DESIGN OF SLOW EXTRACTION FOR HIRFL-CSR *

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Abstract

The new national key project HIRFL-CSR[1-2] is an extending project of present HIRFL (Heavy Ion Research Facility of Lanzhou) project, which consists of two cooler storage rings (CSR). The slow extraction of beam from CSR main ring(CSRm) is described in this paper. Both fast and slow extraction will be arranged in the same passage. Third integer resonant scheme is adopted in slow extraction to obtain smooth extracted beam in about 1 second.

1 OVERALL DESCRIPTION

As the upgrading project of existing HIRFL, CSR project evidently improve the research ability of heavy ions. CSR project will increase the energy and quality of heavy ion beams by an order of about ten. It consists of four parts: beam line from HIRFL to CSR, CSR accumulation ring and synchrotron (CSRm), radioactive ion beam production line(RIB), and experimental storage ring(CSRe).

The beam accumulated, cooled and accelerated in CSRm will be extracted to CSRe or external targets. Both fast and slow extractions are required. For slow extraction, third integer resonant scheme is adopted in order to obtain smooth extracted beam in about 1 second.

Amplitude-momentum selection scheme will be the choice for slow extraction.

2 DESIGN OF SLOW EXTRACTION FOR CSR MAIN RING

The layout of injection and extraction scheme of CSRm is shown in Figure 1.

There are two sets of totally 8 sextuples in the ring for chromaticity correction, high order optics correction and power up the third order resonance. For third order resonance, 4 of the 8 are used.

As described in [3], when the tune is near an even number(i.e. Q_h~2n±1/3), the resonance excitation and chromaticity correction can be done separately. In our case the slow extraction is done at Q_h=4-1/3.

For excitation of resonance, several steps will be taken.

Firstly, the horizontal tune is shifted from 3.63 to 3.67 using normal quadruple pairs and fast quadruples(for crossing the resonant line). The twiss parameters can be calculated, where μ_x, β_x are basically required.

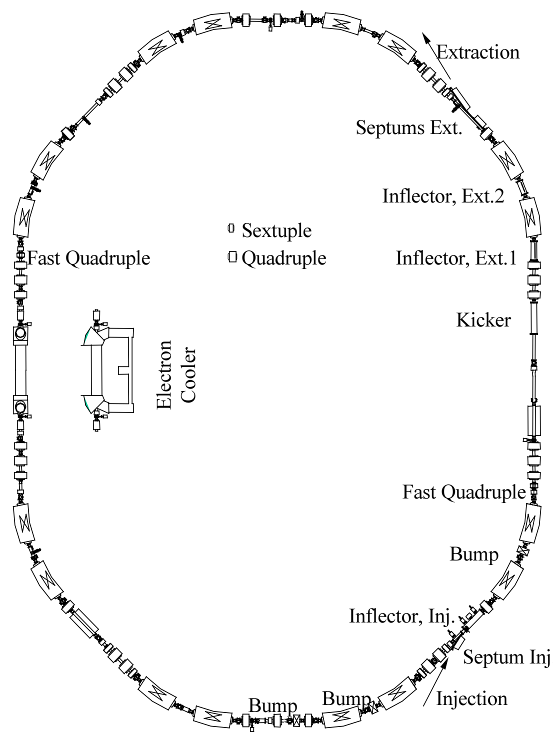

Figure 1: Layout of CSRm injection and extraction

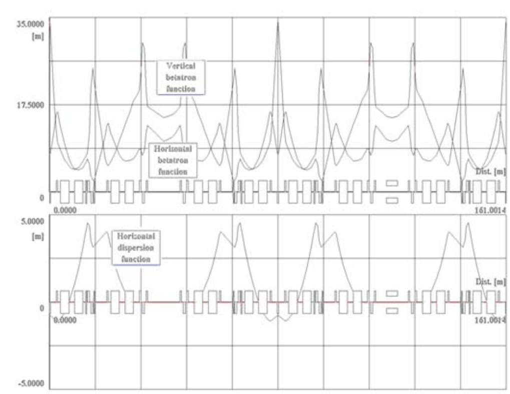

Figure 2: Twiss parameter of CSRm

The second step is setting the strength of sextuples. In order to keep the chromaticity untouched, the four sextuples for slow extraction are chosen symmetrically in the lattice. And their normalised strength are set to:

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$$S_n = -A\cos(3(\mu_x - \mu_{ES}) + \theta) \quad (1)$$

where μ_{ES} is the betatron phase at the first component of the slow extraction tunnel, it's usually an electrostatic septum.

