A SOURCE OF SYNCHROTRON RADIATION FOR RESEARCH AND TECHNOLOGY APPLICATIONS

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Abstract

The synchrotron ring for the scientific and industrial applications in designed at Kharkov Institute of Physics and Technology. The ring is dedicated for Ukrainian Synchrotron Radiation Center in Kiev. The synchrotron light generating by the 800 MeV electron beam with current up to 200 mA and the radiation emittance of $2.5*10^{-8}$ m*rad will be utilized by 24 beam lines. Two wigglers and an undulator will be inserted into the magnet lattice. The ring lattice is to provide large enough dynamic aperture and to decrease sensitivity to the collective effects.

I. INTRODUCTION

The report is concerned with a source of synchrotron radiation (SSR) which is to be the base facility in the Ukrainian Research Center of Synchrotron Radiation in Kiev for fundamental and applied research. A beam of 800 MeV electrons at a current of 200 mA and a radiation emittance of $2.5*10^{-8}$ m must ensure investigations in X-ray lithography, photoelectron spectroscopy, EXAFS, ets. It is anticipated that the SSR will have up to 24 SR channels, including three channels formed by special insertion devices, viz., wigglers and undulators. On designing the facility, special attention has been given to the dynamic aperture and collective effects.

Many physical methods of research in the fields of fundamental (in particular, atomic and molecular physics, biology) and applied sciences (materials science, microelemental analysis, medical diagnostics, etc.) involve the employment of synchrotron radiation. This report describes the proposals for the choice of the storage ring structure and gives a brief outline of the principal systems of the complex. The storage ring under consideration is expected to be the base research tool of the Synchrotron Radiation Center of the Ukraine [1].

In the SSR-800 design, two main requirements were taken into consideration. These are the provision of high spectral brightness of the source in the wavelength band needed, and the possibility of extending the spectral range employed.

To generate SR of the necessary spectral range, we have chosen the beam energy in the storage ring to be 800 MeV and the field in bending magnets to be 1.34 Tesla. After careful tests and comparison between two types of the magnet lattice (Chessman-Green and TBA), comprising a four-superperiod racetrack with long dispersion-free straight sections, we have preference to the TBA-type lattice as providing higher photon beam parameters even though being more complicated in the structure. The main physical parameters of the storage ring are presented in Table 1.

Table 1.

Electron beam energies, MeV	
injected	120
nominal	800
top	1000
Stored current, mA	200
Perimeter, m	46.729
Number of dipole magnets	12
Magnet curvature radius, m	2.005
Magnet length, m	1.05
Magnetic field, T (800 MeV)	1.34
Field index	3.0
Vertical gap, mm	36.0
Number of quadrupole lenses	24
Lens length, m	0.2
Highest gradient, T/m^2	300
Betatron tunes	
horizontal Q_x/vertical Q_z	4.26 / 3.20
Momentum compaction factor, α	0.0247
Natural chromaticity, ξ_x/ξ_z	-7.27/-7.24
Damping times, μs $\tau_x/\tau_z/\tau_s$	8.77/13.87/9.76
Emittance,nm rad $\varepsilon_x/\varepsilon_z$	27.6/1.38
Energy spread, %	5.8 10^{-2}
Energy losses per turn, keV	18.0
RF, MHz	699.3
Number of bunches	109
Accelerating voltage amplitude, kV	200
RF Power, kW	10
Critical photon energy, keV	0.6
Flux, phot/(A*sec*mrad*0.1%BW)	1.25 10^{12}

The storage ring lattice is a combined system comprising four superperiods (Fig.1). Table 2 lists the lattice parameters for one superperiod. The curved-ray trajectory part includes three rectangular magnets with a bending angle of 30^0, a curvature radius R=2.0053 m and the field index n=3, as well as two horizontally focusing quadrupole magnets providing achromaticity of the long straight part of the trajectory.

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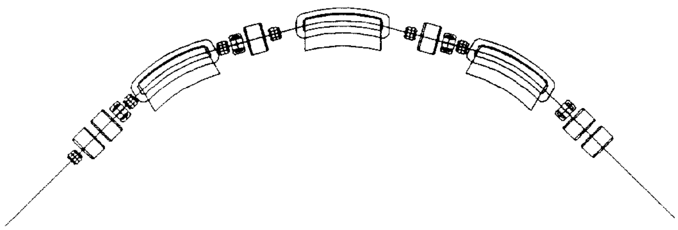

Figure 1. Layout of the storage ring superperiod.

Table 2.

