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Outline of the Compact Electron Storage Ring, KSR

Akira NODA*, Hideki DEWA*, Hirokazu FUJITA*,
Masanori IKEGAMI*, Yoshihisa IWASHITA*, Shigeru KAKIGI*,
Masaki KANDO*, Katsuo MASHIKO**, Toshiyuki SHIRAI*
and Makoto INOUE*

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A compact electron storage ring as a synchrotron light source is designed and is now under construction. Its circumference, radius of curvature at the bending sections, the length of the long straight section, the injection and the maximum energies are designed to be 25.7 m, 0.835 m, 5.62 m, 100 MeV and 300 MeV, respectively. The critical wave length of the radiation from the bending magnets is 17 nm and the light in much shorter wave length region can also be provided with an insertion device.

KEY WORDS: Synchrotron Radiation/ Critical Wave Length/ Insertion Device

1. INTRODUCTION

At Nuclear Science Research Facility of Institute for Chemical Research (Kaken in Japanese), Kyoto University, a compact electron storage ring (called KSR abbreviating Kaken Storage Ring) is now under construction. An s-band (2,857 MHz) electron linac with disc-loaded type is to be utilized as an injector[1]. The injection energy is about 100 MeV which needs a little longer damping time of a few seconds. The layout of the total electron facility is shown in Fig. 1. The electron energy is to be accelerated up to the maximum energy of 300 MeV with the re-entrant type accelerating cavity in the ring with the frequency of 116.7 MHz.

The storage ring is to be optimized for light source with synchrotron radiation and relatively long free spaces are kept for future insertion of such devices as an undulator and/or a wiggler, which are still left to be fixed in design to realize unique characteristics most suitable as a research facility of Institute for Chemical Research, although a typical example is given here for the purpose of stimulating the discussion.

2. LATTICE STRUCTURE

The structure of the KSR is designed to provide as long free spaces as possible for insertion of various equipments for radiation production such as wiggler and/or an undulator and beam monitors etc. in a limited circumference. From this consideration, a race track ring with triple bends doubly achromatic lattice is adopted[2]. Six dipole magnets with deflection angle and

* 野田 章, 出羽英紀, 冨士田浩一, 池上雅紀, 岩下芳久, 柿木 茂, 神門正城, 白井敏之, 井上 信: Nuclear Science Research Facility, Institute for Chemical Research, Kyoto University, Uji, Kyoto 611, Japan.
** 益子勝夫: Nihon Kensetsu Kogyo Ltd.

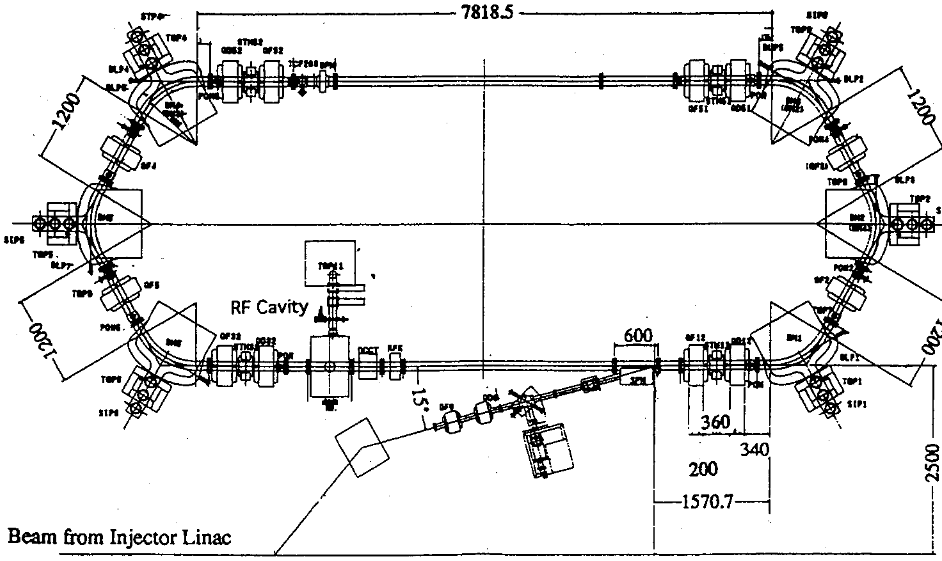

Fig. 1. Layout of the KSR and its injector.

radius of curvature of 60° and 0.835 m, respectively are used in total to form closed orbit. At four short straight sections between two dipole magnets, horizontally focusing quadrupole magnets are utilized, the field gradient of which is fixed at the certain value in order to realize doubly achromatic long straight sections. The RF frequency of the RF cavity is 116.7 MHz and the circumference should be integral multiples of the 2.5689 m and the harmonic number of 10 is utilized taking the size of the available area into account. At the long straight sections 5.619 m in length, doublet focusing structure is adopted. Thus the layout shown in Fig. 1 is determined.

