PRESENT STATUS OF THE SPring-8 (STORAGE RING)

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Introduction

RIKEN and JAERI are going to build an 8 GeV synchrotron radiation facility (SPring-8) in Harima Science Garden City in Hyogo prefecture. SPring-8 (Super Photon ring 8 GeV) is the third generation synchrotron radiation X-ray source. The ring has a circumference of 1436 m and stores a low emittance (ε_n =7 nm•rad) electron beams and is optimized for the insertion devices to get high brilliance radiation from undulators and high flux radiation from wigglers in the X-ray region. The aim of the facility is to promote the basic research and development of advanced technology using high-brilliant synchrotron radiations in X-ray region. This facility will be opened to research groups of universities, national laboratories, and industries not only in Japan but also in the world.[1]

General description of the facility

The accelerator system of the SPring-8 consists of the 1 GeV linac, 8 GeV synchrotron[2], and the storage ring. The general layout of the facility is shown in Fig. 1. The construction was started in 1990 and the facility is scheduled to come to operation in 1997. The ground preparation in Harima Science Garden City in Hyogo prefecture has been started and will be completed in 1992. The construction of the storage ring building has been started and the final specification of the related parts has been fixed. The design of the storage ring was reviewed mainly from the cost reduction point and a part of the magnets was ordered. The construction of the vacuum and RF systems starts this year. The detailed design of the storage ring building are in progress. Major parameters of the storage ring are listed in Table 1.

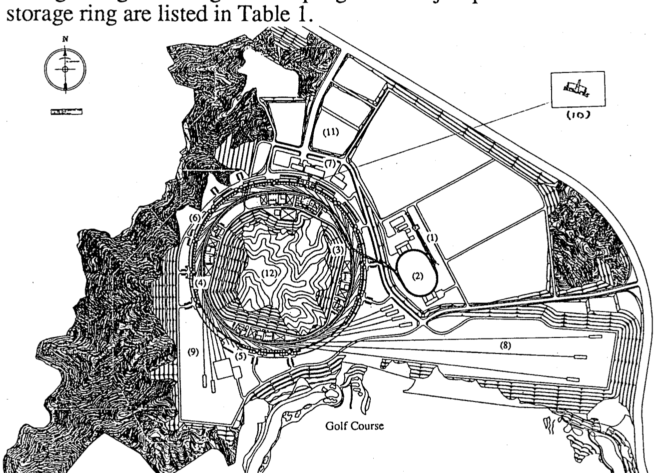


Fig. 1. Layout of the SPring-8 facility.
(1) 1GeV electron/positron building, (2) 8GeV synchrotron tunnel, (3) Storage ring building, (4) Experimental hall, (5) RI research, (6) Lobos for users, (7) Central building, (8) Long beam lines (1000m), (9) Long beam lines (300m), (11) Cafeteria, (12) Hill

Storage ring lattice

Chasman-Green (double bend achromat) lattice structure has been adopted for the storage ring. Number of cells is 48. Forty-four of them are normal cell and the others are straight cells. A normal unit cell is composed of 2 dipoles, 10 quadrupoles, and 7 sextupoles. For a straight cell, dipoles are taken off. The beam optical properties are equivalent for these cells. Magnet arrangements for a normal is shown in Fig. 2. Betatron and dispersion functions are shown in Fig. 3. Insertion devices can be installed at the dispersion-free straight sections. At a straight cell, a long straight section is formed straight sections. At a straight cell, a long straight section is formed and four insertion devices can be installed there. The straight cell can be modified to form a magnet-free long straight section about 30 m and can be used for FEL experiment.[3]

Low emittance ring requires strong quadrupole magnets, which results in a large natural chromaticity. The chromaticity is corrected using three sextupole magnets at a dispersive section in a unit cell to suppress a head-tail instability. Introduction of chromaticity correction sextupole fields results in a small dynamic aperture. For dynamic aperture improvement, harmonic sextupole magnets are used in a dispersion free sections.

