SLOW BEAM EXTRACTION AT KSR WITH COMBINATION OF THIRD ORDER RESONANCE AND RFKO*

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Abstract

Slow extraction system for 100 MeV electron at KSR utilizing third order resonance and RFKO is designed using the same straight section for beam injection. COD control system with use of a steering magnet together with correction coils in three dipole magnets enable coexistence of such injection and extraction channel.

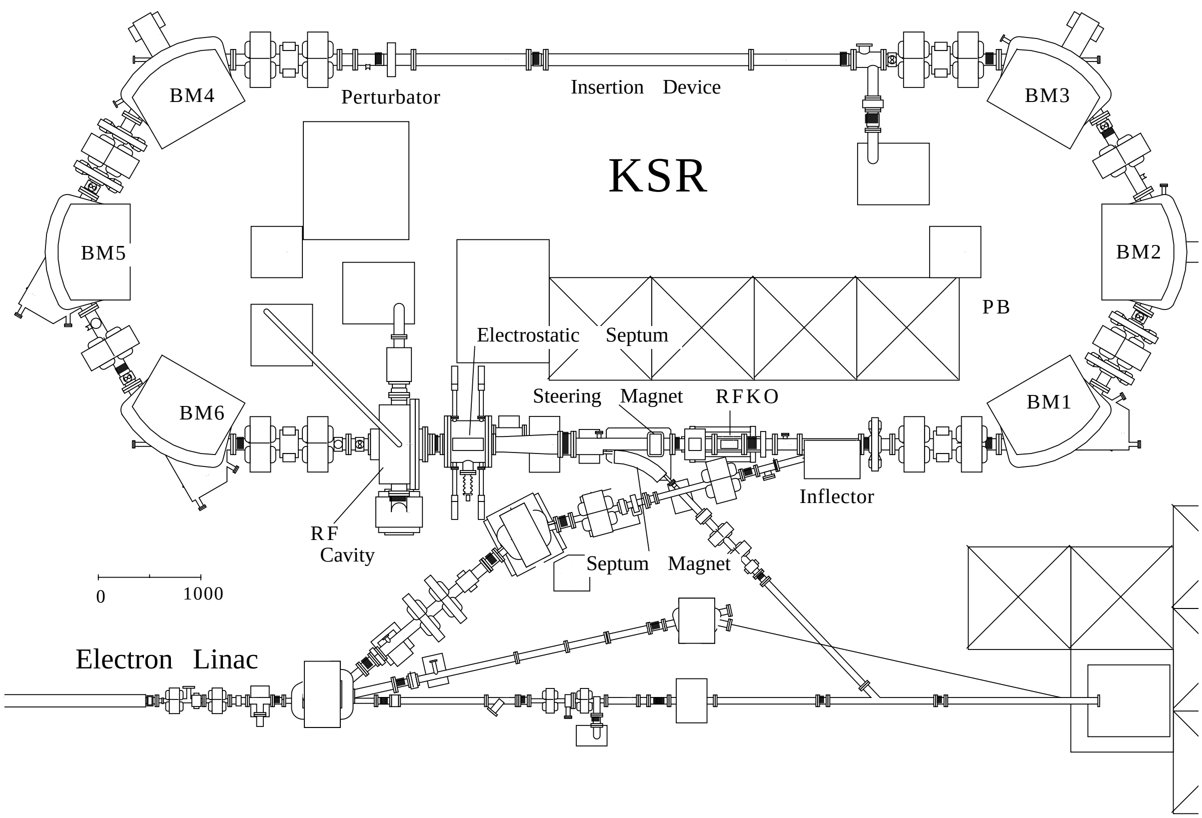

Figure 1: Layout of the injection and extraction system of KSR.

1 INTRODUCTION

At Institute for Chemical Research, Kyoto University, an electron stretcher ring which stretches the duty factor of the 100 MeV electron beam from $2\mathrm{x}10^{-5}$ to ~90% has been constructed[1]. The output beam from the s-band linac operated with the pulse duration of 100 ns is to be injected into the KSR ring[2]. Its repetition rate is reduced to 1 Hz from the former design of 10Hz in order to reduce the X-ray radiation due to beam losses at the beam injection and the extraction processes.

The beam injection is performed with use of a perturbator. For the present case, the slow beam extraction channel composed of an electrostatic septum and a septum magnet is located at the same straight section as the inflector for beam injection as shown in Fig. 1 in order to guide the extracted beam to the same beam dump as the output beam of the injector linac[3].

