# LATTICE FOR ACCUMULATOR COOLER RING FOR MUSES

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*Abstract*

ACR, a storage ring which is one of the parts of a new project named as RI Beams Factory in RIKEN, is an accumulator for a new heavy ion collider (DSR). It will be used for the accumulating and cooling of radioactive isotope beams which are from a Super-conducting Ring Cyclotron (SRC). The qualities of those RI Beams will be improved largely in ACR, and then the acceptance required by the collider will be significantly reduced. The details of the lattice design for ACR will be reported in this paper.

## 1. INTRODUCTION

ACR is an ion beam storage ring which is the combination of a accumulator and a cooler. So, ACR lattice should be satisfied many basic requirements.

1) Electron cooler requirements: ACR will have a e-cooler to cool stable and unstable nuclei beams. So, there should be a long straight free space (nearly 8.0m) to set up it. In this long section, the β-functions should be moderate (5.0--15.0m) and with dispersion-free.

2) Stochastic cooling requirements: In whole ACR, there will be many drifts with dispersion free to arrange stochastic cooling devices, and in those sections between pickups and kickers, the betatron oscillation phase advance should be nearly kπ/4 in order to increase the stochastic cooling rate.

Dispersion should be kept at zero in cooling device sections, which is very important for cooling rate.

3) Beam accumulation requirements: A combination of transversal multiturn injection and longitudinal RF stacking will be used for the beam accumulation in ACR. The multiturn injection requires a nearly π-section which the phase advance of betatron oscillation is nearly π. And in the π-section, there will be three drifts to arrange kickers and septum magnet. Besides, RF stacking requires dispersion in the multiturn injection section.

Specially, the beam accumulation will result in large emittance (=125π.mm.mrad) and large momentum aberration(ΔP/P ~ ±2%). So, ACR will need large acceptance in the horizontal plane.

According to the above requirements, ACR is defined as a race-track shape (see Fig.1), and its average radius is the five times of the mean extraction radius of SRC.

## 2. ACR LATTICE DESCRIPTION

ACR consists of two arc sections and two long straight sections, shown in Fig.1. Each arc section is a mirror symmetrical system, and there are two bending cells. Each bending cell (15.943m) is a dispersion suppresser. The magnetic focusing structure of half bending cell is give as follows.

Lr Lk Li
HCELL = -------DF---B----------B---DF-------

So, the lattice of one bending cell is

CELL = (HCELL, -HCELL)

Where, $L_r$ is a free space with a length of 4.0m. In ACR, there are two $2L_r$ (8.0m) drifts used for RF cavities or stochastic cooling. $L_k$ is 2.0m and used for injection kickers or other devices. $2L_i$ is also a drift of 3.5m for injection septum or stochastic cooling setups. DF is a doublet quadrupole. Fig.2 shows the distributions of β-functions and dispersions of one arc section.

The two long straight sections are also mirror symmetric. The lattice of each section (20.47m) is

Le
STRC = ---Fc----DF--------FD----Fc---

Where, $L_e$ is a long drift of 8.0m for e-cooling apparatus or internal target. DF is a doublet quadrupole which is just same as that in arc sections. Fc is a single quadrupole. Fig.3 shows the distributions of $\beta$-functions and dispersions of one long straight section.

Then, the whole lattice of ACR is described as follows.

ACR = CELL--STRC--2CELL--STRC--CELL

In conclusion, for ACR lattice, the doublet quadruple is the essential part, and there are three independent quadruple variables (QF, QD, QFC) in the whole ring. In each bending cell, two doublet quadruples are in the center drift, then the dispersion of each cell can be converged to the center area. This lattice can avoid large beam dimension in dipoles. In ACR case, many internal target experiments will be carried out, and C-type dipoles will be required for the convenient measurement of reaction productions. So, small beam dimension in dipoles is important to avoid large field width of C-type dipole. Table 1 is the linear lattice parameters of ACR.