Table 1. Storage ring parameters

Energy (GeV)		8
Current(multi-bunch) (mA)		100
Current(single-bunch) (mA)		5
Circumference (m)		1435.948
Dipole magnetic field (T)		0.679
Bending radius (m)		39.2718
Type of lattice		Chasman-Green
Number of cells	Normal/Straight	44/4
Length of straight section	normal/long (m)	6.65/~30
Natural emittance (nm·rad.)		6.99
Critical photon energy (keV)		28.90
Tune	ν_x/ν_y	51.22/16.16
Synchrotron tune	ν_s	0.01005036
Momentum compaction	α	1.4597×10-4
Natural chromaticity	ζ_x/ζ_y	-115.9/-40.0
Energy loss in BM (MeV/rev)		9.2263
Energy spread	σ_e/E	0.0010936
Damping time	$\tau_x/\tau_y/\tau_s$ (msec)	8.30/8.31/4.15
Harmonic number		2436
R.F. voltage (MV)		17
R.F. frequency (MHz)		508.58
Bunch Length σ_s (mm)		3.63

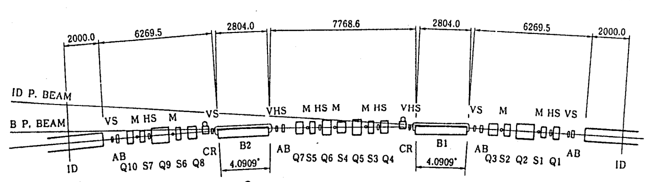


Fig. 2. An arrangement of magnets in unit normal cell.

B: Bending magnet
Q: Quadrupole magnet
S: Sextupole magnet
ID: Insertion device
AB: Absorber
HS(STH)
VS(STV)
VHS(STVH)
CR : Crotch
M: Monitor
Steering magnet

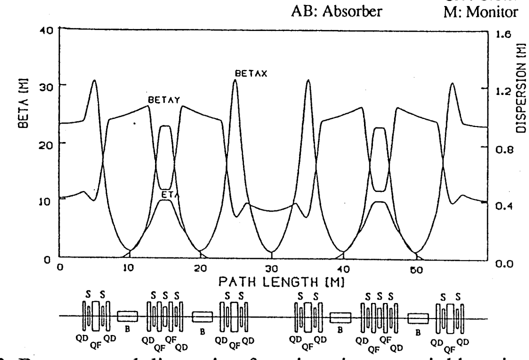


Fig. 3. Betatron and dispersion functions in two neighbouring cells. Betatron functions are alternatively high and low at dispersion free straight sections.

Magnet system

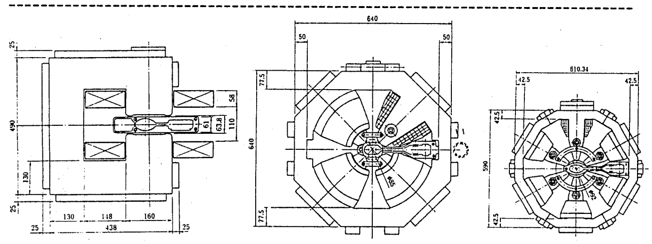
In the storage ring, 88 dipoles, 480 quadrupoles, 336 sextupoles, 480 steering magnets, 4 septum magnets, and 5 bump magnets are used. The final design of the main magnets have been completed[4], and have ordered to the manufacturers. Specification of the dipole, quadrupole, and sextupole magnets are listed in Table 2 and cross sectional views are shown in Fig. 4. Major alterations are shortening width and length of bending magnet, reducing bore radii and lengths of quadrupole and sextupole magnets for cost reduction and saving waste. Steering magnets incorporated into sextupole magnet are separated. These magnets have been orderd to manufacturers.

All the dipole magnets are connected in series and powered by a single power supply. For quadrupole and sextupole magnets, corresponding magnets are connected in series according to the operation mode.[5] The field adjustment of each magnet is controlled by individual small power supplies. Current stability required is 1×10^{-4} for dipole and quadrupole magnets and 1×10^{-3} for sextupole magnets. Design of bump and septum magnets and power supplies for them is under way.

