Overview of the SPring-8 Project

Yoshikazu MIYAHARA
Shinya HASHIMOTO

This annual report summarizes the status and progress of the SPring-8 project for the year 1994. Since this is the first annual report, some remarks on historical particulars from the beginning of the project are also presented. The contents of this report are divided in two parts. The first part provides general and group reports on the activities of the project, and the second includes individual scientific reports contributed by all staff and others assigned to the project.

During the past three decades, synchrotron radiation research has made vast advances in the scientific understanding of matter and living materials. At the same time, the radiation user community in Japan has expanded very rapidly among universities, national institutions and companies. The number of the users which was about 300 twenty years ago is now approximately 1000.

Synchrotron radiation research in Japan began in the late 1960's using a 700 MeV electron synchrotron INS-ES built for high energy experiments. The requirement for high radiation stability promoted the construction of a 300 MeV storage ring SOR-RING dedicated to radiation research in the mid 1970's. A strong nationwide demand for an X-ray source led to the construction of a 2.5 GeV storage ring KEK-PF in the early 1980's. Shortly afterwards, a 600 MeV storage ring UV-SOR was constructed to provide bright radiation in the VUV region by reducing the beam emittance. Meanwhile, insertion devices installed in several storage rings elsewhere in the world proved to be useful in generating intense radiation. The devices were also installed in the storage ring KEK-PF and further in the accumulation ring AR (6.5 GeV) of TRISTAN for a parasitic use of synchrotron radiation. But these rings have rather large beam emittances. As a natural extension and because of the rapid growth in the user community, users began to require a low emittance ring equipped with a number of insertion devices to get very brilliant radiations in the X-ray region.

This coincides with world trends in the late 1980's, when brilliant radiation sources in the X-ray and VUV regions began to be constructed in several institutions. In 1987, the Council for Aeronautics, Electronics and Other Advanced Technology of the Science and Technology Agency (STA) of the Japanese Government decided to promote the construction of a high brilliance radiation source in the X-ray region. The JAERI-RIKEN Project Team, organized in 1988 to promote the design work of the radiation facility, proposed a 6~8 GeV storage ring. Two similar facilities, ESRF (6 GeV) in Grenoble and APS (7 GeV) in Argonne, were already under construction. ESRF was commissioned in 1991 and APS is close to completion at the end of 1994.

The SPring-8 project is to construct a large-scale, advanced synchrotron radiation facility and to promote fundamental science in the field of synchrotron radiation research. The R&D of the project and the project itself have been funded from 1987 and 1990, respectively. The facility, currently under construction in Harima Science Garden City, Hyogo Prefecture, about 100 km west of Osaka, is to be commissioned in 1997. The conceptual design of the facility was reported in SPring-8 PROJECT, PART I, FACILITY DESIGN 1991 [REVISED] and [SUPPLEMENT 1992]. Now at the end of 1994, construction of accelerator buildings is close to completion, and accelerator components will begin to be installed in spring 1995. The design of initial beamlines was finished in 1994 and their fabrication will be started in 1995.

The facility is basically comprised of three accelerators; a 1 GeV preinjector linac, an 8 GeV booster synchrotron, and an 8 GeV storage ring. The storage ring has a circumference of 1436 m and operates at a beam energy of 8 GeV, generating X-ray and also VUV radiation with various kinds of undulators. The ring can be installed with 38 insertion devices in 6.5 m long straight sections, and totally 61 beamlines can be distributed in the experimental hall of the storage ring. Characteristic features of the ring are summarized as follows.

1) To generate a brilliant radiation, the electron beam emittance is reduced to 5.5 nm•rad, which provides an average beam size $\sigma_{x/y}$ = 0.25/0.10 mm around the circumference. The vertical beam size will be further reduced by minimizing the

coupling of horizontal and vertical betatron oscillations.
2) To generate brilliant and intense radiation and to provide it to many radiation users, a total of 38 insertion devices with a length about 4.5 m are installed.
3) To have good stability of the radiation in the experimental area, the electron beam orbit is highly stabilized.
4) To generate extremely intense radiation with very long undulators, four 30 m long straight sections are available by a small modification of the magnet arrangement in the storage ring.
5) To create a very precise angle resolution in some radiation experiments, spaces for very long (300 m and 1000 m) beamlines are provided.

The facility has been constructed by a joint JAERI-RIKEN SPring-8 Project Team with JAERI responsible for the injector and utilities, and RIKEN in charge of building the storage ring. Both institutions are responsible for construction of the beamlines. A new organization JASRI organized in 1990 and formally established in 1994 is charged with the operation, management and improvement of the facility after the commissioning.