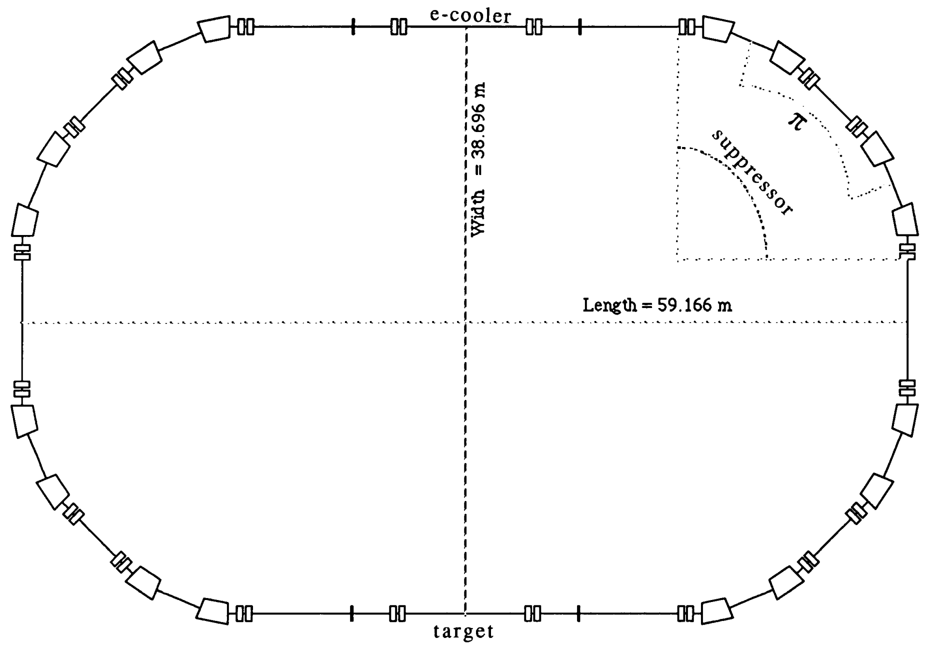

Fig.1 The Layout of ACR

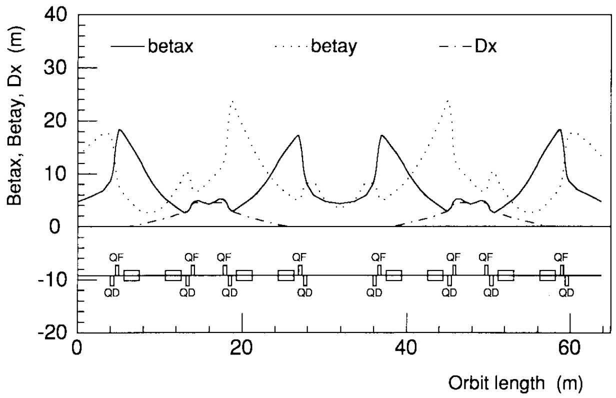

Fig. 2 Distributions of β and Dx in arc section.

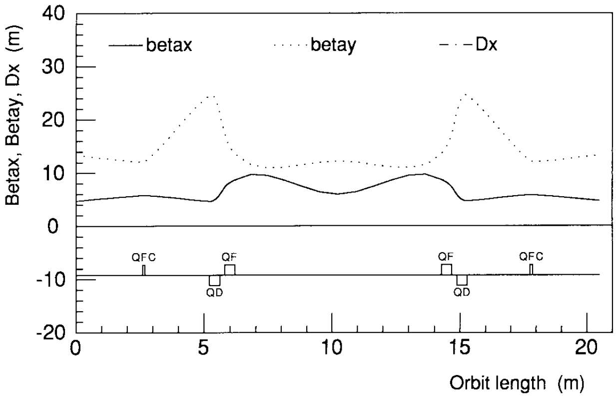

Fig. 3 Distributions of β and Dx in straight section.

Table 1 Lattice Parameters of ACR

| | |
|---|---|
| Circumference | C=168.4836 m |
| Average Radius | $\overline{R}$ = 26.815 m |
| Max. Magnetic Rigidity | Bρ = 7.244 T.m |
| Max. Beam Energy | E = 500 MeV/u (Z/A=1/2) |
| Momentum Compaction | α = 0.0402042 |
| Transition Gamma | γ = 4.987 |
| Betatron Tune Values | Qx/Qy = 4.555/3.540 |
| Natural Chromaticity | Q'x/Q'y = -5.058/-6.571 |
| Max. β-Amplitude | βx/βy= 18.33m/24.53m |
| Max. Dispersion | Dx/Dy= 4.518m/0.0m |
| β at injection point | βx/βy = 4.24m/8.75m |
| Dispersion at injection point | Dx/Dy = 4.518m/0.0m |
| β in e-cooler | βx/βy = 5.968m/12.237m |
| Dispersion in e-cooler | Dx/Dy = 0.0m/0.0m |

## 3. HARMONIC CORRECTION

### *3.1 Chromaticity Correction*

The natural chromaticities of ACR, Q'x/Q'y=-5.058/ -6.571, are very large for the large momentum aberration

(ΔP/P ~ ±2% ). So, the natural chromaticities should be corrected.

### *3.2 Dispersion Correction*

In the linear lattice design of ACR, two families of quadrupoles (QF, QD) are used to match the dispersion to zero in four long straight sections. But it is not enough, because of the following reason, the second order correction at least have to be done.

The RF stacking method will be adopt to accumulating ions in ACR, but RF stacking needs large momentum aberration, and the dispersion distribution on the closed orbit of large ΔP/P will be not same as that on the orbit of ΔP/P=0.0. This will result in the distortion of closed orbit.

