The Synchrotron Radiation Facility at Hiroshima University, HiSOR

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Abstract

Hiroshima Synchrotron Radiation Center, Hiroshima University operates a 700-MeV synchrotron radiation source. The storage ring is of a racetrack type and equipped with a linear and a helical/linear undulator at each straight section. The injector is a 150-MeV microtron, which is also an injector for an electron circulator operated by Venture Business Laboratory, Hiroshima University.

1 Introduction

The synchrotron radiation (SR) facility at Hiroshima University, called HiSOR, was completed in 1997 [1-2] and is now under the management of Hiroshima Synchrotron Radiation Center (HSRC), Hiroshima University [3]. The plan of the laboratory is shown in Figure 1. The SR source is a compact 700-MeV storage ring of racetrack type with a 150-MeV microtron as the injector. A distinguishing feature of HiSOR storage ring is the magnetic field of the bending magnet as strong as 2.7 T which is produced by normal conducting magnet technology. The critical wave length and the total power of the SR from HiSOR are comparable with those by 1-GeV rings with usual magnetic field strength The photon spectrum covers VUV/soft-X-ray range as shown in Figure 2. At each straight section of the ring, a linear and a helical undulator are installed to deliver polarized photons with an intensity three orders of magnitude higher than those from bending sections. The number of photon beam ports is 16 in total including 2 from the undulators. They are open for researchers not only from Hiroshima University but also from regional universities and institutes.

The 150-MeV electron beam generated by the microtron is, after the injection to the storage ring, transported to an electron circulator, which is operated by Venture Business Laboratory at Hiroshima University

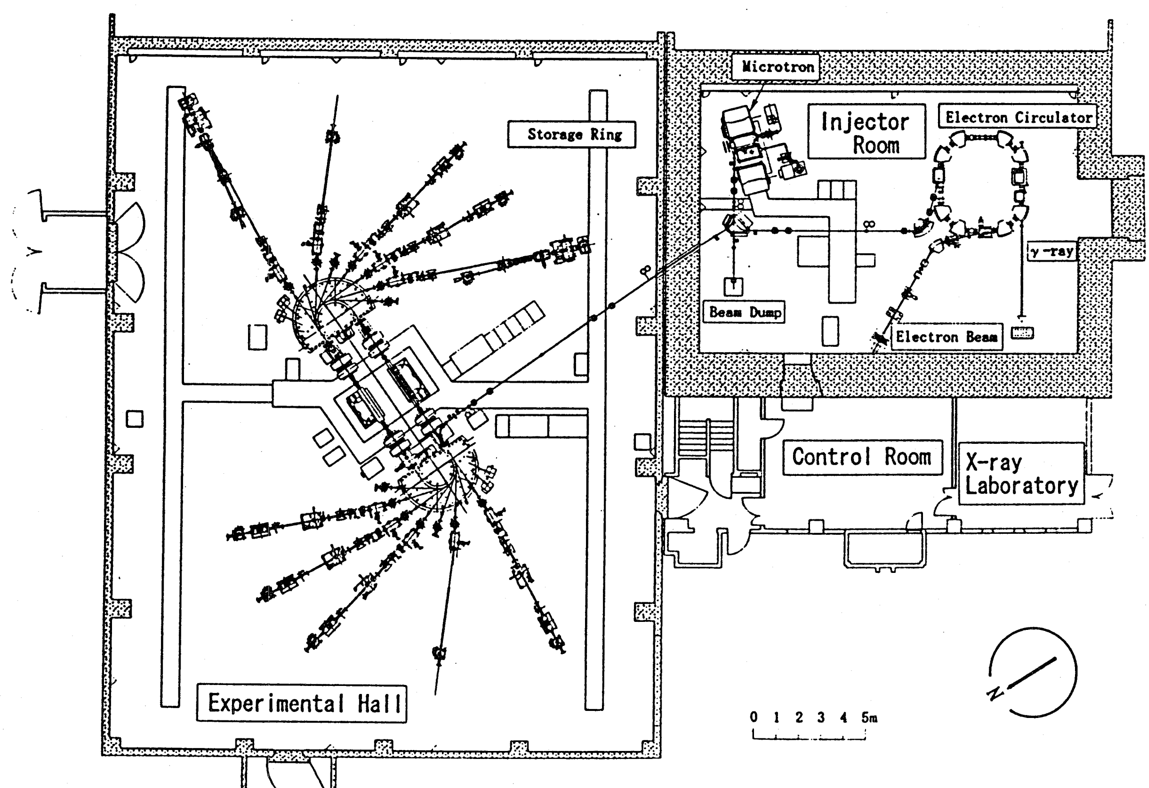

Fig.1 The HiSOR facility consisting of a 700-MeV storage ring, a 150-MeV microtron, and a 150-MeV electron circulator.