The SPring-8 project team has profited from the experience of many institutions at home and abroad. They have kindly offered a number of technical information on the accelerators, beamlines and utilities. Without the information, it might have been impossible to construct such an advanced facility as SPring-8. Without question it is important for further development of the facility to maintain good mutual communication and collaboration with other institutions. Especially, it is supposed that ESRF, APS and SPring-8 share comparable technical problems because of the similarity of the facilities. The three facilities commenced mutual collaboration in 1993 with regard to the light source and beamlines.

Beamlines

When the SPring-8 Project Team was organized in 1988, potential users for the radiation experiments also organized a User Group for the Next Generation X-Ray Source. The Group was classified into 24 subgroups, which reported experimental science programs for the project in SPring-8 PROJECT, PART II, SCIENTIFIC PROGRAM [DRAFT] 1990. The User Group was converted to a formal organization of the SPring-8 User Community in 1993.

Meanwhile, the Experimental Facility Group of the Project Team has since 1988 promoted R&D on beamline components for high brilliance radiation. In 1992, the Project Team decided to construct two pilot beamlines to promote standardization in the design of the beamline components. The Project Team organized the Beamline Committee in 1993, which has performed the task of evaluating the properties of proposals for ten initial public beamlines. The Committee selected four proposals as the initial beamlines from 21 proposals.

Besides the public beamlines to be open to general users, three other kinds of beamlines are to be constructed; contract beamlines to be constructed and used exclusively by authorized research organizations at their own expense, JAERI or RIKEN beamlines to be used for their own activities and R&D beamlines to be used for machine studies and optical element development.

In 1994, the Experimental Facility Group designed insertion devices, front end components, optical elements and detectors to be used in the initial public beamlines. The insertion devices include in-vacuum horizontal and vertical X-ray undulators, a soft X-ray helical undulator, an elliptical wiggler and a Figure-8 undulator. The front end design has been developed through a standardizing approach. It was finally concluded that front end components such as masks, vacuum valves and chambers be set on a common optical bench, and that vacuum pump units be separated from the bench. To overcome high heat load problems on the first optical elements of the beamlines, a Si double crystal monochrometer in a rotated-inclined geometry with a pin-post-cell water cooling and a diamond crystal monochrometer were proposed as the standard monochrometers in SPring-8. Performance of conventional mirrors, multilayers and super-mirrors has been investigated in considering a high heat load operation. Several kinds of detectors have been developed; one dimensional position sensitive CdTe detector, imaging plate, X-ray TV detector, microstrip gas chamber, and proportional scintillation X-ray imaging chamber. Other optical components such as an interferometer, special devices for the 1 km beamline combined with the 30 m straight section of the storage ring, etc., have been studied. The results of these developments were introduced into the final design of the beamlines. The fabrication of the components starts in 1995.

Accelerators

Injector linac

The injector linac, a conventional S-band type totally 140 m long, is divided into four parts; preinjector, linac I (250 MeV), electron/positron converter, linac II (900 MeV). The preinjector produces an electron beam from an electron gun, and accelerates the beam to about 10 MeV with an additional action of bunching. A positron beam is generated by the converter if necessary to avoid ion trapping in the storage ring. The electron or positron beam of 1 GeV is injected into the synchrotron. The electron beam of 250 MeV or 1150 MeV maximum can be extracted out of the linac for other uses in the future.

The preinjector, already constructed at JAERI in Tokai, has been tested for two years to check and improve its performance. Accelerator columns and focusing magnets for the linac were already fabricated, and other parts of the linac including cooling water and high power electricity systems entered into fabrication. The preinjector will be decomposed and transported to the facility site and all the components of the linac will be installed in the linac building in 1995.

Booster Synchrotron

The synchrotron with a circumference of 400 m, accelerates the electron or positron beam from 1 GeV to 8 GeV at a rate of 1 Hz. Fabrication of all components was begun in 1994. Prior to mass production, the performance of some first components such as various kinds of magnets, the RF cavities and beam monitors was checked. The fabrication of the components will be completed in summer 1995, and they will be then installed in the synchrotron building.

Storage ring

The storage ring operates at a beam energy of 8 GeV with an expected beam lifetime of about 50 hrs at a beam current of 100 mA. The ring, composed of Double Bend Achromatic (DBA) lattice with 48 unit cells each about 30 m long, or a total circumference of 1436 m, can provide a low emittance beam of 5.5 nm•rad. Each cell includes a 6.5 m long straight section, in which insertion devices a maximum of 4.5 m long can be installed. Among the 48 cells, 4 cells, distributed equidistantly around the ring, have no bending magnets. By rearranging quadrupole and sextupole magnets in these cells, 30 m long straight sections can be provided so as to install very long insertion devices. To increase the brilliance, the vertical emittance of the beam, usually 10% of the horizontal emittance, is reduced to 1% by skew quadrupole compensation.

