STATUS OF THE BEAM ACCUMULATION AT KSR

T. Shirai, Y. Iwashita, H. Tongu, T. Sugimura, A. Morita, A. Noda,
Institute for Chemical Research, Kyoto University, Uji, Kyoto 611 -0011, Japan
T.-Y. Lee
PLS, POSTECH, San 31, Hyoja Dong, Pohang, Kyungbuk 790-784, Korea

Abstract

KSR (Kaken Storage Ring) is a compact electron ring in Kyoto University. The injection and the maximum energy are 100 MeV and 300 MeV, respectively. It is used for not only an electron storage ring but also a stretcher.

The present stored current is 65 mA at 100 MeV. It is limited by an ion trapping effect and longitudinal single bunch instability. The beam lifetime is 300 sec at 100 MeV.

1 INTRODUCTION

A compact electron ring (Kaken Storage Ring, KSR) is working at Institute for Chemical Research, Kyoto University [1]. The basic parameters are shown in table 1 and the schematic view of the ring is shown in Fig.1. KSR has two operation modes, the storage mode and the stretcher mode. In the former case, the injected beam is accelerated up to 300 MeV. In the latter mode, the beam is extracted by the slow extraction and the beam energy is 100 MeV.

The beam commissioning had started from September 1999. Figure 2 shows the history of the stored electron current during the commissioning stage. At first, only a low current (<10 mA) was accumulated. After the shutdown to install the remaining vacuum chambers and the devices for the slow extraction, we restarted the commissioning from March 2000. The pumping system was also improved at the same period. The stored current reached to 65 mA at August 2000. Since the beginning of 2001, we started a normal operation of KSR. In this paper, we describe some phenomena to limit the beam current, which was found in the commissioning period.

In the year of 2001, the major experiment in KSR is a slow extraction of the electron beam using a RF perturbation [2]. The experiment of a Laser-Thomson scattering has also been carried out. To produce hard X-ray, the electron energy is 100 MeV and the laser wavelength is 532 nm [3].

2 STORED BEAM CURRENT AND THE LIMITATION

The electron linac typically injects a beam pulse at the current of 80 mA and the pulse width of 10 or 20 nsec. Table 1 shows the principal beam parameters at the operation of 100 MeV.

Table 1: Basic parameters of KSR

Maximum energy	300 MeV
Injection energy	100 MeV
Circumference	25.689 m
Straight length	5.62 m
RF frequency	116.724 MHz
RF Voltage	30 kV

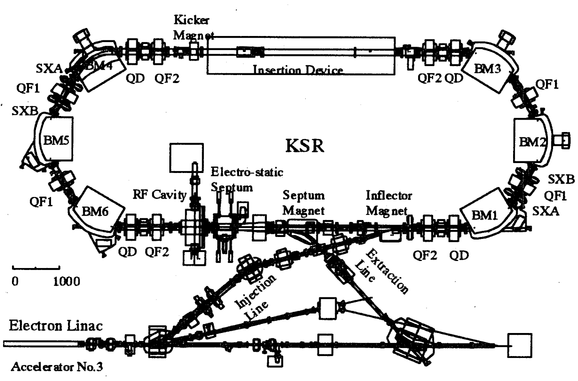

Figure 1: Layout of KSR.

