

STORAGE RING DESIGN FOR THE 8 GEV SYNCHROTRON RADIATION FACILITY
IN JAPAN

MASAHIRO HARA, SUCK HEE BE, TAKUYA KUSAKA, HIROKI MIYADE,
YOSHIHIDE MORIMOTO, SHOSHICHI MOTONAGA, RYUTARO NAGAOKA, JUNICHI
OHNISHI, YOSHIFUMI OIKAWA, SHIGEKI SASAKI, HIDEKI TAKEBE, HITOSHI
TANAKA, KOJI TSUMAKI, TAKESHI WADA, SHIGERU YOKOUCHI, KATSUHISA
YOSHIDA, TAKESHI YOSHIYUKI, and HIROMICHI KAMITSUBO
RIKEN-JAERI Synchrotron Radiation Facility Design Team
2-28-8 Honkomagome, Bunkyo-ku, Tokyo, 113, Japan

Abstract This paper outlines the status of design study for the 8 GeV highly brilliant synchrotron radiation X-ray source ring, recently named Super Photon Ring(SPring-8). The light source ring which stores electrons or positrons, is optimized for insertion devices. The ring is 1428.9 m in circumference, and has 48 straight sections, and is based on the extended Chasman-Green type of achromatic cell. The low emittance ($\epsilon_x = 5.3 \text{ n m} \cdot \text{rad}$) and sufficiently large dynamic aperture are achieved even with field errors and misalignments. The currents of 100 mA for multi-bunch and 5 mA for single-bunch mode operations are expected. The RF frequency and harmonic number are 508.58 MHz and 2436, respectively. R&D work on the vacuum system, magnet system, and RF system are also in progress.

INTRODUCTION

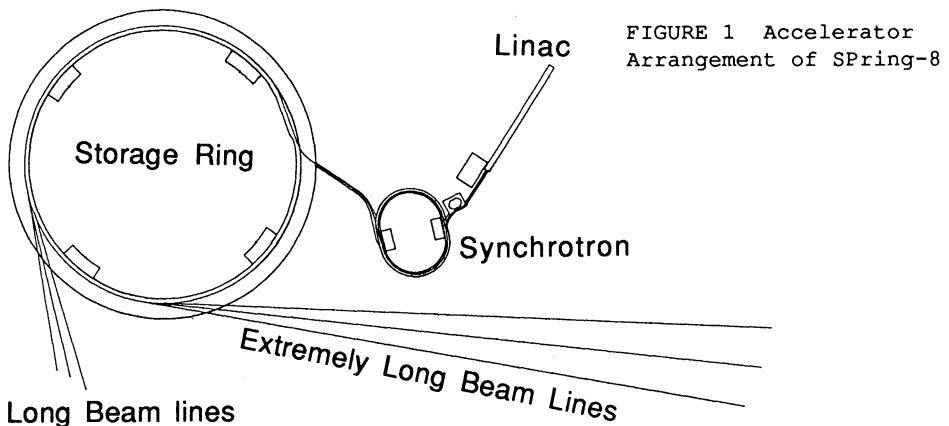
The need for highly brilliant photon beams in X-ray region was widely envisaged. To meet the need, construction of the third generation synchrotron light sources of 4-8 GeV region, such as ESRF¹ and APS², is in progress. In Japan, RIKEN and JAERI, which are supervised by Science and Technology Agency (STA) of Japanese Government made a joint design team and started the design study of synchrotron radiation X-ray source. In 1988, Harima Science Garden City which is under construction in Hyogo prefecture was selected as the site. Recently the light source was named SUPER PHOTON RING (SPring-8). Construction of the facility is expected to start in FY1990, and commissioning will be in 1995.

General description

The facility, as is shown in Fig.1, consists of a main storage ring, a full-energy injector booster synchrotron³ and a pre-injector 1 GeV linac³. The purpose of this facility is to provide stable photon beams with high brilliance in the X-ray region. In the design of a dedicated synchrotron light source, the following conditions are required:

- 1) Low emittance operation with $\epsilon_x < 10$ n m-rad.
- 2) Optimization for insertion devices.
- 3) Up to 120 keV photon beams within the fifth mode of undulator.
- 4) ~200 keV photons from a multipole wiggler.
- 5) Positrons can be stored.
- 6) A full energy injection system.
- 7) Long beam life time (>10 hrs).

The main parameters of the designed ring are listed in Table 1.



