BEAM COMMISSIONING OF THE ELECTRON STORAGE/STRETCHER RING (KSR)

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Abstract

KSR (Kaken Storage Ring) is a compact electron ring in Kyoto University. The circumference of KSR is 25.689 m and the maximum beam energy is 300 MeV. It is designed for a synchrotron light source and an electron stretcher ring. The lattice is a triple bend achromatic and has two 5.62m straight sections to install an insertion device and a beam injection and an extraction devices.

The beam commissioning had started in September 1999. In September 17th, the first beam was accumulated successfully. In the present, the beam current is 40 mA at 100 MeV and 10 mA at 300 MeV. It is limited by the ion trapping. The conditioning operation is undergoing now. The present beam lifetime is 1000 seconds at 100 MeV and 600 seconds at 300 MeV at 6 mA.

1 INTRODUCTION

A compact electron ring (Kaken Storage Ring, KSR) is under commissioning at Institute for Chemical Research, Kyoto University [1]. The basic parameters are shown in table 1 and the layout of the ring is shown in Fig.1. KSR has a triple bend achromatic lattice (TBA). The design issue of the ring is to provide 5.62 m straight sections where the dispersion is zero (see figure 2). One of the straight sections is used for a beam injection, an extraction and an RF cavity. An electrostatic septum and a septum magnet for the slow beam extraction are installed in this section [2]. The another straight section will be used for an insertion device. An undulator or a superconducting wiggler is under consideration now. There is also a plan to use KSR for the R&D programs, such as a free electron laser and a laser synchrotron light source. In any cases, the maximum storage beam current is important. The first design goal of the beam current is 100 mA and then the next step is 300 mA. The injection energy is 100 MeV and the beam is accelerated up to 300 MeV.

Table 1: Basic parameters of KSR

Maximum energy	300 MeV
Injection energy	100 MeV
Lattice	TBA
Number of cell	2
Circumference	25.689 m
Curvature of bending magnet	0.835 m
Length of straight section	5.62 m
RF frequency	116.724 MHz
RF harmonics	10

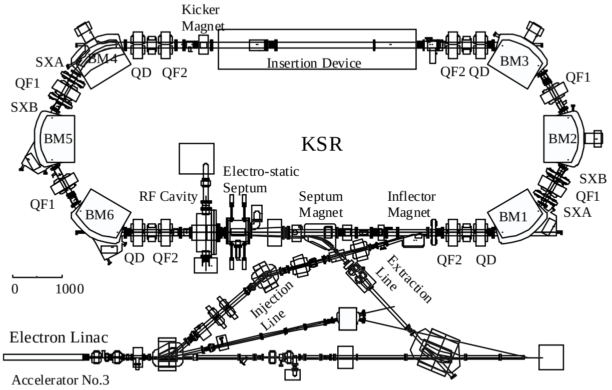

Figure 1: Layout of the electron storage/stretcher ring, KSR.

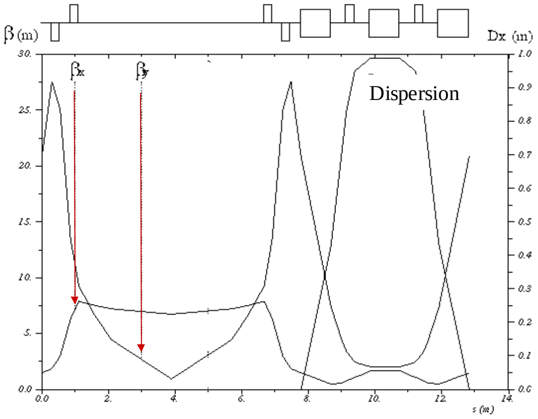

Figure 2: β-function and the dispersion function at the operating point (2.300, 1.275).

The beam commissioning had started from September 1999. In September 17th, a low current (<1 mA) was accumulated successfully. After the short shutdown for the installation of the remaining vacuum chambers and the improvements of the vacuum pumping system, the beam of 3 mA was accumulated in October. The beam stacking and the acceleration test started from November 1999. In December, the beam was accelerated up to 300 MeV.

The test of the slow beam extraction had started from March 2000 and the extracted beam has already been observed [2].