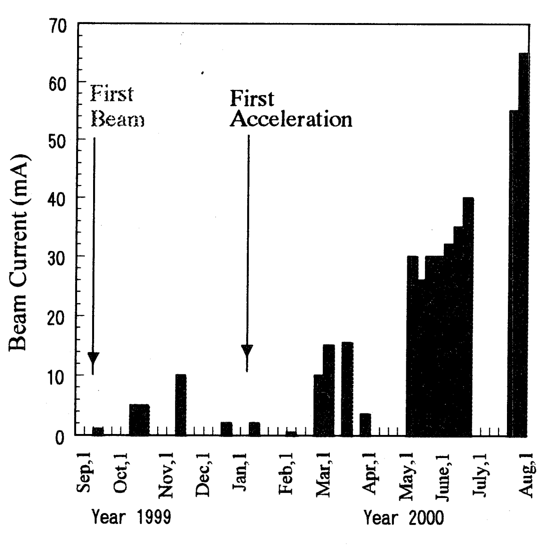

Figure 2 History of the stored current of KSR

Table 2: Beam parameters of KSR

	100 MeV (Calculation)	100 MeV (Measurement)
Betatron tune	(2.300, 1.275)	(2.285, 1.255)
Storage current	100 mA (Design value)	65 mA
Momentum compaction factor	0.106	---
Damping time (τ_X, τ_Y, τ_S)	(3.4, 1.7, 0.67) sec	---
Chromaticity (ξ_X, ξ_Y)	(-2.5, -8.1) (Natural)	(-3.1, -6.4) (Natural) (0.0, 0.1) (with Correction)
Horizontal Emittance	15.4 π.nm.rad (Equilibrium) 160 π.nm.rad (at 10 mA)	 130 π.nm.rad (at 10 mA)
Vertical Emittance	---	6.4 π.nm.rad (at 10 mA)
Energy spread	8.23×10^{-5} (Equilibrium) 3.3×10^{-4} (at 10 mA)	 ---
Average vacuum pressure	0.63 nTorr	1.1 nTorr

2.1 Lifetime

The stored current (I) is determined by the beam lifetime (τ) in the simplest case,

$$I = \tau f_{rep} I_0 \tag{1}$$

where f_{rep} is a repetition of the injection and I_0 is a stored current per one injection. I_0 is typically 2 or 3 mA and f_{rep} is 0.3 Hz, which corresponds to the horizontal damping time.

Because the RF voltage is 30 kV, the quantum lifetime is enough long. The beam lifetime is limited by the scattering with the residual gas and by Touschek scattering. Touschek lifetime is generally a severe limitation in a small ring. But the horizontal emittance becomes much larger than the natural emittance because that the injection energy is low and the effect of the intrabeam scattering (IBS) is strong. This effect extends the Touschek lifetime.

Figure 3 shows the measured lifetime bellow 40 mA without any instability and the calculated Touschek lifetime which includes IBS effect. It shows that the present major limitation comes from the residual gas scattering. Even in the present lifetime, the expected stored current is higher than 100 mA from eq. (1) but actually it is limited by following reasons.

2.2 Head-tail instability

The natural chromaticity is very large in KSR because the curvature of the bending magnet is small and the β function at the end of the straight section is large. It is difficult to accumulate the beam without a chromaticity correction. Even after the correction, the beam instability was found around the stored current of 15 mA when the chromaticity was slightly below zero.

Figure 4 shows the variation of the stored current measured by DC current transformer (DC-CT). The beam was injected every 4 seconds. The horizontal and vertical chromaticity was 0.3 and –0.5, respectively. The sudden

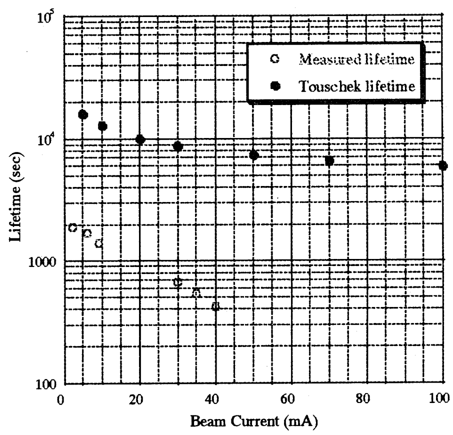

Figure 3 Measured lifetime without any instability and the calculated Touschek lifetime, which includes IBS effect.