For slow beam extraction, it is essential to make the aperture minimum at the entrance of the first septum, which is the electrostatic septum (ESS) for the present

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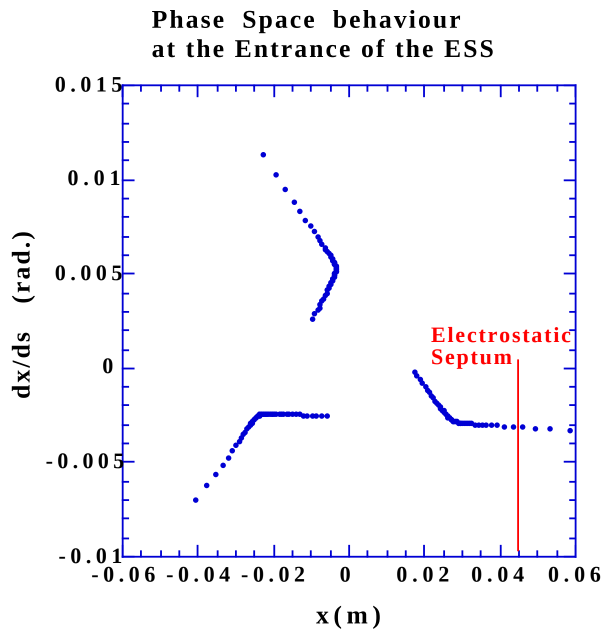

Figure 2: Phase space behavior at the entrance of the first septum.

case. It is important to compromise the beam injection and extraction to be made at the same straight section. In the present paper, the closed orbit control for this purpose is described together with the basic scheme of slow extraction.

2 BASIC SCHEME OF STRETCHER OPERATION OF KSR

The output beam from the linac is injected into the KSR through the inflector with use of the perturbator located just half circumference away from the inflector[1]. From the condition that the radiation shielding of the accelerator room is concrete wall 1 m in thickness, it is required to restrict the beam loss during injection and extraction processes below a certain amount. From this consideration, the repetition rate is reduced from 10 Hz to 1 Hz. In order to realize the duty factor ~90%, beam extraction should be performed slowly enough. For

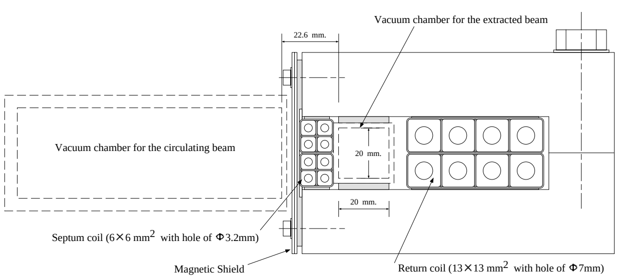

Figure 3: Cross-sectional view of the septum magnet.

heavy ions, slow beam extraction with duration about 1.5 sec has been successfully performed and the damping time of 100 MeV electron at KSR is estimated at 3.4 sec and 1.6 sec for horizontal and vertical directions, respectively. So the similar beam spill is considered to be possible for 100 MeV electron beam.

The horizontal betatron tune is adjusted at 2.364 in order to make the adequate size of the triangular separatrix with existence of sextupole field as a resonance exciter for the third order resonance, $3\nu_H = 7$. The injected beam circulates the ring stably at first and then application of an transverse RF electric field which resonates with the horizontal betatron oscillation (RFKO), its betatron-oscillation amplitude becomes larger and after reaching the separatrix, its motion becomes unstable and comes out along the outgoing separatrix as shown in Fig.2. The beam which deviates more than 45 mm from the central orbit of the KSR is deflected outwards by the electrostatic septum, the septum of which is 0.1 mm in thickness, locates at the position of 45 mm. The extracted beam is then guided to the septum magnet located ~1.2 m downstream from the exit of the ESS. The extracted beam is further deflected as large as 45˚ by the magnetic field of ~5kG. In Fig. 3, the cross-sectional view of the septum magnet is shown.

3 CLOSED ORBIT CONTROL FOR INJECTION AND EXTRACTION

The central position of the injection beam from the linac is set at 41 mm from the central orbit of the KSR. The inflector is a magnetic one and the septum thickness is 5 mm and the minimum distance of the inflector septum from the KSR central orbit becomes as small as 31 mm at the exit of the inflector. In order to cope with this situation, we consider the closed orbit control. The required condition to be satisfied for such control is summarized as follows,

(1) the aperture minimum should be realized at the entrance of the electrostatic septum,

(2) the beam injected through the inflector, the center of which is 41 mm apart from the ring central orbit, should avoid the extraction septum and circulates until it is enlarged in amplitude by application of horizontal transverse RF electric field(RFKO voltage).