Element	Length, m	Strength
D0(1/2)	1.6162	
Q1	0.2	4.4765 m^{-2}
D1	0.15	
Q2	0.2	-2.6920 m^{-2}
D2	0.7	
RB	1.05	30^{o}, -0.7453 m^{-2}
D3	0.6	
Q3	0.2	7.520 m^{-2}
D4	0.6	
RB(1/2)	0.525	15^{o}, -0.7453 m^{-2}

The straight part of the trajectory comprises four quadrupole magnets, which, being used in combination with two quadrupole magnets of the curved ray part and the vertical-correcting dipole magnets, ensure the stability of radial and vertical motion. Fig. 2 shows the lattice focusing functions for a superperiod (calculations were performed by the DeCA program [2]). The mode of the SSR-800 operation is characterized by a low radiation emittance , which is due to a greater rigidity of the lattice. This leads to the increase in the natural chromaticity which can be compensated by sextupole lenses mounted in the sections with a nonzero dispersion. The dispersion-free section incorporates the second family of sextupole lenses to correct the dynamic aperture. Fig.3 depicts the computer-simulated dynamic aperture in the center of the long straight section. It is seen that with the sextupole compensation lenses turned on, the dynamic aperture is greater than the geometrical one.

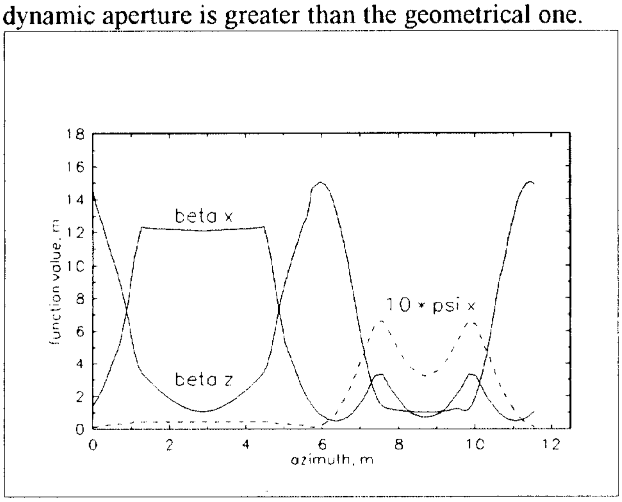

Figure 2. Structure functions of the storage ring.

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          Z
          !+------+-------+-------+-------+!
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          !. X     .  X    XXXX    .       .!
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 0.02000  +. . . XXX $ $ $..XX$.X.X. . .X..+
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          !.      .XX     X XX    .   X   .!
 -.04000  +. . . ... . .XX..XX . ... . . ..+
          !+------+-------+-------+-------+!X
     -.30000 -.15000 0.00000 0.15000 0.3000
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Figure 3. Dynamic aperture. x: lost particles; $: stable particles.

We have considered the effect of a three-pole wiggler with a field amplitude of 10 T on the beam dynamics in the storage ring, which results in the tune shift (mainly, vertical), ΔQ_z=0.2, and the decrease in the dynamic aperture size. As a result, the system of wiggler focusing was chosen. The added doublets of quadrupole lenses placed at the wiggler ends provide a complete coincidence of the transport matrix of the insert section with that of a standard long straight section. As a consequence, the dynamic aperture has decreased by less than 5%, and the linear optics of the lattice has been restored.

Residual gas molecules in the vacuum chamber of the storage ring cause the scattering of circulating beam particles. This involves an increase in the transverse dimensions and the divergence of the beam, and also increases its losses. To attain the accetable beam lifetime value (about 6 h), which is determined in the storage ring mainly by the Touschek effect and residual gas scattering, it is necessary to ensure a pressure of about 10^{-9} Torr and to mount ion clearing electrodes.

As an injector, we intend to employ the 120 MeV electron linac, designed at the Kharkov Institute, with a pulsed beam current of 100 mA and a transverse emittance of $2x10^{-7}$m. The injection to the storage ring is accomplished in the horizontal plane by means of three kicker magnets and a magnet septum.

Beam energy losses by synchrotron radiation and parasitic losses in the vacuum chamber walls are compensated with the help of a 10 kW RF (699.3 MHz) system. The accelerating voltage of 200 kV chosen in view of the Touschek lifetime, is provided by a single half-wave cavity, whose shape has been optimized against the shunt resistance at the main (operating) mode (Ω-cavity). As calculations and measurements [3] indicate, this cavity has lower coupling impedances at higher-order modes than the cylindrical cavity has and, therefore, is less sensitive to the excitation of coupled oscillations of bunches.

Sixteen pickup stations and a current transformer are used to monitoring the beam in the storage ring.

We expect that the construction of the building for the SSR-800 will be started in 1993, the fabrication and installation of the equipment are scheduled for 1994, and in 1995 initial experiments using the SR will be started (four SR dedicated channels at the first stage).

V. REFERENCES

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