The 6th Symp. on Accelerator Science and Technology, 1987, Tokyo, Japan (© Ionics, Tokyo, 1987)

DEVELOPMENT STATUS OF COMPACT SUPERCONDUCTING SR RING

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ABSTRACT

Present status of constructing the compact superconducting SR ring and the microtron as an injector is reported. Developments of key technology and detailed designs of the machines have already been finished. Prototype machines are now under fabrication, and are to be installed in 1988 in the building, which are being constructed at SHI Tanashi Works, Tokyo in Japan. After their test operations, the facilities are used for a verification of industrial uses as a total system including synchrotoron radiation beam lines.

GENERAL DESCRIPTION

Synchrotron-radiation (SR) light sources are demanded for industrial use, especially for an X-ray lithography. It is necessary for the industrial-based SR ring to be compact, reliable and economical. In order to satisfy such requirements, Sumitomo Heavy Industries, Ltd. (SHI) has been developing a compact system for the SR light source.[1-4] A plane view of the system is shown in Fig.1 and its principal design parameters are listed in table 1. This system consists of a 150-MeV microtron injector, a 650-MeV superconducting electron storage ring, and SR beam lines. The system produces an SR spectrum with 1.0-nm critical wavelength. The present source size is azimuthally uniform, σ_r=1.4 mm in the radial direction, and σ_z=0.2 mm in the vertical direction. The irradiative power is 1.5 W/mrad at the stored electron current of 300 mA.

The injector is a pulsed racetrack microtron.[1] The size of this microtron is 1.5 m in width, 3.7 m in length, and 1.5 m in height. Its weight is less than 30 tons. Electrons produced by an electron gun are boosted up to the energy of 120 keV, and are injected into an acceleration column. A commercially available standing-wave linac is used as the column. The electrons gain the energy of 6 MeV per turn by the linac, are turned back by two main 180° bending magnets, and are extracted at 150 MeV after 25-turn accelerations. A width of the beam pulse is from 0.5 to 2.0 μsec, and its repetition rate is adjustable from 1 to 180 Hz. A disign intensity of the beam is 5 mA at the peak of the pulse. An emittance of the beam is less than 1 π·mm·mrad in both the horizontal and vertical directions, and its energy spread is less than 0.1%. The machine is under fabrication.

The storage ring is a compact superconducting machine with 1.0-m orbital diameter.[2] The size of the machine is 3 m in outer diameter, and 2.2 m in height. A 1/2 resonance injection method[3] newly introduced is used to inject 150-MeV electrons into the small ring under the strong magnetic field of 4.3 Tesla. The electrons injected are accelerated to 650 MeV, and then stored. Sixteen outlets are available for the SR light from the ring. This new-type machine requires several unique components. The first one is a superconducting weak-focusing single-body magnet. The second is injection instruments for the new 1/2 resonance injection method. The third is a small and high-power rf resonator located at the bending orbit in the strong magnetic field. The fourth is a ultra-high-vacuum chamber and pumping system. We have been performing studies and developments of these unique components. A prototype machine is now being fabricated.

This storage ring together with the injector microtron will be installed in the spring of 1988 at a new building at SHI Tanashi Works, and then the test operation will start.