Magnet alignment is very important for our ring. Global positioning system(GPS) for geodetic reference, alignment tolerance, magnet supporting structure, fixing of the support and alignment method are intensively investigated.[6]

Table 2. Specification of the main magnets of the storage ring

Magnet	Dipole	Quadrupole	Sextupole
Max. field strength	0.679 T	18 T/m	420 T/m
Gap or bore diameter	64 mm	85 mm	92 mm
Effective field length	2.804 m	0.35/0.41/ 0.51/0.97 m	0.30/0.53 m
Field uniformity	$<5\times10^{-4}$	$<5\times10^{-4}$	$<3\times10^{-3}$
region	H:±30 mm V:±15 mm	H : ±35 mm V : ±15 mm	H : ±35 mm H : ±15 mm



(a) Dipole magnet (b) Quadrupole magnet (c) Sextupole magnet
Fig. 4 Cross sections of dipole, quadrupole, and sextupole magnets. Quadrupole and sextupole have two types of cross sections to avoid the interference with the photon beam extraction pipe.

RF system

The role of the RF system is to provide sufficient accelerating voltage and power to compensate the beam energy loss due to synchrotron radiation and due to the excitation of parasitic modes by the beam. The energy loss in bending magnets, insertion devices, and in vacuum chamber and cavities amounts to 12.9 MeV/turn. A frequency of 508.58 MHz has been adopted for the storage and the synchrotron RF system. The storage ring has five RF stations.[7] One is the third harmonic system and used for instability control. The other four are used for beam acceleration. Each normal RF station has 8 single-cell cavities which are powered by 1.2 MW klystron.

Test stand with 1 MW klystron has been constructed and operated. Using this stand, high power test of prototype five cell cavity, tuner, couplers were performed.[8]

Designed single-cell cavity for storage ring is bell-shaped, and is optimized for low impedance of higher order mode (HOM).[9] Special care is taken to reduce the impedance of TM110 mode. Two prototype single-cell cavities are designed and manufactured. High power test for these cavities are in progress. Figure 5 shows the layout of the RF station. In Fig. 6, cross section of the single cell cavity is shown. Arrangement of the cavities and vacuum components is shown in Fig. 7.

Table 3. RF power requirement

Power transfered to the beam at 100 mA	1.3 MW
Power dissipated in the cavities	1.6 MW
Total power	2.9 MW
Input power per cavity	90 kW
Power dissipated per cavity	50 kW

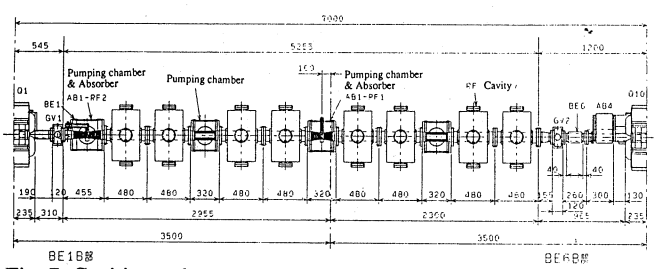


Fig. 7. Cavities and vacuum components arrangement at acceleration section

Vacuum system

In order to get a long beam lifetime, beam-on pressure of 1 n Torr or less is required. Vacuum system consists of two types of vacuum chamber, crotches, absorbers, and various components such as bellows, flanges and valves and chamber mounting. The detailed design and the related R&D are intensively progressed.[10] Figure 8 shows the layout of magnets and vacuum components in a normal cell. The cross sectional shape of the chambers are shown in Fig. 9.

Most of synchrotron radiations are intercepted by crotches and absorbers which are located downstream and upstream of the bending magnets. The chamber wall is designed not to intercept the radiation. The maximum power density of the dipole radiation at the crotch amounts to 20 kW/cm^2. Figure 10 shows the isomeric view of a crotch. At present, after review in a const reduction point, final design of the vacuum system is almost fixed, and vacuum components are going to be orded to manufacturers.

