Commissioning of an Electron Ring, KSR at Kyoto University

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Abstract

In Kyoto University, we are constructing a compact electron storage/stretcher ring (KSR). The circumference is 25.7 m and the maximum beam energy is 300 MeV. The construction of the injection line and the ring had been finished. Now the various operating parameters are optimised carefully, such as an operating tune, the bump orbit for the injection and a beam extraction orbit. In parallel to the parameter optimisation, the tests of the magnets, a RF system, beam monitors, and a control system had been carried out. After getting the permission, the beam commissioning will soon start.

1 Introduction

A compact electron ring (Kaken Storage Ring, KSR) is now under construction at the Institute for Chemical Research, Kyoto University. The main parameters are shown in table 1 and the view of the ring is shown in Fig.1. KSR has a triple bend doubly achromatic lattice (TBDA). The design issue of the ring is to provide 5 m straight sections where the dispersion is zero. One of the straight section is used for the beam injection, extraction and RF cavity. The electrostatic septum and a septum magnet for the extraction are placed in this section.

The another straight section is used in a storage mode. The insertion device will be installed for the experiments. The injection energy is 100 MeV and it is accelerated up to 300 MeV. The design beam current is 100 mA. In this paper, the storage mode is mainly discussed.

2 Operating Point

Figure 2 shows the relation of the possible horizontal tune and the horizontal natural emittance. The program code MAD is used for the calculation [1]. The preferable tunes are 2.3 and 2.8. In the stretcher mode, the tune around 2.3 is suitable because the third order resonance of 7/3 is used for the beam extraction. On the tune of 7/3, the sextupole field for the chromaticity correction doesn't affect the resonance [2]. In the storage mode, the similar tune of 2.3 is adopted to share the operation experience. The vertical tune is 1.25 to minimise the effect of the perturbation induced by the insertion device [3].

The resonance diagram around (2.3, 1.25) is shown in Fig. 3. The resonance lines up to 4th order are drawn. The operating point is set (2.3, 1.275) to avoid the resonance line $\nu_x+3\nu_y=6$. The tune spread is an important problem at the injection because the energy spread from the linac is +/- 1% (2σ). Two sextupole magnets SXA, SXB (see Fig.1) are used for the chromaticity correction. The strong sextupole

Table 1 Main parameters of KSR

Circumference	25.689 m
Lattice	TBDA
Curvature	0.835 m
Length of straight section	5.619 m
RF frequency	116.7 MHz
Injection energy	100 MeV
Maximum energy	300 MeV

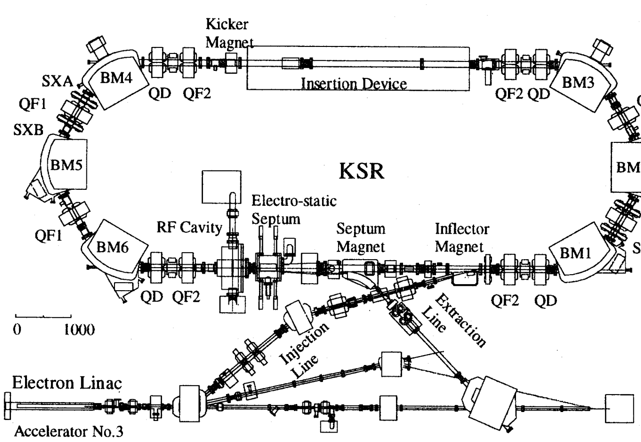

Fig. 1 Layout of the electron storage/stretcher ring, KSR.

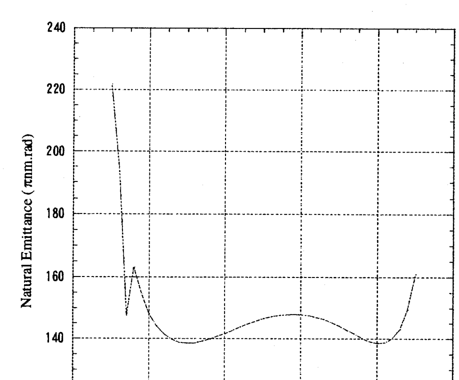

Fig. 2 The relation between the horizontal natural emittance and the horizontal tune. The vertical tune is 1.25.