The operating point around (2.75, 0.75) is assumed for the normal mode operation, where β-functions in horizontal and vertical directions and dispersion function in horizontal direction

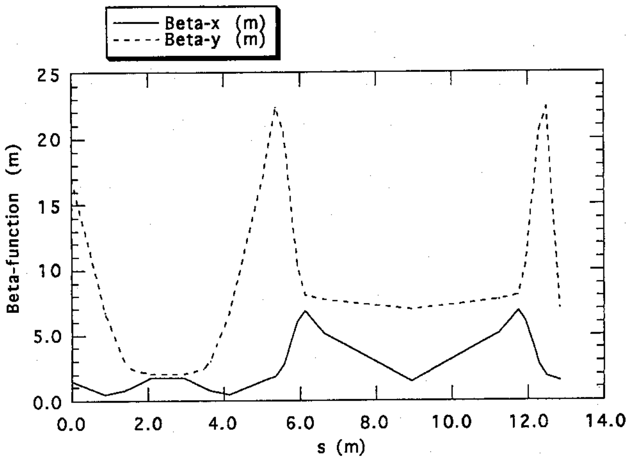

Fig. 2. β-functions in the half circumference. Solid and dashed lines represent ones in horizontal and vertical directions, respectively.

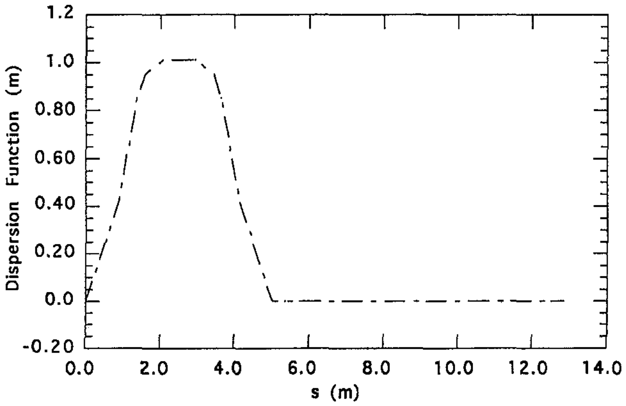

Fig. 3. Dispersion function in the half circumference.

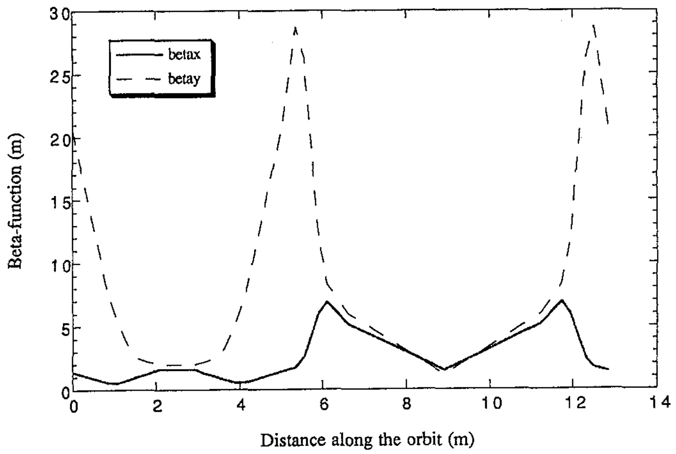

Fig. 4. β-functions in the half circumference for the operating point of (2.75, 1.25).

behave as shown in Fig. 2 and Fig. 3, respectively. In case of utilization of insertion device, the vertical tune depression due to such an insertion device might cause beam instability and stronger vertical focusing might be preferable. In Fig. 4, β-functions for the operating point of (2.75, 1.25) are shown. More extensive studies about beam dynamics of this operating points are needed before final decision of the operating point for the insertion device. In Table 1, main parameters of KSR are listed up.

The natural chromaticity (defined by $\Delta Q/(\Delta p/p)$) is estimated to be -2.7 and -7.6 in horizontal and vertical directions, respectively considering the fringing field effect of the dipole magnets. For the purpose of chromaticity correction, sextupole magnets should be set in limited positions in two arcs where the dispersion function has finite value. It is found that rather strong sextupole strength is required in order to attain small chromaticity size, which should be studied in connection with the nonlinear effect of the sextupole fields.

Table 1. Main Parameters of KSR.