All the components of the systems for the magnet, vacuum, RF, beam monitor, computer control and networks are under fabrication. Field measurement of the magnets was performed in parallel. Method and instruments for magnet alignment were prepared. A vacuum system for one unit cell was assembled together with the magnet arrangement on the girders in order to test the vacuum and mechanical performances. One unit of the RF system was also tested. To avoid the coupled bunch instability caused by the HOM impedances of the cavities, a three plunger system was developed. Calibration of beam position monitors is currently being conducted. Software of the computer control system is also being developed.

Buildings and utilities

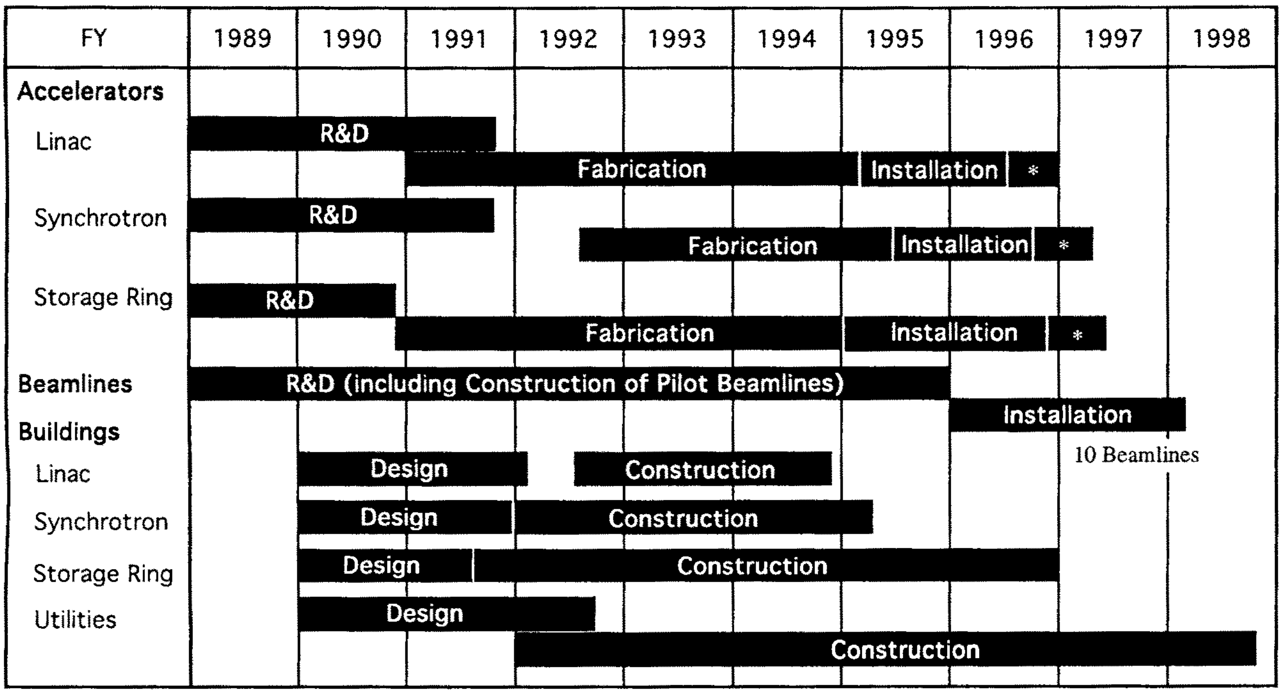
The project has also been supported by the local government of Hyogo Prefecture, which donated a 141 ha piece of land to RIKEN in 1992 as the facility site. The site is located in Harima Science Garden City, newly developed by the local government from 1990 in a wide mountainous area in the western part of the prefecture. Although the area is still in the process of being developed, the science faculty of a university, a computer college and a company laboratory have already been built in the city, and they have begun carrying out their activities.

The facility site is located on a very hard rock bed, which will benefit the stability of the stored beam and also of the generated radiation axis. The construction of the infrastructure of the facility site such as land development, road construction and water drainage was begun in 1990.

Construction of the building for the storage ring which started in 1991, progressed steadily, and after one year, one fourth of the building had been completed. The construction was continued, and by the end of 1994, the whole building with a long circumference about 1500 m appeared surrounding a small mountain. Construction of the buildings for the injector linac and booster synchrotron started in 1993, and was completed or close to completion by the end of 1994, respectively. In addition, two high electric power stations have been nearly completed, and a water supply system, already supplying for the air conditioning of the newly constructed buildings, is ready to be connected to the accelerator components.

From the spring of 1993, accelerator group members of RIKEN and JAERI moved in turns to the facility site, and they have tentaively occupied the preparation rooms of the storage ring as their working offices. A cafeteria, a central building for research and administration, and a dormitory for visitors and construction collaborators are now being planned.

Time Schedule



* : Commissioning