Present status of SPring-8 project

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Abstract

SPring-8 (Super Photon ring- 8 GeV) is the facility of a "third generation" synchrotron radiation source in the X-ray region. The facility consists of an accelerator complex and 61 photon beamlines, and is under construction in Harima Science Garden City, Hyogo Prefecture, Japan. The commissioning of the storage ring is expected in spring 1997 and 10 beamlines will be installed by FY 1998. The present status is described in this paper.

Review of SPring-8 Facility

The accelerator complex[1] consists of an injector system and a storage ring. The main parameters are shown in table 1. The injector system is composed of a 1 GeV linac and an 8 GeV synchrotron to realize the stable operation of the storage ring by full energy injection system and to supply the beam to future applications such as beam injection into a VUV storage ring, a high power FEL storage ring and the production of slow positron beam. The linac consists of a 250 MeV high-current linac, an electron/positron converter, and a 900 MeV main linac. The electron is to be accelerated up to an energy of 1.15 GeV by removing the converter from the linac beam line. The maximum repetition rate of this linac is 60 Hz. The synchrotron is a race-track type with two-fold symmetric lattice composed of 40 FODO cells. RF cavities and the devices for injection and extraction are installed in two straight sections. The maximum repetition rate is 1Hz. The natural emittance is 2.3×10^{-7} mrad at 8 GeV. The storage ring has a fourfold-symmetric lattice composed of 44 Chasman-Green cells and 4 straight cells. The circumference is 1436 m to realize the low emittance of 5.6 nmrad at 8 GeV. The Chasman-Green cell consists of two bending, 10 quadrupole and 7 sextupole magnets. The straight cell composed of the Chasman-Green cell with its two bending magnets removed. Each cell has a straight section for installation of insertion devices. The storage ring has 61 photon beamlines. Among the beamlines, 38 beamlines are available for high-brilliance or high-flux radiations from insertion devices (undulators and wigglers) and 23 beamlines for high-flux and high energy radiation from bending magnets. In the future, the four straight cells are to make the magnet free space of 30 m by the rearrangement of the quadrupole and sextupole magnets. In the free space, very long undulators are installed to obtain higher brilliance and an improvement in the coherence of light source.

Table 1 Main Parameters of Accelerator Complex

1. The storage ring	
Particle	electron/positron
Energy	8 GeV
Circumference	1435.948 m
Lattice	Chasman-Green
Superperiods/No. of cells	4/48
Natural emittance	5.55 nmrad
Stored current	
multi bunch/single bunch	100 mA/5 mA
Harmonic number	2436
rf frequency	508.6 MHz
Betatron tune(β_x/β_y)	53.22/20.16
Synchrotron tune	0.0101
Momentum compaction	1.46×10^{-4}
Energy spread (σ_E)	1.01×10^{-3}
Damping time(msec)	
($\tau_x/\tau_y/\tau_s$)	8.3/8.3/4.15
Number of ID sections	38
standard(~4 m)/long(~30 m)	34/4
Critical photon energy	28.9 keV
2. The injectors	
1) linac	
Energy(electron/positron)	1.15/0.9 GeV
Emittance	
electron/positron	< 1 mmmrad/< 1.5 mmmrad
Beam current	
electron	100mA(1 μs), 300mA(1ns)
positron	10mA
Repetition	60 Hz
rf-frequency	2856 MHz
No. of accelerator sections	26
Accelerator section	
structure	Traveling wave
mode	$2\pi/3$
length	2.835m
energy gain	45 MV
No. of accelerator section	26
No. of klystron	26
Klystron output power	35 MWmax.
2) synchrotron	
Energy(injection/extraction)	0.9GeV/8GeV
Circumference	396.12 m
Lattice	FODO
Superperiods/No. of cells	2/40
Natural emittance	222 nmrad
Beam current	10 mA
rf frequency	508.6 MHz
Repetition	1 Hz
Betatron tune(β_x/β_y)	11.73/8.78
Momentum compaction	1.01×10^{-2}

Storage Ring

The overall design of the storage ring has been almost completed. The magnet, vacuum and rf system are now under fabrication. By the end of this year, one cell of the storage ring will be assembled at the SPring-8 construction site, to check the interference between the magnet and vacuum systems before the whole vacuum system is manufactured.

Magnetic measurements of pilot magnets

Four magnets, one bending, 2 quadrupole and 1 sextupole, were built as pilot models. The field profile, multipole strength and excitation curve were measured by a hall prove for the bending magnet, a twin flip coil for the quadrupole magnets and a harmonic coil for the sextupole magnet. On the bending and sextupole magnets, the measured multipole field strength(except for fundamental component) satisfied field tolerance required from orbit analysis. On the other hand, for quadrupole magnets, the strength of the integrated dodecapole component was several times larger than the field tolerance required from orbit analysis. The dodecapole component, therefore, was corrected by attaching an iron shim of 9.1 mm thick to the end plate of both sides of the magnet core. The result is shown in fig.1. The real line is the profile measured with the shim, while the dotted line is the profile without the shim. A useful aperture of about 30 mm was obtained over a wide range of excitation levels by this end shim technique.