Maximum energy	300 MeV
Injection energy	100 MeV
Circumference	25.689 m
Lattice structure	Triple bend doubly achromatic lattice
Superperiodiciwy	2
Bending angle	60°
Radius of Curvature	0.835 m
n-value	0
Edge angle	0°
Length of long straight section	5.619 m
Harmonic number	10
RF frequency	116.7 MHz
Number of Betation Oscillations	
Horizontal	2.75
Vertical	0.75 (1.25)
Critical wave length from dipole	17 nm

3. BEAM CHARACTERISTICS OF KSR

As the injection energy is rather low at ~100 MeV, the damping time of the ring is anticipated to be rather long. Damping times of the betatron oscillations in horizontal and vertical directions and energy oscillation are estimated to be 3.4 sec, 1.6 sec and 0.64 sec, respectively[2)]. So the repetition rate of the beam injection from the linac should be less than 1 Hz, although the injector linac is able to be operated up to 20 Hz for beam tuning.

The emittance of stored beam at the maximum energy is estimated to be close to the natural emittance of ~150 nm·rad while it is estimated a few times larger than this value due to intra-beam scattering for the case of storage of the beam with the intensity of 100 mA. The beam life at the injection energy of 100 MeV is considered to be limited by Touschek life, which is estimated to be 15 min. while it becomes to be 2.7 hours at 300 MeV.

4. SPECTRUM OF THE LIGHT

The electron radiates the light when it is curved by the magnetic field. The magnetic field of the dipole magnet is 1.2 T at the maximum energy and radius of curvature (ρ) is 0.835 m, which results in the spectrum shown by the solid line in Fig. 5. The photon strength assumes the accumlated beam current of 100 mA. The critical wave length of the light from the dipole section is calculated to be 17.3 nm from relation,

$$\lambda_c=\frac{4\pi\rho}{3\gamma^3},$$

where γ is the ratio of the total energy and the rest mass of the electron[3)]. The light strength decreases rapidly for the wave length of several nm as is shown in the figure. In order to remedy this situation, possibility to insert a superconducting wiggler in one of the long straight sections is now studied. As a typical example, such a three pole wiggler with magnetic field and periodic

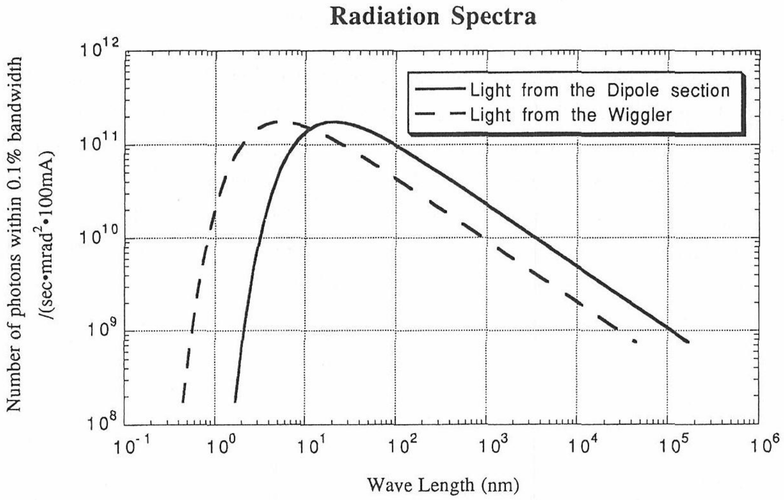

Fig. 5. Spectra of the light radiated from the dipole (solid line) and the proposed superconducting wiggler in the long straight section (dashed line).

length of 4.6 T and 0.15 m, respectively will provide the spectrum as given by the dashed line in Fig. 5. It can be seen that the spectrum is enlarged toward the wave length region of several nm.

In addition to the wiggler above mentioned, an optical klystron for free electron laser in infra-red region is also studied. Much more discussion about the utilization of such lights is required before final decision of the insertion devece. The KSR ring is now under construction as shown in Fig. 6 and all the magnets and the RF cavity are already installed in the experimental hall and the precise alignment is scheduled to be started soon.

Fig. 6. The overall view of the KSR.

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REFERENCES

(1) T. Shirai, *et al.*, Paper in this bulletin.
(2) A. Noda, *et al.*, Design of an Electron Storage Ring for Synchrotron Radiation", Proc. of the 4th European Particle Accelerator Conference, London, United Kigdom, pp. 645–647 (1994).
(3) S. Krinsky, M.L. Perlman and R.E. Watson, "Characteristics of Synchrotron Radiation and of its Sources", Handbook on Synchrotron Radiation, Edited by E. Koch, North-Holland Pub. Co., pp. 65–171 (1983).