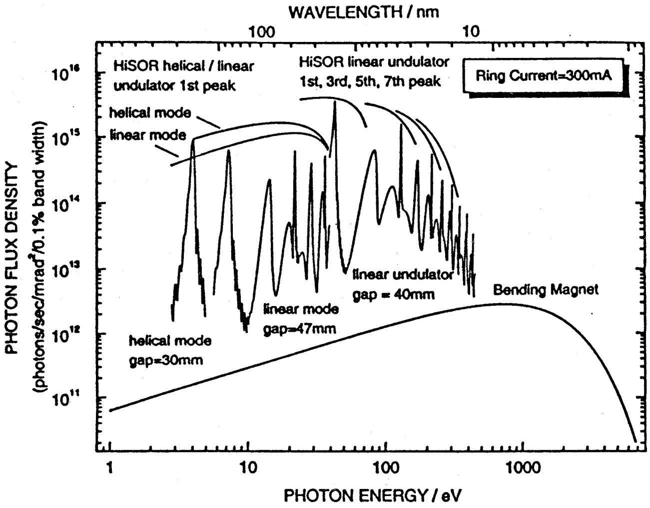

Fig.2 Spectra of photons from bending sections and undulators of HiSOR storage ring.

aiming at developing a new hard X-ray source based uponthe interaction of the circulating electrons with a crystal target in the ring.

2 Storage Ring

In Figure 3, a drawing of HiSOR storage ring is shown with dimensions. The lattice is composed of two 180° bending magnets with edge focusing and four quadrupole

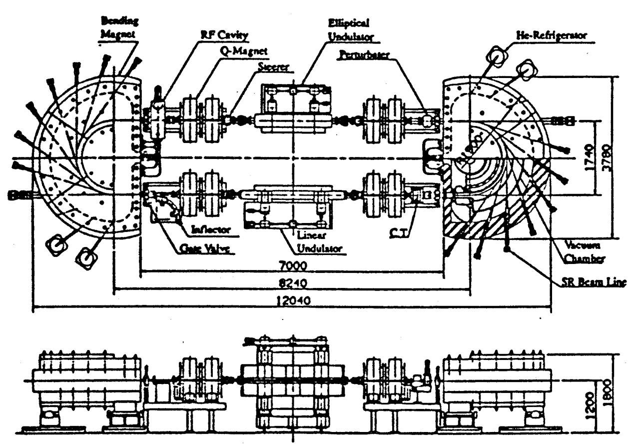

Fig.3 The HiSOR storage ring.

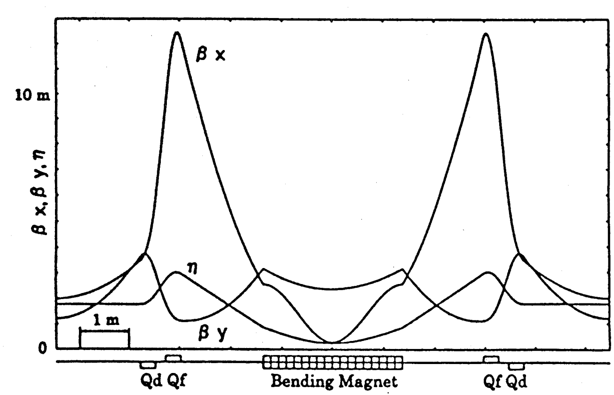

Fig.4 Betatron- and dispersion-functions of the HiSOR storage ring.

doublets. The pole gap of the bending magnet is as narrow as 42 mm in order to generate the magnetic field as strong as 2.7 T keeping the necessary magnetomotive force below a reasonable level [4].

As seen in Figure 4 showing the beam optics for this lattice, the vertical betatron-function at bending magnets is well suppressed by edge focusing, while it is controlled by quadrupoles at straight sections where undulators with a gap of 30 mm are installed.

Another merit of high bending-field is that it reduces the radiation damping time for injected beam, which is 0.51 sec for 150-MeV beam. Thus we are able to employ a low-energy injection scheme, and to inject 150-MeV electrons with a repetition rate of 2 Hz.

General parameters of HiSOR storage ring are listed in Table 1.

Table 1
Parameters of the HiSOR Storage Ring.

