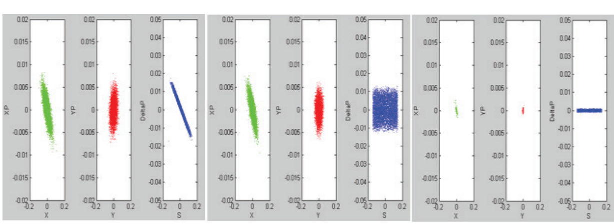

Figure 7: Stochastic cooling phase space change during 10000 circles(ε =200 pi*mm*mrad ， Δ p/p=±0.01).

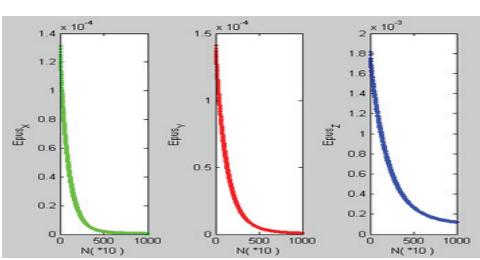

Figure 8: Phase space area change after 10000 circles. (ε =200 pi*mm*mrad ， Δ p/p=±0.01).

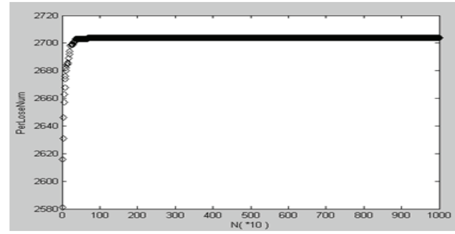

Figure 9: Process of particle loss during 10000 circles (ε =200 pi*mm*mrad ， Δ p/p=±0.01).

Table 3: Stochastic Cooling Simulation Results after 10000 Circles

	ε=20 pi*mm*mrad, Δp/p=±0.003	ε=200 pi*mm*mrad, Δp/p=±0.003	ε=200 pi*mm*mrad, Δp/p=±0.01
X phase space	3.8%	0	0
Y phase space	9.0%	0	0
Longitudinal phase space	25%	32%	5.6%
Particle loss rate	25.42%	0.43%	27.04%

CONCLUSION

The results of the CSRe lattice design accord with stochastic cooling system. But there are more to be improved of the CSRe lattice design. Such as the working tune distribution should be far away from the resonance line, the dynamic aperture area with sextupole may become larger than without, and dispersion both in the internal target section and electron cooling section should not change a lot as it will not be symmetric.

By analysis of Table 3, we can get the results that stochastic cooling is suitable for beam cooling with large momentum spread or emittance. Therefore, it is necessary to build a stochastic cooling system on CSRe.

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