

# DESIGN OF AN ELECTRON STORAGE RING FOR SYNCHROTRON RADIATION

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## Abstract

A small electron storage ring with the maximum energy of 300 MeV is now under construction. As the injector, an electron linac with disc loaded type of s-band is to be used and the injection energy is about 100 MeV. A triple-bend doubly achromatic lattice is adopted to provide two long straight sections as long as 5.62 m for installation of an optical klystron.

## 1 Introduction

At Nuclear Science Research Facility of Institute for Chemical Research(Kaken in Japanese), Kyoto University, a small electron storage ring (called KSR abbreviating Kaken Storage Ring) with the maximum energy of 300 MeV is now under construction. As an injector, an s-band disc-loaded type electron linac, which consists of an electron gun, a pre-buncher, a buncher and three accelerating tubes, is to be utilized. The total electron facility consisting of KSR and the injector linac is to be installed in the experimental area of the 7 MeV proton linac which is already operating since 1992 and available space for the electron facility is limited to be less than  $10 \times 25 \text{ m}^2$  as shown in Fig. 1. Thus the injection energy is set to be 100 MeV due to the limitation of the the available site for the injector linac, which causes a little long damping time of a few seconds. The accelerator facility is to be used for the beam dynamics study, the research of the electron beam, development of insertion devices for free electron laser and so on. The facility is mainly used for accelerator related R&D for the moment. The ring is, however, can serve as a light source for such researches as study of the electric structures of atoms and molecules,

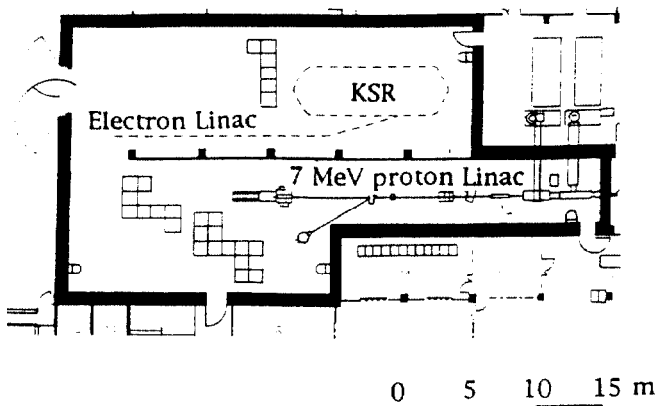


Fig. 1 Layout of the Experimental Area

Table 1 Main Parameters of KSR

Maximum Energy	300 MeV
Circumference	25.689 m
Lattice Structure	Triple bend doubly achromatic
Superperiodicity	2
Bending Angle	$60^\circ$
Radius of Curvature	0.835 m
n-value	0
Edge Angle	$0^\circ$
Length of Long Straight Section	0.619 m
Harmonic Number	10
RF Frequency	116.7 MHz
Number of Betatron Oscillations	
Horizontal	2.75
Vertical	0.75

synchrotron-radiation induced reaction, fine structure analysis, crystal structure analysis and so on after the facility for producing synchrotron radiation and/or free electron laser is completed. The future usage of the ring is now the discussing stage at the institute.

## 2 Lattice Structure

So as to provide rather long straight sections for installation of insertion device in a limited area, triple-bend doubly achromatic lattice as shown in Fig. 2 is adopted. Owing to the reflection symmetry with respect to the center of the middle dipole magnet, the doubly achromatic long straight sections are realized by merely satisfying the following relation[1],

$$\begin{aligned} & \cos(\sqrt{k}l) \left[ -\frac{\sin \frac{\theta}{2}}{\rho} \{ \rho(1 - \cos \theta) + L \sin \theta \} + \sin \theta \left( \cos \frac{\theta}{2} - \frac{L}{\rho} \sin \frac{\theta}{2} \right) \right] \\ & + \sin(\sqrt{k}l) \left[ -\frac{1}{\sqrt{k}} \frac{\sin \frac{\theta}{2} \sin \theta}{\rho} - \sqrt{k} \left( \cos \frac{\theta}{2} - \frac{L}{\rho} \sin \frac{\theta}{2} \right) \{ \rho(1 - \cos \theta) + L \sin \theta \} \right] \\ & + \sin \frac{\theta}{2} = 0 \end{aligned}$$