Table 2 Beam parameters of KSR

	100 MeV	300 MeV
Tune	(2.300, 1.275)	←
Beam current	100 mA	←
$P_{radiation}$ (I_b=100 mA)	1.0 W	82.7 W
Damping time (x)	3.4 sec	120 msec
Damping time (y)	1.7 sec	62 msec
Damping time (z)	0.67 sec	25 msec
Emittance (x)	15 πnm·rad	140 πnm·rad
Critical wavelength	460 nm	17 nm
δp/p	8.2×10^{-5}	2.5×10^{-4}

field is required for the complete correction, B''l/Bρ=-35.7 m^{-2} for SXA and 26.1 m^{-2} for SXB. It is not a realistic value due to the small dynamic aperture. In figure 3, the tune spreads are shown with δp/p=+/-1 % in the following two cases,

Case 1 : SXA=SXB=0 (symbol x),
ν_x'=2.4, ν_y'=8.3,
Case 2 : SXA=-8.5 m^{-2}, SXB=0 (symbol o),
ν_x'=2.9, ν_y'=4.0.

In the case 2, the tunes at δp/p=+/-1% are close to the resonance lines but most of the beam are apart from those. The dynamic apertures in the case 1 and 2 are shown in Fig. 4. The particle loss is checked after the 10000 turns at δp/p=0. The alignment error is not included in this calculation. The decrease of the dynamic aperture is small even after the correction.

This operating point (2.3, 1.275) is free from the higher resonance up to 6th order. The life of the 100 MeV beam is expected to be limited by the scattering with the residual gas [4]. The expected lifetime is 200 sec with the vacuum pressure of 1×10^{-8} Torr. It's long enough for the injection and the acceleration. The operating point will be also adjusted fine to control the horizontal emittance using the coupling resonance ν_x-ν_y=1. This adjustment will be done based on the horizontal emittance measurement.

The β-function and the dispersion function at the present operating point are shown in Fig. 5. In the straight section, β_x is almost constant (7.5 m) and the dispersion function is 0 m. Table 2 shows the beam parameters. The horizontal damping time is 3.4 sec, which determines the repetition of the injection to 0.3 Hz.

3 Beam Injection

The injection beam current is 100 mA from the linac and the beam pulse width is 100 nsec, which corresponds to the revolution time of the ring. The beam emittance is much increased by the multiple scattering in the foil because the thin foil is attached in the inflector magnet to isolate the vacuum system between the beam line and the ring. The foil is Kapton with the thickness of 25 μm. The estimated angular spread by Moliere's formula [5] is +/-1.7 mrad (2σ) and the resultant emittance is 6.8 πmm·mrad (2σ).

Figure 6 shows the injected beam emittance and the acceptance of the ring at the injection point. In X-X' phase space, the injection point is 41 mm away from the geometrical centre. To shift the beam to the centre, the

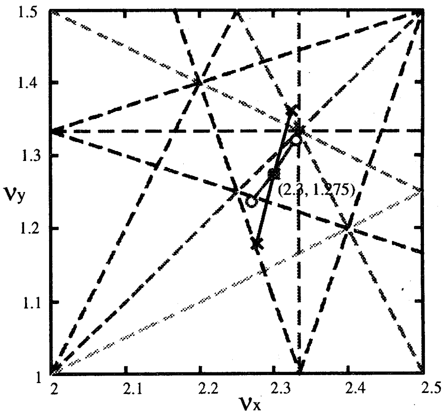

Fig. 3 Tune diagram with up to 4th order resonance. The operating point is (2.3, 1.275). The symbol x shows the tunes without the sextupole field at δp/p=+/-1 %. The symbol o shows tunes with SXA=-8.5 m^{-2}, SXB=0.

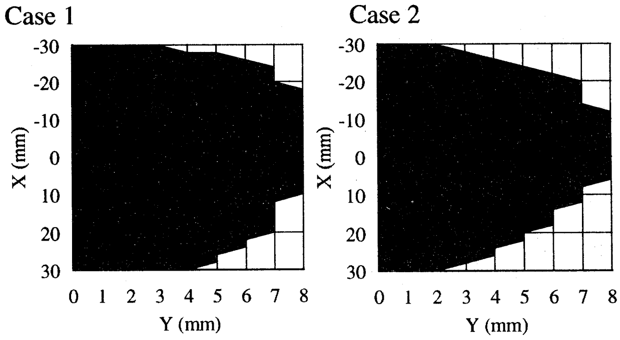

Fig. 4 Dynamic aperture at δp/p=0. SXA=SXB=0 in the case 1 and SXA=-8.5 m^{-2}, SXB=0 in the case 2.