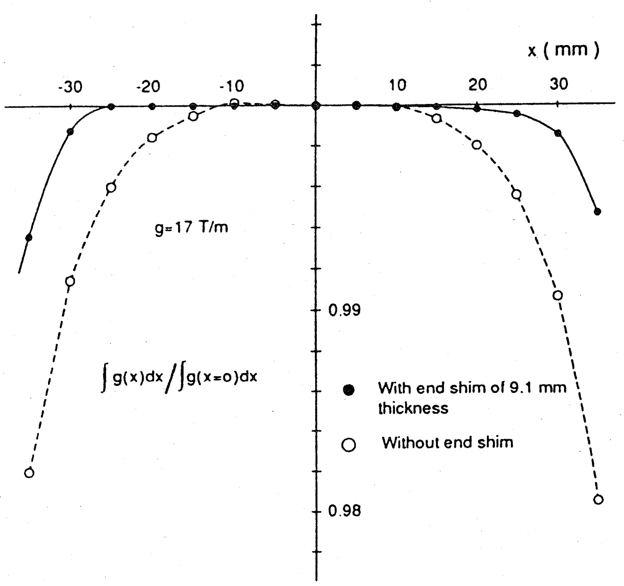

Fig..1 Radial profile of integrated field gradients with and without end shim.

RF system

The new power supply[2] for the 1 MW klystron, which has no crowbar circuit to protect the klystron, was designed and its small size model was fabricated as a pilot model. This power supply is a primary rectifier controlled by SCR with a primary filter inductor. The SCR rectifier can control the klystron voltage close loop by phase control with a regulation of better than 0.1%. The real type is now under fabrication. Field profiles of resonant dipole modes of a R&D cavity(bell shaped cavity) were measured with a bead perturbation method and coupling impedances over the Q-factor for coupled bunch instabilities were obtained. Frequencies of higher order modes are affected by positions of plungers set on the cavity and one of the suppressing methods for coupled bunch instabilities is shown in this conference[3].

Beam Dynamics

To obtain a higher brilliance of light source, we must correct a betatron coupling as small as possible.The design goal of the coupling coefficient is less than 1 %. The coupling is induced from a skew quadrupole component along the ring, whose component is generated from the tilt error of quadrupole magnets, the alignment error of sextupole magnets and a residual COD. The coupling behavior varies along the storage ring, and is not constant or uniform, because the rotation angle between the eigen axis of normal mode and those in the laboratory flame vary according to the distribution of the skew quadrupole component. It is ,therefore, difficult to realize the vertical emittance of less than 1 % to the horizontal one at any position of the storage ring. For this correction, we found the good correction scheme to keep the maximum vertical emittance less than 1% of the horizontal one at any position as shown in fig.2. The details will be given elsewhere.

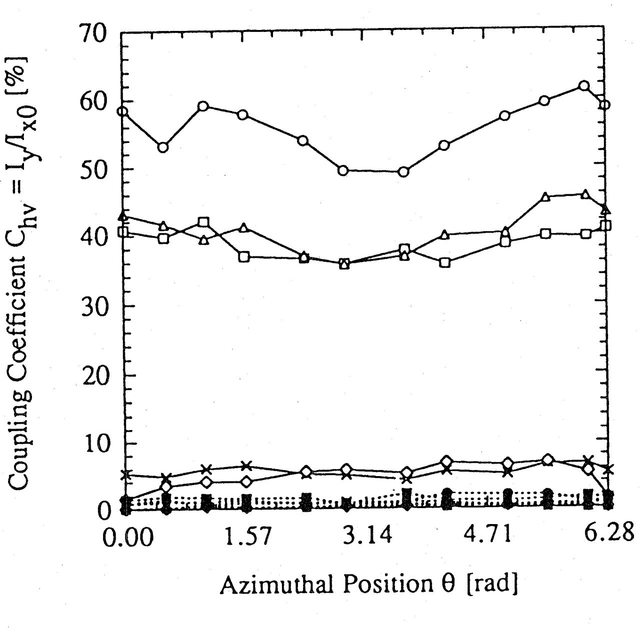

Fig.2 Maximum vertical emittance. Real lines and dotted lines show before and after corrections, respectively. Each shape of symbols corresponds to a different case of sextupole alignment errors.

Beam Monitor

The first stage of the R&D for BPM(Beam Position Monitor) is successfully finished. Button electrodes are to be directly welded to the extruded Al alloy vacuum chamber to avoid any problems on vacuum leakage in many cycles of baking process. The electrode is made of stainless steel with 10mm in diameter and is screwed and welded to the central conductor. The electric center is calibrated by a moving antenna. The calibration system is now in operation at the Harima site. The BPMs have their own reference planes(horizontal and vertical planes) outside the vacuum chamber. The position of these reference planes are precisely calibrated to the magnetic center of sextupole magnet after the magnetic alignment and the vacuum baking.