Type	Racetrack Synchrotron
Injector	Racetrack Microton
Beam Energy at Injection	150 MeV
at Storage	700 MeV
Magnetic Field at Injection	0.6 T
at Storage	2.7 T
Magnet Pole Gap	42 mm
Bending Radius	0.87 m
Circumference	21.95 m
Betatron Tune, Horizontal	1.72
Vertical	1.84
RF Frequency	191.244 MHz
Harmonic Number	14
RF Voltage	220 kV
Stored Current(Normal)	300 mA
Beam Filling Time	5 Minutes
Beam Lifetime(at 200 mA)	>8 Hours
Beam Emittance	0.4 π mm・mr
Critical Wave Length	1.42 nm
Photon Intensity(5 keV)	1.2×10^{11}/sec/mr^2 /0.1%B.W./300 mA
Beam Ports at Bend. Sec.	7×2 with 18° Interval
at Straight Sec.	2
Angular Width of Beam Port	20 mr
Ring Dimensions, Width	3.1 m
Length	12 m
Height	1.8 m
Beam Level	1.2 m
Total Weight	130 Ton.

The vacuum chambers in the bending sections are evacuated by cryo-pumps with a pumping speed of 40,000 litters/sec in total. The reason of employing cryo-pump is that a high pumping ability is needed to absorb the outgasses released by strong SR power and that there is not enough spaces for installing usual pumping system.

As the control system, personal computers supported by LAN have been employed instead of the mini-computer with large console [5]. This scheme will enable us to catch up with the current computer technology by replacing part of the hardware with the newest version.

3 Undulators

Main parameters of the linear and helical/linear undulators are shown in Table 2 [6]. The linear undulator generates linearly polarized photons in a energy range between 25 and 300 eV. The helical/linear undulator, on the other hand, produces photons with controlled ellipticity, from linear to circular, in the energy range from 4 to 40 eV, according to selected magnet array arrangement. The energy spectra of photons from the undulators are shown in Figure 2.

Table 2
Parameters of undulators at HiSOR

Linear undulator	
Period length	57 mm
Number of periods	41
Total length	2354.2 mm
Gap distance	30-200 mm
Max. Magnetic field	0.41 Tesla
Magnet material	Nd-Fe-B(NEOMAX-44H)
Helical/linear undulator	
Period length	100 mm
Number of periods	18
Total length	1828.6 mm
Gap distance	30-200 mm
Max. magnetic field in helical mode	0.347 Tesla
Max. magnetic field in linear mode	0.597 Tesla
Magnet material	Nd-Fe-B(NEOMAX-44H)

4 Injector Microtron

We have adopted a microtron as the injector on account of its cost, better beam quality and smaller machine size compared with other conventional accelerators such as the linac and the synchrotron. Sumitomo Heavy Industries had developed the racetrack microtron of the present type until 1990 based on the concept designed at University of Wisconsin [7]. After some improvements, the performance and the stability of the microtron are well established. In Table 3, general parameters of the microtron are listed.

Table 3
Parameters of the Racetrack Microtron

Output Beam Energy	150 MeV
Input Beam Energy	80 keV
Peak Beam Current	2-10 mA
Beam Pulse Width	0.2-2 μ sec
Repetition	0.2-100 Hz
Beam Emittance	0.5 π mm-mr(1 σ)
Energy Dispersion	$\pm$0.1%(1 σ)
Mag. Field of Bending Mag.	1.23 T
Magnetic Field Gradient	0.14 T/m
Pole Gap of Bending Mag.	10 mm
Number of Turns	25
Energy Gain per Turn	6 MeV/turn
Accelerator Structure	8 Cell Side-coupled Cavity
Accelerator Bore	10 mm
RF Frequency	2856 MHz
RF Field Gradient	15 MV/m
RF Wall Loss	1.5 MW(Max.)
Beam Loading	2.0 MW(Max.)

Due to the multi-turn injection, the beam accumulation speed of the storage ring is higher than 10 mA/sec for a peak injection beam current of 2 mA with a repetition of 2 Hz. A stronger peak current of 10 mA and higher repetition of 100 Hz are prepared for the injection to the electron circulator.

5 Electron Circulator

The electron circulator, called REFER (Relativistic Electron Facility for Education and Research), is a 150-MeV weak focusing ring with two super periods. Since the ring has not rf acceleration system, the orbits of the injected electrons shrink due to radiation loss and the electrons hit an internal target. The target is a crystal and thus the electrons can generate coherent radiation such as channeling radiation, coherent bremsstrahlung and parametric X-ray through the interaction with the crystal lattice. It is especially expected that the parametric X-ray can be a new hard X-ray source for practical use.

The electron circulator can work also as a pulse stretcher. A bremsstralung from an internal target and an extracted electron beam are available for researches in intermediate energy region.

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