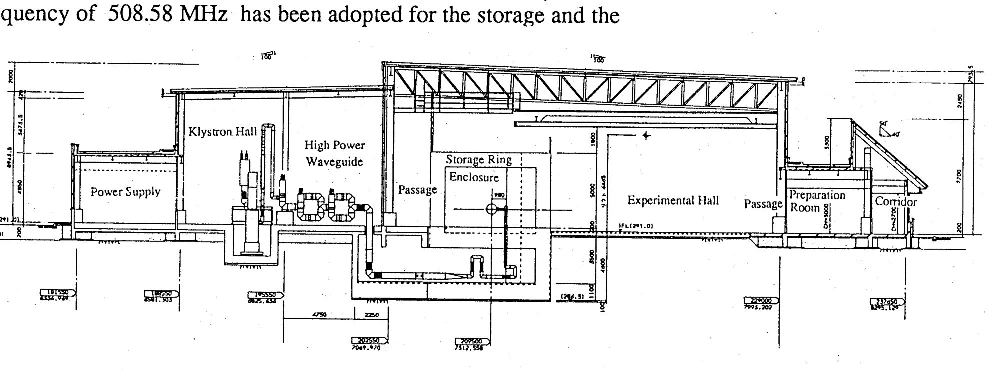


Fig. 5. Cross section of the storage ring and the layout of the RF station in the storage building.

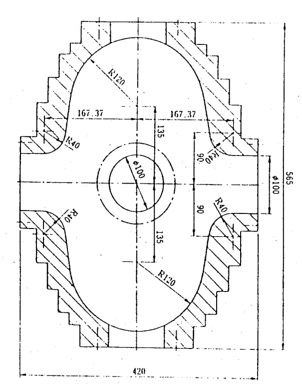


Fig. 6. Shape of the single-cell cavity

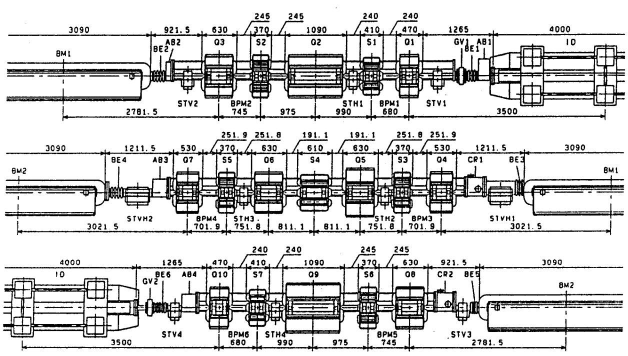


Fig. 8. Layout of magnets and vacuum components in a cell. Unit cell has two bending chambers and three straight section chambers.

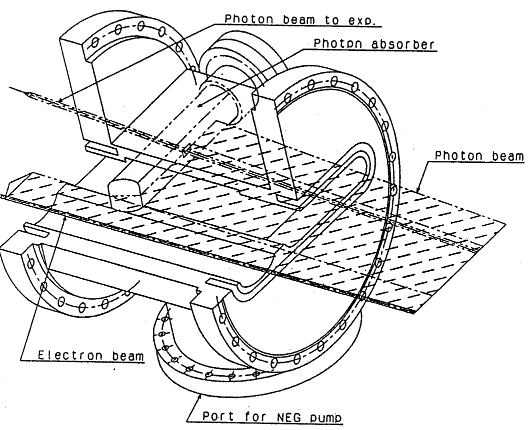


Fig. 10. Isometric view of a crotch.
Most of the radiation from bending magnets are intercepted by this crotch and absorber(not indicated).