The equivalent single 'virtual' sextuple has strength[3]:

$$S_{virt} = \sqrt{\left(\sum_n S_n \cos(3(\mu_x - \mu_{ES}))\right)^2 + \left(\sum_n S_n \sin(3(\mu_x - \mu_{ES}))\right)^2} \quad (2)$$

and the equivalent betatron phase:

$$\mu_{x,virt} = \begin{cases} \tan^{-1}(SIN/COS)/3 + \pi/3 & COS < 0 \\ \tan^{-1}(SIN/COS)/3 + \pi/6 & COS > 0 \end{cases} \quad (3)$$

where:

$$SIN = \sum_n S_n \sin(3(\mu_x - \mu_{ES})) \qquad COS = \sum_n S_n \cos(3(\mu_x - \mu_{ES})) \quad (4)$$

The area of stable region can be changed mainly by changing of the amplitude A. The extraction angle of beam can be tuned by changing of the initial phase of setting θ(Figure 2). Here θ is about 0.75π, and $\mu_{x,virt}$ is about 37° in first quadrant.

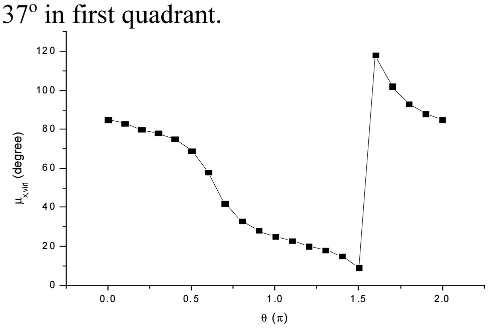

Figure 2: The extraction angle of beam

The actual strength of sextuples can be given by the following relation:

$$S = \frac{1}{2}\beta_x^{3/2}\frac{l_s}{|B\rho|}\left(\frac{d^2B_z}{dx^2}\right) = \frac{1}{2}\beta_x^{3/2} l_s k' \quad (5)$$

During the slow extraction procedure, the centre momentum of beam is shifted by RF cavity, as the horizontal chromaticity is set no zero(<0), beam is drawn out of the stable region and near to the inflector, finally is extracted. The phase space of slow extraction can be seen in Figure 3.

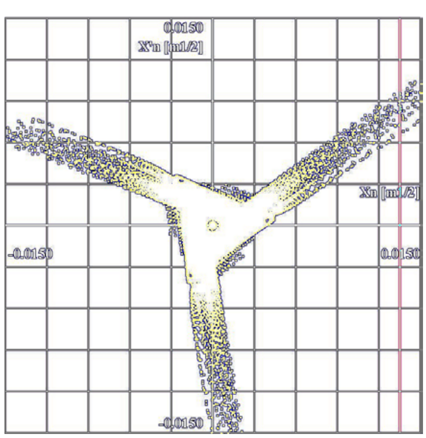

Figure 3: Tracking in normalised phase space

In order to reduce the strength of inflector and magnet septums needed for extraction, local orbit distortion is formed by using horizontal correction coil in the dipoles.

In Figure 4, the tracking of beam in real phase space is shown, the centre of beam is shifted by orbit distortion.

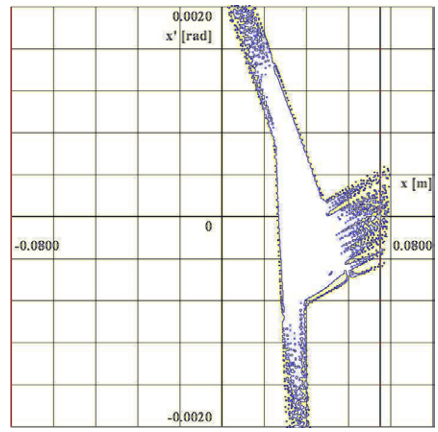

Figure 4: Tracking in real phase space

The fast extraction orbit and beam envelope for fast extraction is shown in Figure 5. The emittance of extraction beam is $\varepsilon_{x,y} = 10\pi$ mm.mrad, $\Delta p/p = \pm 1\times10^{-4}$.

For slow extraction the same tunnel is used, but two additional dipole coils and fast quadruples are required for bumping and tune shift, two inflector is used instead of the kicker magnet. Final turns before extraction and extraction orbit is shown in Figure 6.