In ACR, two cooling methods, stochastic cooling and electron cooling, will be adopted to cool RI-Beams which have large momentum spread (ΔP/P ~ ±0.5% ), and the dispersion in many cooling straight sections should be kept at nearly zero in order to achieve a very small distortion of closed orbit. This is an essential option for stochastic cooling and guarantees that the beam is always in the center of the stochastic pickups[1]. The cooling rate is also affected by the beam size in the kickers, so here, the dispersion should be as low as possible.

Then, the dispersion compensation in cooling sections have to be considered simultaneously while correcting the chromaticities. In ACR lattice design, this harmonic corrections are very difficult, and it should be very carefully to arrange sextupoles. Fig.4 shows a sufficient arranging of sextupoles in the arc sections. Four families of sextupoles (SF, SD, SF1, SD1) are used for the harmonic corrections.

Fig.5 shows the operation area (ΔP/P ~ ± 3.0 % ) in the tune diagram after the chromaticity correction.

Fig.6 shows the distortions of closed orbits for large momentum aberrations (ΔP/P=2.14%) after the dispersion compensation.

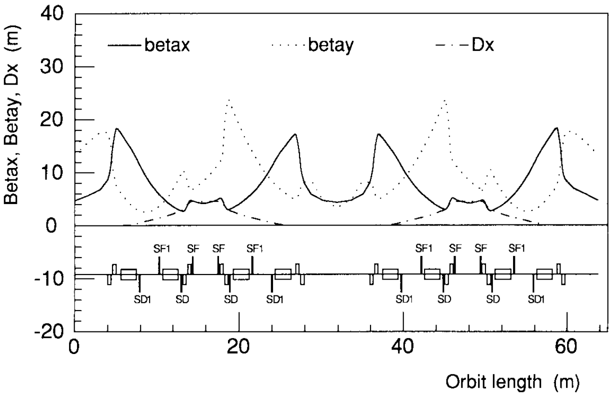

Fig. 4 Sextupole layout in the arc section.

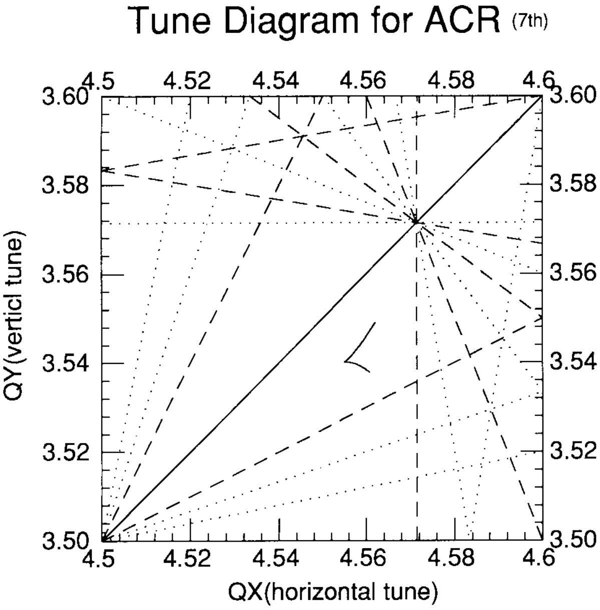

Fig.5 Operation area ( ΔP/P = ±3.0 %) after chromaticity correction

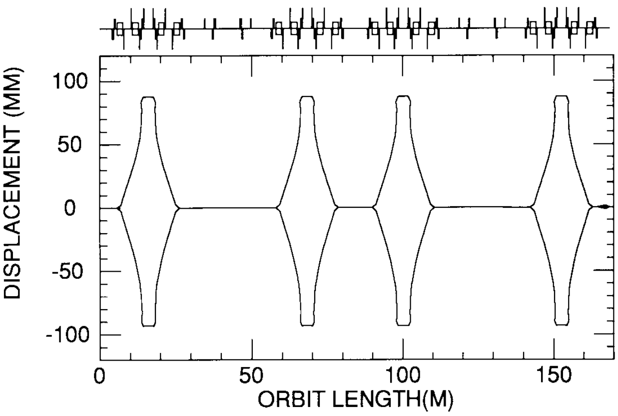

Fig. 6 Closed orbit distortion( ΔP/P = ±2.14 %) after dispersion compensation.

## 4. CONCLUSION

According to the lattice design, ACR have large momentum acceptance (ΔP/P ~ ± 2.0 % ) for beam accumulation in the horizontal plane, and the preliminary high order correction shows that

i) The closed orbit distortion less than 0.15mm over a momentum aberration range of ΔP/P=±2.0 %.

ii) The operation point variation over a momentum aberration range of ΔP/P=±3.0 % are less than ΔQx = 0.007 and ΔQy = 0.009.

## REFERENCE

[1] P.krejcik, etc., "COSY-lattice Description", EPAC, 1988, P788-790.