Magnet lattice

The magnet lattice of SPring is based on the double bend achromat (extended Chasman-Green) structure. The length of free straight section for the insertion devices is 6.5 m. Figure 2 shows the lattice functions for hybrid mode. This mode has the alternative high and low beta functions at the long straights. In this mode, the ring has the super-periodicity of 24 at the maximum. The chromaticity is corrected by 3 sextupoles in the dispersive sections. Harmonic sextupoles are placed in dispersion-free sections to enlarge the dynamic aperture. Their strengths were optimized using the computer code CATS⁴, and the detailed sextupole optimization is reported in this conference⁴. The

TABLE 1 Summary of Major Parameters of the Storage Ring

Energy	E (GeV)	8
Current (multi-bunch)	I (mA)	100
Current (single-bunch)	I (mA)	5
Circumference	C (m)	1428.87
Dipole magnetic field	B (T)	0.61
Bending radius	ρ (m)	43.72
Number of cells	Nc	48
Length of straight section	L (m)	6.5
Natural emittance	ϵ_n (π m-rad)	$5.265 \cdot 10^{-9}$
Critical photon energy	ϵ_C (keV)	26.0
Tune	ν_x	51.22
	ν_z	19.16
Synchrotron tune	ν_s	0.00952
Momentum compaction	α	$1.373 \cdot 10^{-4}$
Natural chromaticity	ζ_x	-119.35
	ζ_z	-40.34
Energy loss in the arcs	U_0 (MeV/rev)	8.3
Energy spread	σ_e/E	0.00103
Damping time	τ_x (msec)	9.203
	τ_z (msec)	9.206
	τ_e (msec)	4.604
Harmonic number	h	2424
R.F.voltage	V_{rf} (MV)	16
R.F.frequency	f_{rf} (MHz)	508.58

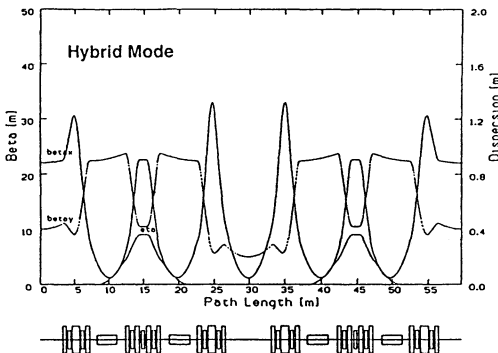


FIGURE 2 Lattice functions over a superperiodic cell for hybrid mode.

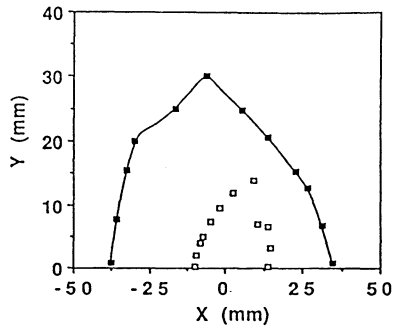


FIGURE 3 Dynamic aperture of the ideal lattice. Empty and dark squares indicate the apertures with and without harmonic correction.

obtained dynamic aperture for the ideal machine is shown in Fig. 3. Tracking with various errors in the ring and a correction of closed orbit distortion is done by RACETRACK⁵. A closed orbit distortion (COD) is induced by quadrupole misalignments. The COD induces a tune-

shift at every sextupole around the ring, which makes dynamic aperture small. The COD correction is done with 8 monitors and 6 horizontal and vertical correctors in a cell. Monitors are installed near sextupoles, and COD is basically corrected near sextupoles.

Beam stability

Instabilities are studied using ZAP code⁶ to achieve 5 mA beam currents for single-bunch operation and 100 mA for multi-bunch operation. To obtain good lifetime, momentum spread should be less than 0.3 % due to chromatic behavior of particles. Since momentum spread without bunch-lengthening is 0.1 %, three times bunch-lengthening which corresponds to 1 cm, are allowable. Figure 5 shows the relation of bunch length vs current with SPEAR scaled broad band impedance $Z_{//}/n$. From the figure, broad band impedance should be less than about 1.5 Ω to obtain 5 mA beam currents. As for the coupled impedance, higher order modes of each rf cavity should be de-Qed by about a factor of 10.

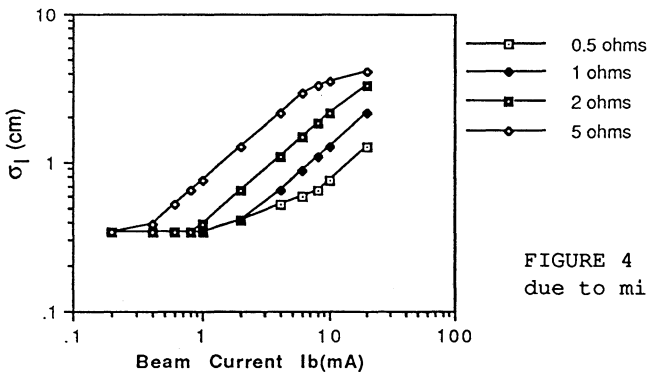


FIGURE 4 Bunch lengthening due to microwave instability.