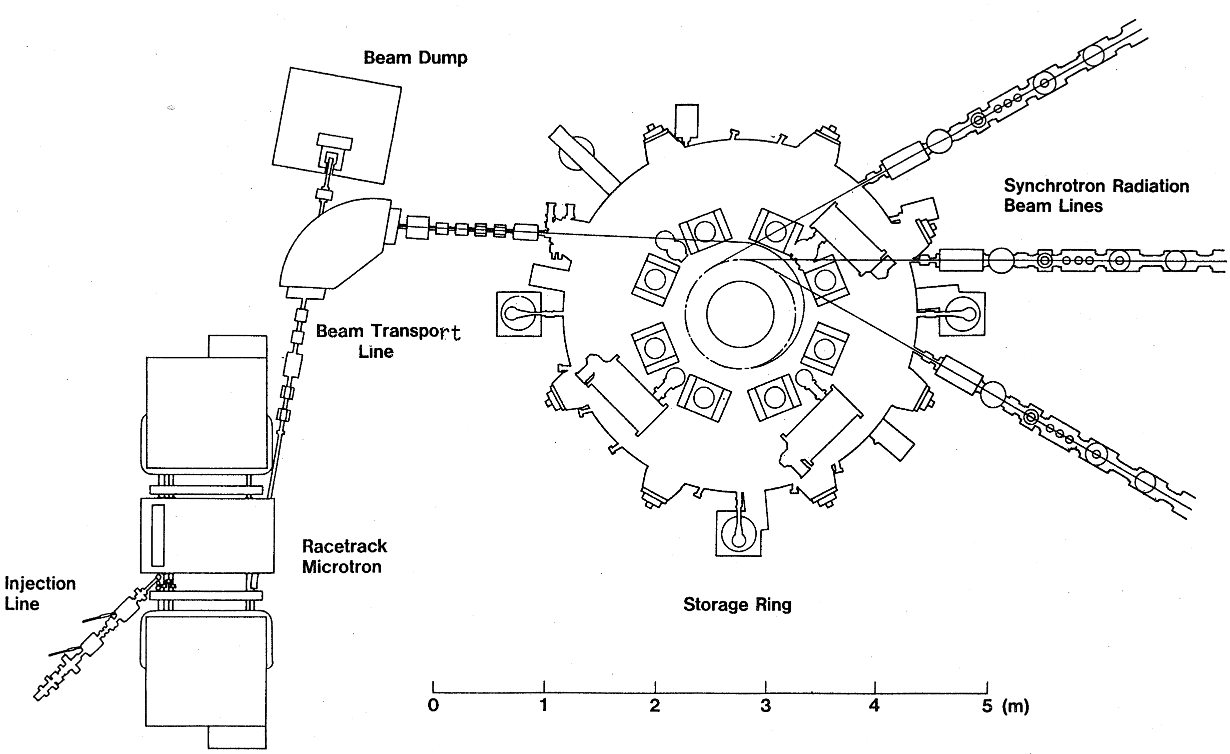

Fig.1 A plane view of a compact SR-light-source system consisting of the racetrack-microtron injector and the superconducting electron storage ring.

Table 1

Principal design parameters of a compact system for the SHI-SOR lignt source.

INJECTOR		
Type	Racetrack microtron	
Energy	150	MeV
Beam currents(peak value)	5	mA
Pulse width of beam	0.5-2.0	μsec
Repetition rate	< 180	Hz
Number of turns	25	turns
RF frequency	2856	MHz
Magnetic field	1.234	T
SR RING		
Type	Superconducting weak-focusing single magnet	
Energy	650	MeV
Beam currents	300	mA
Critical wavelength	1.02	nm
Beam lifetime	> 24	hours
Magnetic field	4.34	T
Bending radius	0.5	m
Field index n	0.70 - 0.25	
Injection energy	150	MeV
Injection field	1.00	T
Excitation rate	0.02	T/sec
RF frequency	190.86	MHz
Harmonic number	2	
RF voltage	120	kV
Vacuum pressure	6×10^{-10}	Torr

INJECTOR

Details of the racetrack microtron are presented in another session in the present symposium.[1] This machine namely consists of an injection line, an acceleration column, two main magnets, beam-focusing elements, extraction elements, a vacuum system. There are two bunchers and a single-gap cavity as well as an electron gun and focusing elements on the injection line. The single-gap cavity boosts electron beams from 20 keV to 120 keV. A commercially available 6-MeV linac is used as the acceleration column, which has side-coupled structure, and is operated at a 2856-MHz radio frequency. A klystron in rf system supplies 5 MW peak power to the linac. The main magnet generates the magnetic field of 1.23 T in the gap of 10 mm. A size of a pole tip is 0.50 m in length, and 1.10 m in width. A yoke of the magnet is in common with a reverse magnet. Permanent quadrupole magnets are used as the focusing elements at each turn except for the first turn.

Detailed design of the machine has been finished. The injection line and the linac have already been fabricated. The remaining components are under way of fabrication.