where  $\rho$ ,  $\theta$ ,  $l$  and  $L$  are radius of curvature, bending angle of the dipole magnet, length of the quadrupole magnet and distance between dipole and quadrupole magnets in the arc, respectively and  $k$  is defined as  $G/B\rho$  using the field gradient of the quadrupole magnet,  $G$ . The doublet focusing is adopted for the long straight sections and the  $\beta$ -functions

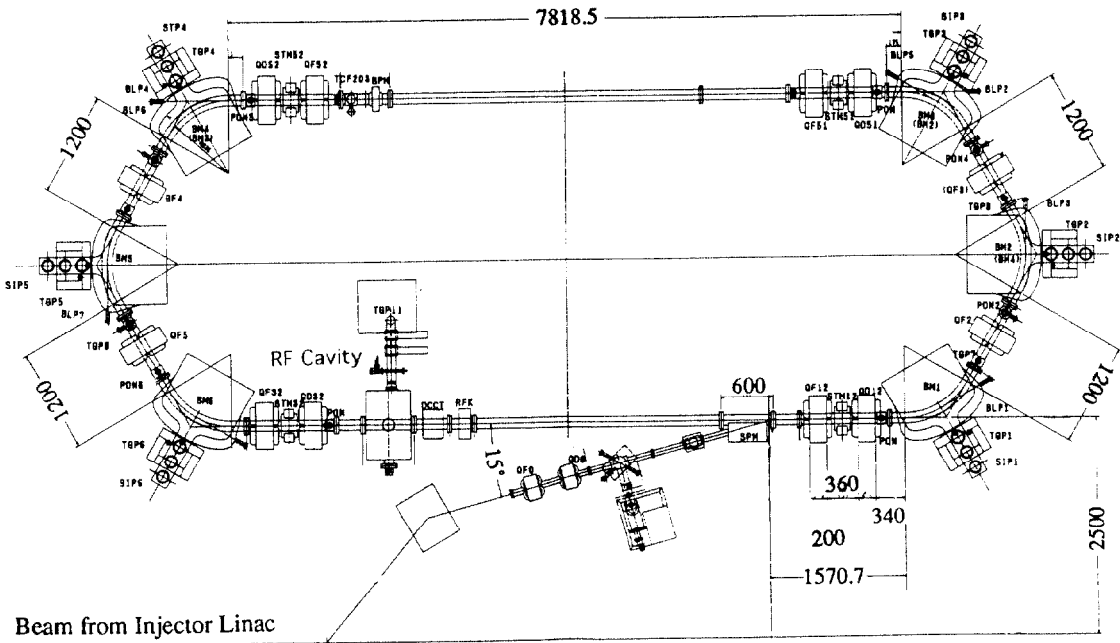


Fig. 2 Layout of the Electron Ring (KSR)

remain in moderate sizes. The maximum value of the dispersion is also the moderate size of 1.0 m. In Fig. 3,  $\beta$ -functions in horizontal and vertical directions (a) and dispersion function (b) are shown for the half circumference.

The natural chromaticity (defined as  $\Delta Q/(\Delta p/p)$ ) of the ring is estimated to be -2.7 and -7.6 in horizontal and vertical directions, respectively, taking the effect of the fringing fields of the dipole magnets into account, while corresponding values without the effects are -4.3 and -6.1, respectively as shown in Fig. 4(a) and (b). The above calculation is performed with use of the computer code MAD[2]. In order to correct the chromaticity to a small size, rather strong sextupoles are needed, whose nonlinear effect on the electron orbits needs further studies. The main parameters of the ring is given in Table 1.