Magnet system

In total, 98 dipoles, 480 quadrupoles, and 336 sextupoles are used. The required field quality is 5×10^{-4} for dipoles and 1×10^{-3} for quadrupoles, and 5×10^{-3} for sextupoles. The required good field region is ± 35 mm in horizontal and ± 15 mm in vertical. We carried out numerical calculation on magnetic fields using the program code LINDA and TRIM. The bending magnet is C-shaped rectangular type. Quadrupole and sextupole magnets were designed to install vacuum vessel having extraction space for synchrotron radiation. Moreover sextupole magnet is required

to provide a horizontal or vertical dipole field for the closed orbit correction. The detailed design of prototype magnets have already been finished and the fabrication of them is now in progress.

RF system

The RF system consists of four 1-MW klystrons and 508.58 MHz cavities which are located in four 6.5-m straight sections with low betatron functions. Thirty two single-cell cavities are used. First, we investigated a single cell with nose corn. In order to reduce the impedance of HOM, single cell without nose corn (Fig. 5) is studied now. High power tests using a 1-MW klystron and proto- type cavity, are planned in order to determine the final specifica- tions of the RF system. The control system will be also developed through these tests.

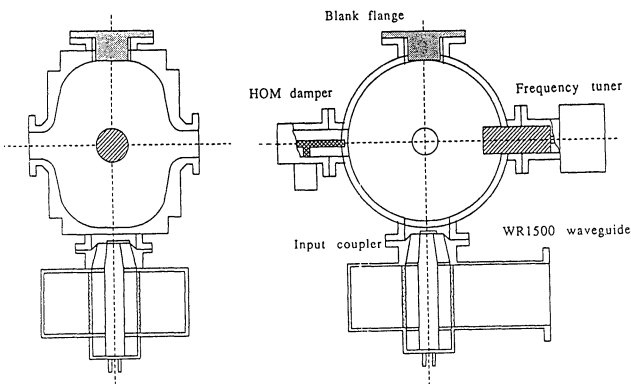


FIGURE 5 Schematic diagram of 508.58 MHz single cell cavity without nose corn.

Vacuum system

Our philosophy of the vacuum system for the storage ring is that most of synchrotron radiation is intercepted by crotches and absorbers placed just downstream and upstream by a bending magnet, and not intercepted by the vacuum chamber all around the ring. The crotch is designed so as 1) to trap reflected photons and their associated photo-electrons, and released gas molecules, and 2) to reduce RF impedance, introduced owing to the crotch, by means of smoothing the electron beam chamber side. At present, prototype bending magnet- and straight section- chambers have been manufactured by extrusion methods. Prototype crotch and Lumped NEG have been completed. Tests on

these prototypes would give some elucidating results by the end of this year. The vacuum chamber components such as the bellows with RF contact, all metal gate valve, and so on will be designed and manufactured within this year.

Beamlines

Main light sources are from the Insertion Devices. Radiations from some bending magnets are also used. The "hybrid" mode operation is basically expected. Four low-beta straight sections are used for cavities, and one high-beta straight section for injection. Undulators will be installed in the high-beta straight sections, and wigglers in the low-betas. The radiation spectra from typical undulators, wiggler, and bending magnet are shown in Fig. 6. A design on shielding wall was performed considering the users' request that the first mirror or monochromater be installed as near to the source as possible. With the choice of double shielding-wall structure, we can make the first wall thin, and therefore, the distance between source and the wall short. The second shielding-wall will be helpful in reduction of radiation background caused by mirrors.

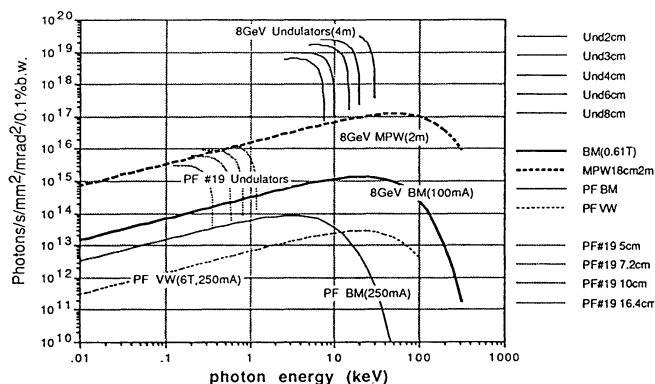


FIGURE 6 Spectral brilliance of SPring with currents 100 mA. For Comparison, the brilliance of PF are also calculated.

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