Injector System

Test of the preinjector

A preinjector of the linac, shown in fig.3, was constructed in Tokai(JAERI) for test operation. The preinjector consists of an electron gun, 2 prebunchers, 1 buncher and a beam monitoring system to observe the beam quality. The beam energy is 9 MeV at the exit of the buncher. It is to be operated in two modes. One is a high current mode for positron production and the other a low current for electron use. The electron gun(model Y796 with a cathode area of 2 cm^2) is designed to produce a 200 keV pulsed beam with a peak current of 20 A and a width of 1nsec. As the result of beam tests, the beam current was obtained in the range of several tens mA to 20 A, by varying the emission current from the gun and physically defining the beam size using iris. Three types of grid pulsers were tested to generate different pulse lengths and stable operated. Two prebunchers were operated with a gap voltages of 20kV and 30 kV, respectively. Each buncher is a type of standing-wave structure with 13 gaps. The bunching efficiency obtained was about 65 %. The energy spread at the maximum energy was within $\pm 2\%$, which was measured by an energy analyzer located behind the buncher.

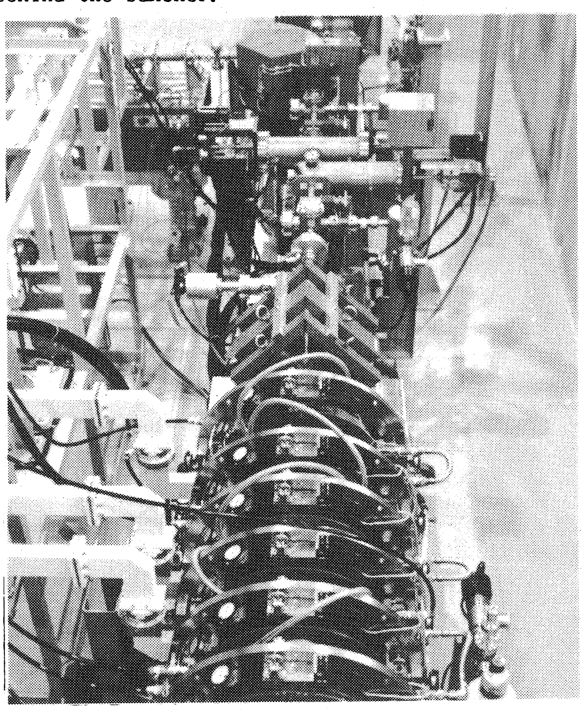

Fig.3 Preinjector of linac

Control System

As the accelerator complex and experimental equipments are distributed geographically and functionally over the SPring-8 site, a distributed computer control system is adopted. The design concept of SPring-8 control system is to use standard hardware and software. The control system consists of a operating system located in a central control room, several control system for accelerators and beamlines ,and a computer system for program development. Each system is linked by a high speed computer networks such as FDDI. The control system is composed of a host computer and several front end processors(FEP) such as VME and programmable logic controller, which are connected with each other by sub networks. As for the operating system, an UNIX is used for upper level computers, and a real time OS's, which conform to IEEE POSIX standard, will be used for FEP's. C and C++ are used as languages to describe application programs for machine control, since many application programs developing tools are prepared by C library functions. FORTRAN is useful for large numerical calculation programs, such as COD correction and a calculation of beam dynamics.

Beamline

The SPring-8 Project Team plans to construct 10 beamlines by FY 1998, of which 6 are assumed to have insertion devices as light sources and the rest from bending magnets. To make the standardization of beamline components in the front-end channel and optics and of the control system of the beamlines, two beamlines are designed and constructed as pilot beamlines from this year.

R&D of Insertion Device

Two kinds of prototype devices have been fabricated. One is a wedged-pole-hybride undulator, and the other is a variable polarized undulator embodying a new concept[4]. The wedged-pole-hybride undulator has a magnetic period of 33mm long, 123 magnetic poles and a peak magnetic field of 5.87kG at the minimum gap of 13.5mm. The magnetic measurement was performed. By using the data obtained, the radiation intensity expected by this undulator was estimated. The variable polarized undulator consists of two pairs of planar permanent magnet arrays above and below the horizontal plane. Therefore, the device has no magnetic structures in the horizontal plane and no conflict with a vacuum chamber. The on-axis magnetic field generated by this device, the strongest among existing planar helical devices, induces helical and sinusoidal beam orbit motions by shifting the relative positions of a pair of magnet arrays. It leads to the generation of circularly and linearly polarized undulator radiation. The test of this new undulator has been performed by using JSR in Tokai(JAERI) and its performance confirmed.

References

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