The tunable frequency range of the RF cavity is  $116.7 \text{ MHz} \pm 0.15 \text{ MHz}$  and the circumference of the central orbit is determined to be 25.683 m adopting the harmonic

number of 10. The circumference should be adjusted with the precision of better than a few cm. Consideration of future installation of optical klystron led us to determine the harmonic number of 10. Thus the length of the long straight section is determined to be 5.6185 m.

### 3 Property of the Electron Ring

#### 3.1. Damping Time

The damping time is calculated with use of the computer code SYNCH[3]. The rather lower injection energy of 100 MeV results in rather longer damping times as long as 3.4 sec, 1.6 sec and 0.64 sec for horizontal, vertical and energy damping, respectively, which should be compared with the corresponding ones of 0.13 sec, 0.06 sec and 0.02 sec at the energy of 300 MeV. So the repetition rate of the injector linac is not required so high (less than 1 Hz is enough), while its maximum is set to be  $\sim 20 \text{ Hz}$  for the merit of easy machine tuning.

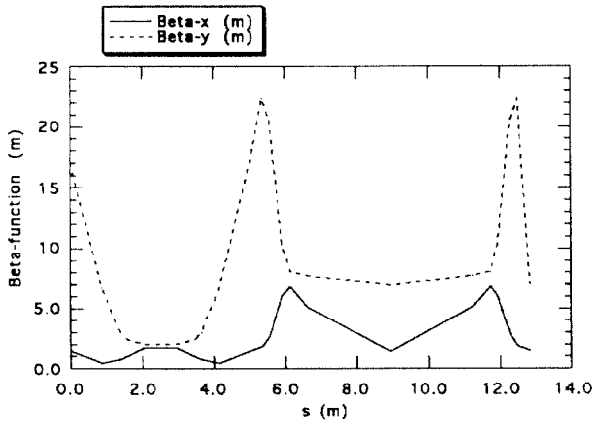


Fig. 3(a)  $\beta$ -functions for the half circumference.

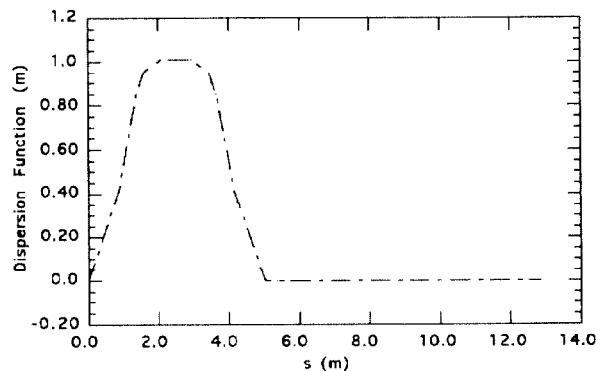


Fig. 3(b) Dispersion function for the half circumference.

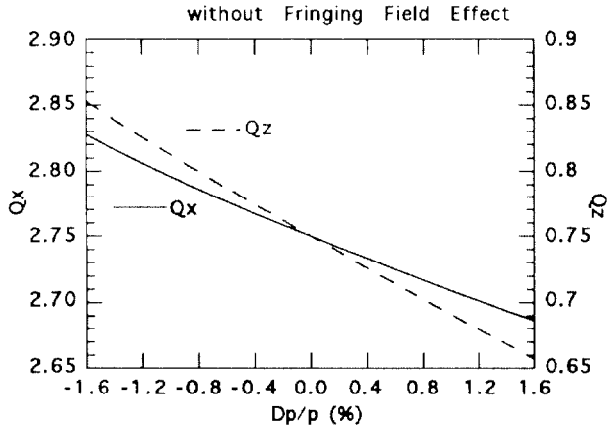


Fig. 4(a) Momentum dependence of tunes without fringing field effect.