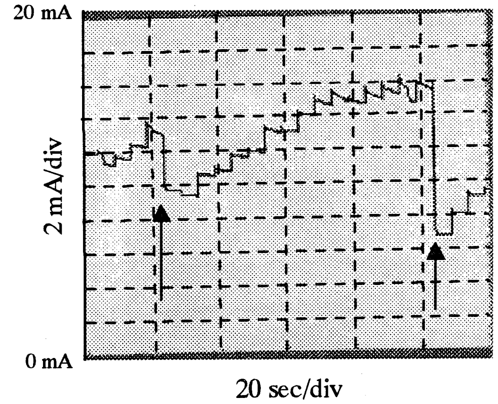

Figure 4 Stored beam current measured by DC-CT. The beam was injected every 4 seconds. The horizontal and vertical chromaticity was 0.3 and –0.5, respectively

beam loss was found and the beam current could not exceed 20 mA. After the chromaticity is changed to 0.0 and 0.1, the beam loss disappeared. This sensitivity to the chromaticity means that it comes from the head-tail instability.

2.3 Ion trapping instability

Due to the low injection energy (100 MeV), the beam trapping is remarkable in KSR, even though there are 2 ion clearing electrodes to apply 500 V. Figure 5 shows the DC-CT signal, when all RF buckets are filled with the beam bunches. At three seconds after the injection, the beam lifetime becomes extremely short (about 15 seconds). When the beam current decreased below 8 mA, it recovered rapidly to about 1000 seconds. At the same time, the vertical tune shift of 0.026 is also observed. The following relation is known between the tune shift ($\delta\nu_Y$) and the ion density (d_i) [4],

$$\delta\nu_Y = \int \frac{d_i \beta_Y}{1 + \frac{\sigma_Y}{\sigma_X}} ds \qquad (2)$$

where β_Y is a vertical β function and σ is a beam size. The measured result is consistent with this relation.

The ion trapping effect can be reduced by empty buckets. When the filled buckets is less than half, the drastic ion trapping is not observed. But it seems that the weak effect still exists because the measured beam lifetime in Fig.3 is shorter than the calculated one from the average vacuum pressure.

2.4 Longitudinal single bunch instability

In small electron rings, a strong longitudinal single bunch instability was reported because the revolution frequency is high. In KSR, a similar phenomenon is observed. Figure 6 shows a frequency spectre of a pickup signal from an electrostatic monitor. The centre peak corresponds to the revolution frequency and the side two peaks are synchrotron oscillation sidebands. It shows the existence of the longitudinal instability. The sideband sometimes grows up and leads to the beam loss. This instability does not depend on the number of the beam bunch.

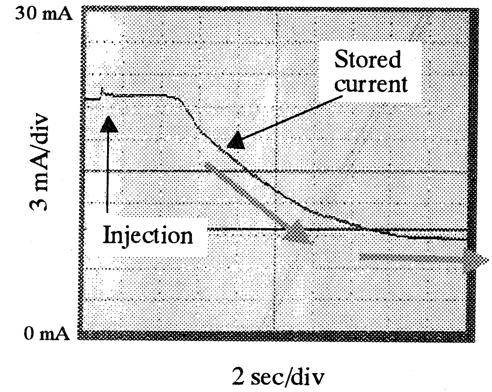

Figure 5 Stored beam current, when all RF buckets are filled with the beam bunches. At three seconds after the injection, the beam lifetime becomes extremely short.

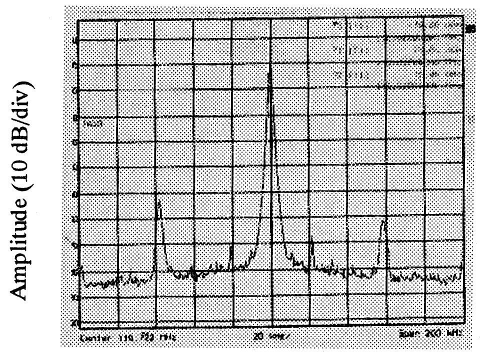

Figure 6 frequency spectre of a pickup signal from an electrostatic monitor. The centre peak corresponds to the revolution frequency and the side two peaks are synchrotron oscillation sidebands

3 CONCLUDING REMARKS

The present stored current is 65 mA and the beam lifetime is about 300 seconds at 100 MeV. They are limited by the longitudinal instability and the weak ion trapping. To clarify the situation and increase the lifetime, we continue the aging by the synchrotron radiation. The present beam lifetime at 300 MeV is also reported in another contribution paper [5].

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