In order to satisfy the first condition, it is required to kick the beam toward inside of the ring between the electrostatic septum and the inflector as shown in Fig. 4.

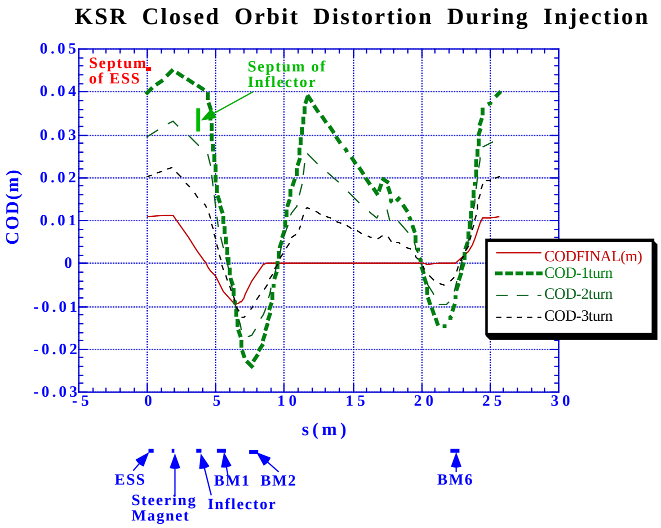

Figure 4:Closed orbit distortions during injection and after injection.

For this purpose, a steering magnet, which deflects the beam in horizontal direction, is to be utilized. With such a kick, however, it is anticipated that the closed orbit distortion will spread out to the whole circumference. Correction coils wound in three dipole magnets are also to be utilized as shown in Fig. 4 in order to localize the closed orbit distortion in the region between BM6 and BM2. The closed orbit distortion at the position s, $x_{COD}(s)$, caused by the kick, ψ_i made by the steering magnet or the correction coils in the dipole magnets can be written as,

$$x_{COD}(s) = \frac{\sqrt{\beta(s)\beta(s_i)}}{2\sin\pi\nu}\cos\left\{\nu\pi - \left|\mu(s) - \mu(s_i)\right|\right\}\psi_i$$

where $\beta(s)$ and $\mu(s)$ represent beta-function and betatron-oscillation phase at the azimuthal position, s, respectively and ν is the number of betatron oscillations per turn. Imposing the condition that superposed COD should vanish at the outside of the region between BM6 and BM2, we have obtained the closed orbit distortion as is shown in Fig.4 by the solid line. From the figure, it is known that the distance from the central orbit to the septum of the ESS is ~34 mm, while that of the inflector septum is 29 mm, which seems not to satisfy the first condition above mentioned. The beam increased in betatron oscillation amplitude, however, always comes out along the outgoing separatrix. The beam which pass just inside the septum of the ESS has phase space coordinate of (0.045 m, -3 mrad) and comes inside of the aperture almost 10 mm during passage of the drift space between the ESS and the inflector. Thus the minimum aperture is realized at the entrance of the ESS.

The closed orbit displacement made by the excitation of the perturbator is superposed on the effect of the orbit distortion by correction coils and the steering magnet at the injection process. In Fig. 4 such superimposed

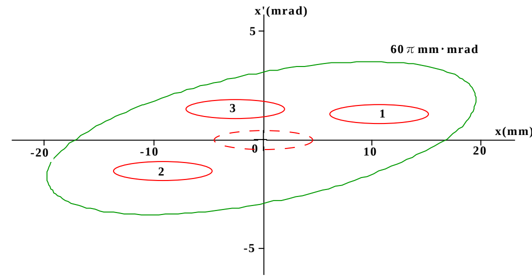

Figure 5: Phase space plot at the position of the exit of the inflector.

closed orbit distortions are shown. The beam from the injector linac comes into the KSR ring 41 mm apart from the ring center orbit at the inflector position. If the COD is displaced as shown in Fig.4 by bold broken line (COD-1turn), the beam is injected to the center of the transverse phase space as is indicated by a dashed ellipse. For this case, the beam with the amplitude ±4mm is just on the closed orbit and comes to the dashed line (COD-2turn) after 1 turn and collide with the inflector septum which exists in the region between 31 and 36 mm as indicated in the figure. So as to avoid this situation, the beam is injected as is indicated in Fig.5 by making COD of ~30 mm at the inflector position then the beam rotates in the phase space as is indicated in Fig.5. Thus the beam comes into inner part of the KSR aperture after 1 turn and collision with the inflector septum can be avoided.

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