2 LATTICE AND BEAM PARAMETERS

The lattice of KSR is TBA. One cell consists of 3 bending magnets, 2 single quadrupole magnets and 2 doublets of quadrupole magnets. Two sextupole magnets are placed between the bending magnets for the chromaticity correction. The possible horizontal tune in KSR is from 2.0 to 3.0. The horizontal natural emittance becomes small at the tune of 2.3 or 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. The vertical tune is around 1.25 to minimise the effect of the perturbation induced by the insertion device. The resonance diagram is shown in the figure 3. The resonance lines up to 6th order are drawn. The working point is (2.300, 1.275). It is enough far from the higher resonance up to 6th order. It is possible to control the vertical emittance to adjust the distance to the coupling resonance (ν_x- ν_y=1).

The optical function is shown in the figure 2. It is a half of the whole ring. In the straight section, βx is almost constant (7 m) and the dispersion function is 0 m. The measured dispersion is within +/-1cm at the straight section.

Figure 4 shows the design β-function and the measurement results. When the excitation current (I) of the quadrupole magnet is changed (δI), the relation between β-function ($\beta_{x,y}$) and the tune shift ($\delta\nu_{x,y}$) is given by the following formula,

$$\delta\nu_{x,y} = \frac{kl}{4\pi}\frac{\delta I}{I}\beta_{x,y}$$

k is a focusing strength and l is a length of the quadrupole

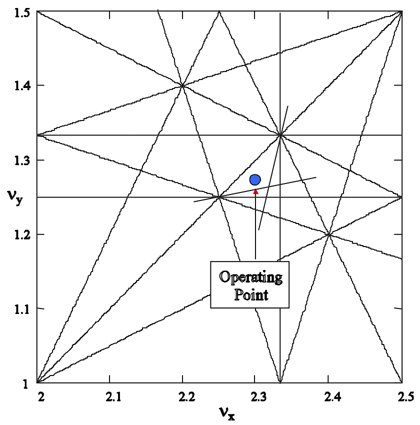

Figure 3: Present working point of KSR in the synchrotron radiation mode. ν_x is 2.300 and ν_y is 1.275. In the slow extraction mode, ν_x is 2.340 to used the 3rd order resonance ($3\nu_x$ =7).

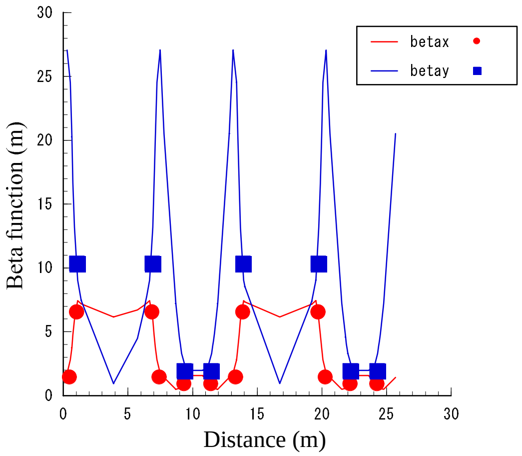

Figure 4: Design and measurement results of β-function at the operating point of (2.300, 1.275). It is measured from the tune shift when the excitation current of the quadrupole magnet is varied.

Table 2: Beam and lattice parameters of KSR

	100 MeV (design)	300 MeV (design)	100 MeV (measurement)
Betatron tune	(2.300, 1.275)	<---	<---
Storage current	100 mA	100 mA	40 mA
Radiation power (at 100 mA)	1.0 W	82.7 W	---
Critical wave length	460 nm	17 nm	---
Momentum compaction factor	0.106	0.106	---
Damping time $\tau_{x,}$ $\tau_{x,}$ τ_s	3.36, 1.68, 0.67 sec	124, 62.2, 24.9 msec	---
Natural Chromaticity	(-2.5, -8.1)	(-2.5, -8.1)	(-3.1, -6.4)
Chromaticity after correction	---	---	(0.0, 0.1)
Horizontal Emittance	15.4 π.nm.rad	138 π.nm.rad	
Energy spread	8.23×10^{-5}	2.47×10^{-4}	---
Average vacuum pressure	0.63 nTorr	0.7 nTorr	1.1 nTorr
Beam lifetime	3000 sec (residual gas)	5400 sec (Touschek)	1000 sec (residual gas)

magnet. The difference between the design and the measured value is within 3 %.