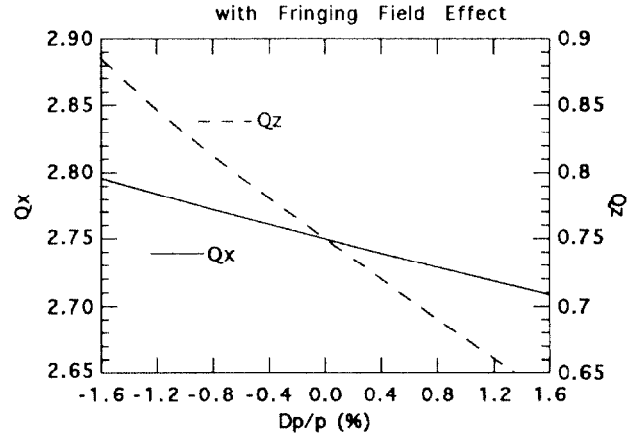


Fig. 4(b) Momentum dependence of tunes with the fringing field effect.

### 3.2. Beam Emittance

At the maximum energy of 300 MeV, the beam emittance of the stored beam is close to the natural emittance and is estimated to be  $\sim 150\text{nm}\cdot\text{rad}$  while at the injection energy of 100 MeV, the emittance is mainly determined by intra-beam scattering and is estimated to be a few times larger than the above value for the case of high intensity beam accumulation more than 100 mA.

### 3.3. Touschek Life

As the beam life largely depends on the manner of the real fabrication of the ring, it might be difficult to tell the exact beam life of the ring at the present stage of the construction. For example, it depends the final vacuum pressure and the orbit distortion etc. In the present case, the injection energy is as low as 100 MeV and Touschek life is anticipated to be dominant compared with the life due to outgassing and/or residual gas. Assuming the RF voltage of 30 kV, the Touschek life time is estimated to be 15 min. and 2.7 hours at 100 MeV and 300 MeV, respectively which seems to be tolerable.

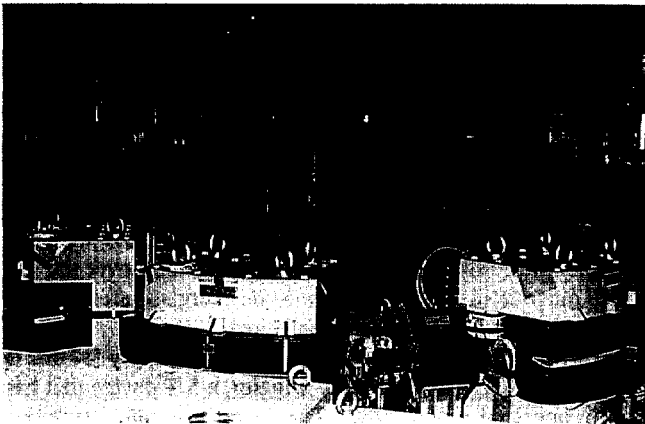


Fig. 5 Overall view of the KSR.

### 3.4. Spectrum of the Light

The critical wave length of the synchrotron radiation of 300 MeV electron from the bending section with the radius of curvature of 0.835 m is 17 nm. Thus the region of the wave length from vacuum ultraviolet to violet will be provided from this port. As the complementary one, the optical klystron to be installed in the long straight section is now oriented for free electron laser in infrared region, because the mirror system seems to be of less difficulty in this wave length region compared with much shorter wave length, although it is not yet fixed and needs some discussion among users in various fields in the institute before final decision.

## 4 Present Status

The electron facility is now under construction and the power sources is already set in the experimental hall. The operation of the injector linac is scheduled to be started within this fiscal year. The magnets of the KSR are also already set at their rough position although they are still to be precisely aligned. Figure 5 shows the present status of the facility quite well.

## 5 Acknowledgement

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## 6 References

- [1] J.J. Livingood, "The Optics of Dipole Magnet", pp.148.
- [2] F. C. Iselin and J. Niederer, "The MAD Program", CERN/LEP-TH/88-38.
- [3] A. Garren and J. W. Eusebio, "SYNCH A Computer System for Synchrotron Design and Orbit Analysis", Lawrence Radiation Laboratory Report, UCID-10154 (1965).