Beamlines

The storage ring will be operated in the hybrid mode which has alternatively high and low betatron function at the dispersion-free straight sections. Undulators will be installed at the high b section where the electron size is large but the angular divergence is small. Wigglers will be installed at the low b section. The storage ring has 44 dispersion-free straight sections, 38 of which can accommodate the insertion devices. The others are used for RF cavities (5 low b sections) and for injection (high b section). Four among 38 are long straight sections which can accommodate very long insertion devices. In addition, 23 beamlines can be extracted from bending magnets. The lengths of beamlines and that of the inside the shielding wall are 80 m and 32 m, respectively. If longer beamlines are needed in some special experiments, eight beamlines can be expanded up to 300 m and three up to 1000 m. In these beamlines, 6 insertion beamlines and 4 bending beamlines will be prepared at the commissioning of the storage ring. The remaining beamlines will be built according to the yearly program. Special stations for RI research and Medical are to be prepared.

Site and Buildings

The SPring-8 will be built on a 141 ha site in Harima Science Garden City which is in the hill area and is being developed for the research institutions and industries. Ground preparation on the site was started in 1990 and almost finished. The storage ring will be built on a hard rock bed at 290 m above sea level, surrounding a small hill (Miharakuriyama Hill 350 m) (Fig.1). The linac and the synchrotron will be built at 280 m level. The storage ring has a circumference of about 1.5 km and a width of 36 m. Construction of the storage ring building is divided into four phases. The first phase (about 9 %) has already been started. The building of this part will be finished at the end of next year. Commissioning of the storage ring is scheduled in 1997. Figure 11 shows the plan view of the D area of the SPring-8 storage ring. The first construction area is shown between two bold lines.

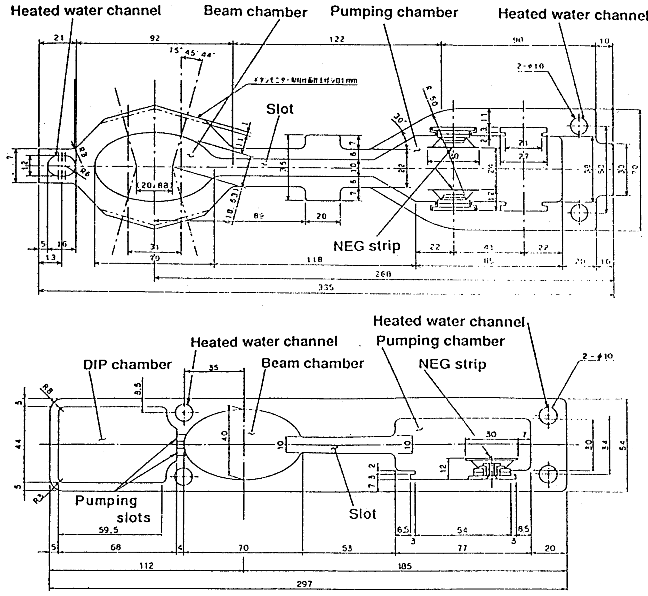


Fig. 9. Cross section of vacuum chamber.
Upper is a straight section vacuum chamber and bottom is a bending section chamber. Main pump is the NEG strip attached to the antechamber part. Distributed ion pump is used for bending chamber using the magnetic field of dipole magnet.

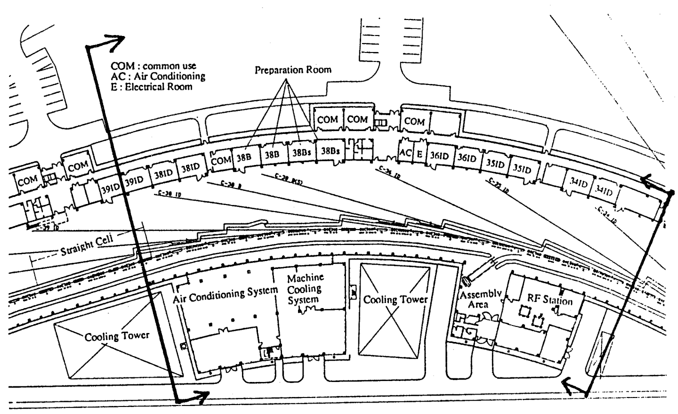


Fig. 11. Layout of the beam lines in a part of D area (south east).
The first constraction area is between two bold lines.

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