The measured natural chromaticity is -3.1 in the horizontal and -6.4 in the vertical plane. The prediction by MAD8 [3] is -2.5 and -8.1, respectively. The differences come from the sextupole components in the fringe field of the bending magnet. In the operation, the typical chromaticity is (0.0, 0.08) using the sextupole magnets to avoid the head-tail instability.

3 STORAGE BEAM CURRENT LIMIT AND LIFETIME

The electron beam is injected from the 100 MeV S-band RF linear accelerator. The beam pulse width is 100 nsec and the beam intensity is 100 mA. In the present injection scheme, all RF buckets are filled with the beam bunch. The typical injection current is 2 - 3 mA in each time and the repetition is 0.3 Hz, that corresponds to the horizontal damping time.

Figure 5 shows an output signal of the DC current transformer to monitor the circulation beam current. The present maximum current is 40 mA at 100 MeV. The relation between the beam current and the lifetime is shown in Fig. 6. When the beam current is bellow 8 mA, the lifetime is longer than 1000 sec. It is reasonable value under the average vacuum pressure of 0.76 nTorr. Over 15 mA, the beam lifetime becomes very short, while the average vacuum pressure is 1.1 nTorr. The most probable source is an ion trapping because the beam life is sensitive to the applied voltage on an ion-clearing electrode, that is a button-type electrode with the diameter of 50 mm.

If the ion trapping occurs, the vertical betatron tune shifts by the ion space charge force. The relation is given by the following formula [4],

$$\delta\nu_y = \frac{r_p}{\gamma}\int \frac{d_i \beta_y}{1+\sigma_y/\sigma_x} ds$$

r_p is a classical proton radius and d_i is an ion density. At 25 mA, the tune shift of 0.0026 is observed. The estimated ion density is 2.8×10^{15} /m^3. The resultant beam life with the ion trapping is 18 seconds and it is shown in Fig. 6 as a horizontal line. It is consistent with the lifetime measurements. During this summer shutdown, it is scheduled that the vacuum pumping system is improved and a new ion-clearing electrode is installed at a diagonal position. To create an empty RF bucket is also planned.

The accelerated beam current up to 300 MeV is around 10 mA due to the above reason. In the design, the beam lifetime at 300 MeV is limited by the Touschek lifetime but now it is limited by the scattering with the residual gas. The beam lifetime is 600 sec at 6 mA. The average vacuum pressure becomes 8 nTorr after the beam acceleration while it is 1 nTorr before acceleration [5]. The conditioning operation is going on now.

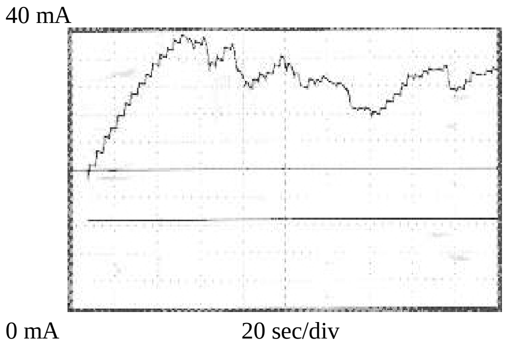

Figure 5: Output signal of the DC current transformer to monitor the circulation current. The maximum current is 40 mA.

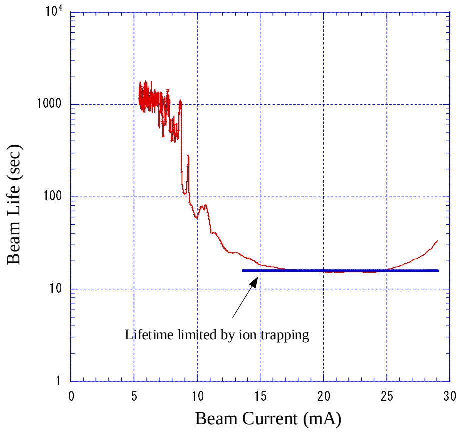

Figure 6: The relation between the beam current and the lifetime at 100 MeV. The horizontal line in the figure is an estimated lifetime when the ion trapping occurs.

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