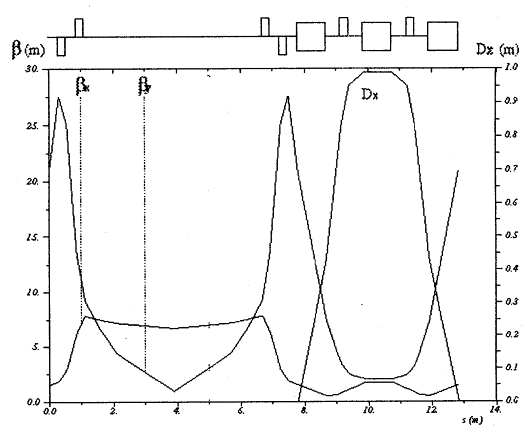

Fig. 5 β-function and the dispersion function at the operating point (2.3, 1.275). It shows the half of the ring.

bump orbit is formed by a kicker magnet (see Fig.1). The kick angle is 4.5 mrad and the field decays in 400 nsec. The following beam positions are shown in the figure 6. The index in the figure is a turn number of the beam. The shaded area is a septum wall. After the 7th turn, the magnetic field of the kicker disappears and the beam turns in the ordinary orbit. It is found that the dynamic aperture of +/-23 mm is required in the horizontal direction. In the vertical direction, the angular spread of the beam is almost same as that of the acceptance. The large dynamic aperture is preferred but some mount of the beam loss is inevitable.

4 Beam Monitors

The tests of the beam monitors had been carried out. Four kinds of monitors are installed in KSR, which are a current transformer (CT), a beam position monitor (BPM), a beam profile monitor (PM) and a DC current transformer (DC-CT). The layout is shown in Fig. 7.

The CT is used to measure the peak current of the beam. The monitor test was done using the beam from the linac. The beam current is 75 mA and the pulse width is 10 nsec. The signal of the CT is amplified by the RF-AMP, whose bandwidth is 100 kHz to 500 MHz. The output signal is shown in Fig 8. The signal width is 12 nsec. The stored beam in a single bucket can be measured by the CT. The current sensitivity is 7.5 mV/1mA.

The BPM consists of 4 electrostatic pickups. The output signal of each pickup is amplified by integration AMP with high input impedance. The BPM had been also tested by the test beam. The response speed of BPM pickup is almost same as that of the CT. The current sensitivity is 60 mV/1mA.

5 Schedule

The tests of the magnets, the RF system, the beam monitors and the control system were finished. The improvement of the vacuum system is going on. The beam commissioning will start in this September after getting the license of the radiation protection. At first, the beam accumulation and acceleration tests are scheduled. After the installation of the extraction beam line, the test of the stretcher mode will start in this year.

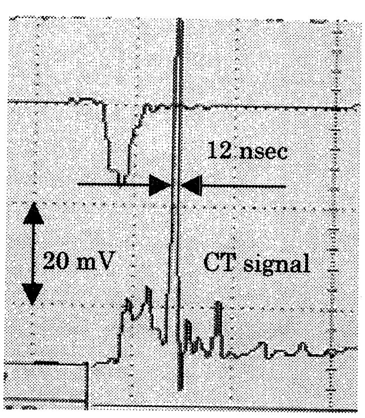

Fig. 8 Beam test of the CT for KSR. The current of the test beam is 75 mA and the pulse width is 10 nsec.

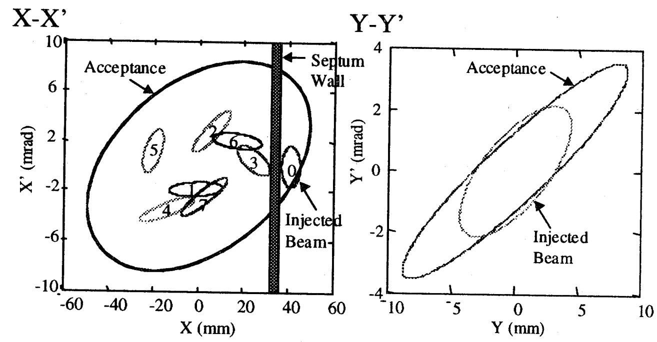

Fig. 6 Emittance of the injected beam and the acceptance of the ring at the injection point. The emittance is 6.8 πmm·mrad. The acceptances are 161 and 11.7 πmm·mrad in X-X' and Y-Y' planes, respectively. The index shows a circulation number of the beam in X-X' phase space.

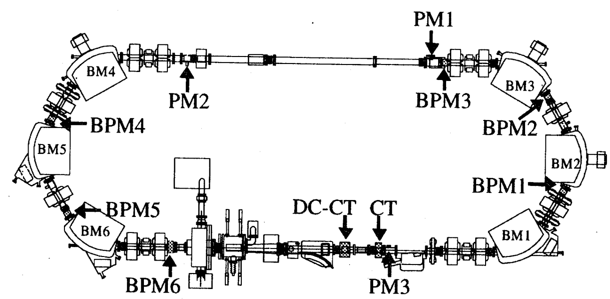

Fig. 7 Layout of the beam monitors. 6 beam position monitors (BPM), 3 beam profile monitors (PM), 1 current transformer (CT) and 1 DC current transformer (DC-CT) are installed.

Acknowledgement

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