SUPERCONDUCTING MEGNET

A cylindrical single-body magnet is mainly composed of superconducting coils, iron poles and a yoke. This magnet is separated into the upper and lower halves for easy maintenance. The coils are split into two sections, upper and lower parts with 1948 turn each. The dimention of the coils is 1.480 m in inner diameter, 1.800 m in outer diameter, and 0.162 m in height. The distance between the coils is 0.620 m at their centers. Each coil bobbin is supported in position by carbon-fiber-reinforced plastics (vertically and radially). The coils are cooled down by immersing into liquid He.

The poles are made of homogeniously forged steel with low carbon contents. The dimention of the cylindrical pole is 0.700 m in inner diameter, 1.300 m in outer diameter, and 0.580 in height. The pole gap is 0.280 m at the central orbital radius. This pole is shaped so as to provide the field distributions corresponding to the dynamical tune transition from n=0.73 to 0.25. Six trim coils are directly mounted on the pole face. The yoke is of cylindrical type, and is devided into small sheets of slabs for convenience of transportation and construction. Each sheet weights less than 5 tons.

The upper system of the coil and cryostat was fabricated, and preliminary test of their performance such as characteristics in the cooling and the magnetic excitation has been accomplished by using a large iron plate to generate a mirror field. The full excitation was attained with no training. The coil was very stable, and has good performance in accordance with the design.

RF SYSTEM

The rf frequency is 190.86 MHz. The rf cavity consists of two $\lambda/4$ coaxial resonators. It has a curved structure along the electron orbit, and its vertical cross section has a race-track shape. The dimention of the cavity is 0.64 in length along the orbit, 0.12 m in width, and 0.23 m in height. It is operated by TEM push-pull mode, and supplies the maximum voltage of 120 kV at the 2-cm acceleration gap. The cavity has slits to release the synchrotron radiation out of stored electrons.

The rf characteristics of the cavity were measured using a full-scale model before fabrication of a real cavity. The data obtained are in satisfactory agreement with the design values. The fabrication of the real cavity have already been finished. An rf power supply of 190.86 MHz and 40 kW also was prepared. The test operation has been being carried on by suppling high rf powers to the cavity. At present the power of 12 kW can be supplied successfully in the CW mode.

INJECTION SYSTEM

Main elements for our new 1/2 resonance injection method are a perturbator, magnetic channels, and an electrostatic inflector.[3] The first two components are unique. The perturbator generates pulsed octupole fields, the decay time of which is about 1 μsec. This perturbator is an air-core magnet, and has a coaxial structure consisting of four inner conducters and four outer conducters. The outer conducters acts as a screen to cut off leakage magnetic flux out of them. A full scale model of the perturbator and a power supply has been manufactured, and tested. Measured characteristics satisfied fairly well the design values.

The magnetic channels installed in the fringing-field region focus the injected electron beams and guide them to the perturbator. This channel also is an air-core magnet of a coaxial type to have no magnetic flux outside the coils. It is necessary for it to have a large magnetomotive force and a small size. Therefore, high current density and good cooling performnance are required for the coiles. A full-scale model was made for the magnetic channels also, and its characteristics were measured. Measured leakage flux outside of the coils is not serious but rather large around both the edges. This defect will be improved in the case of real magnetic channels. Measured coil temperatures agreed well with the design values, and this result shows good cooling performance of the coils. All the real components for the injection system have been designed, and are being manufactured.

VACUUM SYSTEM

The vacuum chamber has a hybrid structure to keep a vacuum in the beam duct less than 1×10^{-9} Torr.[4] The beam duct is separated from a room in which intensive synchrotron radiations are dumped. These two rooms are connected by a narrow slit to let the radiation pass, and a large number of cryosorption panels are mounted in these rooms. We have developed a new cryosorption panel. A prototype model having the same scale as the 1/4 section of the real chamber has been fabricated, and its characteristics have been tested. Measured pumping speed of the cryopanels reached 16000-22000 l/sec, which was better than the required speed of 10800 l/sec. Measured pressure was 8×10^{-10} Torr for the H_2-gas load of 1.2×10^{-5} Torr·l/sec, and 5.8×10^{-10} Torr for no load. These results indicate that the required pressure of less than 1×10^{-9} Torr is attainable using this type of the chamber. Detailed design of the real chamber has been finished, and it is now under fabrication.

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