As a substitution of amplitude-momentum selection scheme, amplitude selection of third integer resonance with horizontal RF knock-out can also be adopt, at zero chromaticity condition. But in this case, the requirement for stability of power supplies is more strict to get smoothly extracted beam[3].

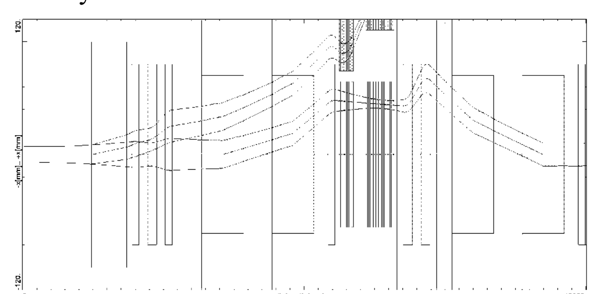

Figure 5: Fast extraction of CSRm

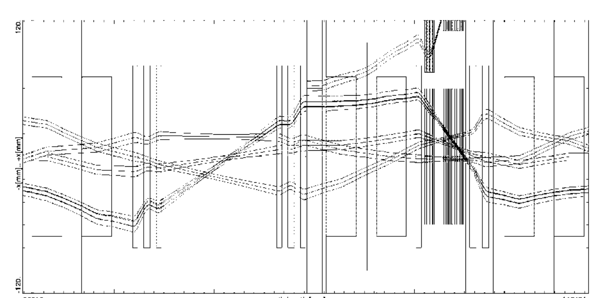

Figure 6: Slow extraction of CSRm

3 SLOW EXTRACTION OF CSRE

The layout of injection and extraction scheme of CSRe is shown in Figure 7.

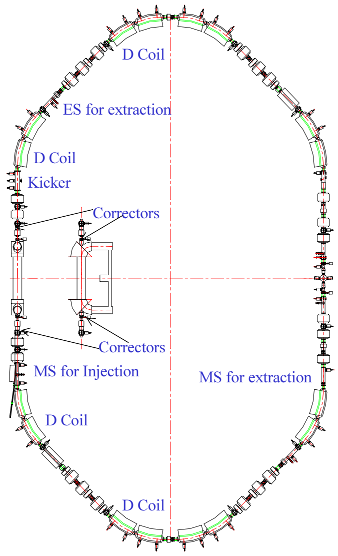

Figure 7: Layout of CSRe injection and extraction

Both fast and slow extractions will be adopted in CSRe for the future requirement. The extraction schemes are designed only for high resolution mode.

The extraction orbit and beam envelope for fast extraction is shown in Figure 8. The emittance of extraction beam is $\varepsilon_{x,y}$=20πmm.mrad, Δp/p=±0.2%.

For slow extraction the same tunnel is used, but two fast quadruples are required for tune shift and an inflector is used instead of the kicker magnet.

The same method of slow extraction as CSRm is adopt for CSRe, the final turns before extraction is shown in Figure 9. It can be seen that the position of electrostatic inflector is near to the centre of ring, further improvement of the design is required. As a substitution, charge exchange extraction will be designed for CSRe.

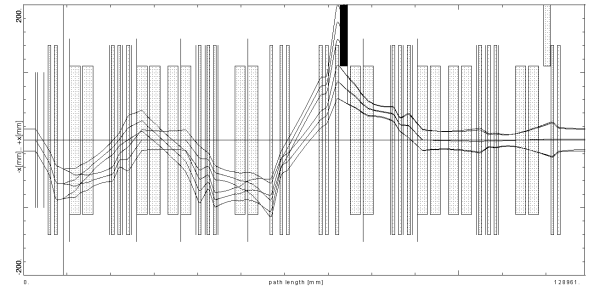

Figure 8: Fast extraction (high resolution mode)

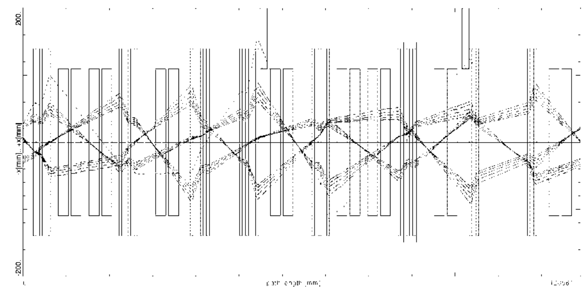

Figure 9: Slow extraction (high resolution mode)

4 ACKNOWLEGEMENTS

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