Nuclear Instruments and Methods in Physics Research A308 (1991) 57–60
North-Holland

Multipole wiggler and undulator for the TNK SR source

G.I. Erg, V.N. Korchuganov, G.N. Kulipanov, E.B. Levichev, E.M. Trakhtenberg, V.A. Ushakov and A.G. Valentinov

Institute of Nuclear Physics, Novosibirsk 630090, USSR

Modern SR sources are dedicated for a wide use of bright and intense radiation from insertion devices Here the description, the conceptual design and the parameters of a multipole wiggler and an undulator are given for a new storage ring TNK for microelectronics applications.

1. Introduction

The 1–2 GeV dedicated electron storage ring TNK [1] has 12 straight sections, three of which are intended for injection and rf equipment, and in the rest of the ring two superconducting wigglers [2], two undulators and five multipole wigglers will be installed. Here the main parameters of the undulators and multipole wigglers are presented.

2. Undulator

2.1. Source properties

Electron energies of 1 to 2 GeV are optimal for obtaining bright undulator radiation in the soft X-ray and VUV ranges. For the undulator the wavelength range was chosen from tens to one thousand ångströms

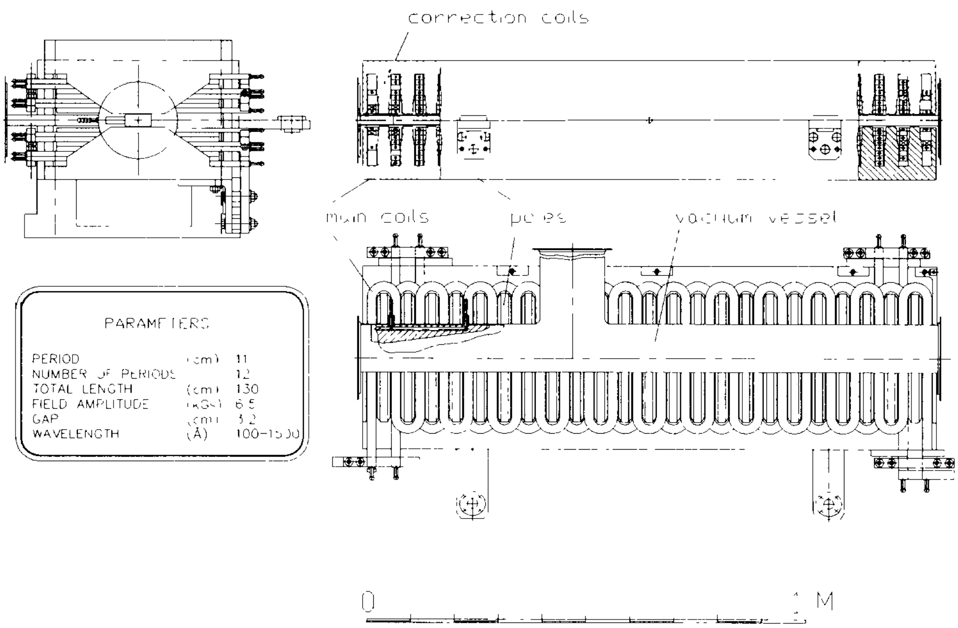

Fig 1. Undulator layout.

Table 1
Design parameters of the TNK undulator

Period [cm]	11
Number of periods	12
Total length [cm]	130
Gap height [mm]	32
Maximum magnetic field [T]	0 1–0.65
First harmonic wavelength [Å]	100–1470
Current [A]	2000
Voltage [V]	32
Power consumption [kW]	64

(atomic and molecular spectroscopy, photoelectron spectroscopy, photochemistry, etc.).

For emission of high-brightness radiation in the bandwidth $\Delta\lambda/\lambda \sim 1/N$ (N = number of periods), the angular spread of the electron beam has to be less than the diffraction divergence of the photon beam. With this fact in view, one can derive the well-known expression for the horizontal envelope function in the undulator straight section:

$$\beta_x \gtrsim \pi\epsilon_x L/\lambda,$$

where ϵ_x is the horizontal emittance of the electron beam, λ is the radiation wavelength, and L is the length of the undulator. To limit β_x, the phase volume of the electrons must be reduced, and to reach high brightness, a very small emittance is required. In our case, in the undulator straight section $\beta_x = 16$ m, $\sigma_x = 0.86$ mm and $\sigma_{x'} = 0.04$ mrad, while the electron energy $E = 1.6$ GeV and the horizontal emittance $\epsilon_x = 3.1 \times 10^{-6}$ cm rad.

2 2. The design of the undulator

The general layout of the undulator is shown in fig. 1, and the parameters are presented in table 1. The array of electromagnets has a period $\lambda_0 = 11$ cm and produces on the orbit a nearly sinusoidal magnetic field with a maximum amplitude $H_{max} = 0.65$ T. The gap height $g = 32$ mm does not reduce the beam aperture. The poles together with the base plate are made from ARMCO steel. To avoid field distortion due to the parasitic magnetic flux, the lower and upper parts are connected by 20 mm ARMCO plates.

To simplify manufacture, connection and cooling of the coils, a winding comprising 16 (eight each for the upper and lower parts) snake-like buses was chosen [3]. Each 10×18 mm copper bus has a cooling hole of 6 mm diameter. Besides the main coils, the outer poles have correction coils for the compensation of the possible orbit distortions.

The undulator vacuum vessel is made from stainless steel of 2 mm thickness.

2 3. Properties of the photon beam

The expected on-axis brightness of the radiation produced by the undulator at 1.6 GeV energy and 0.3 A current is shown in fig. 3. For comparison, the brightness of the light from the storage ring, a 1.1 T dipole magnet, is also shown. The intensity of the undulator photon beam integrated over all angles is shown in fig. 4. The comparison in this case is with the vertically integrated intensity from a bending magnet, for a 1 mrad horizontal opening angle. So the total opening angle from the dipole is a few mrad, and the undulator provides in the chosen wavelength region a useful intensity enhancement as compared with a conventional beam line.

3. Multipole wiggler

3.1. Requirements for the photon beam

Multipole wigglers are intended for providing lithography experimental stations with intense photon beams in the 5–40 Å wavelength range. For lithography, a radiation power distribution with a good homogeneity across the sample is required. In our case, a relative spread of the radiation power absorbed in the center of the sample and at its edge of $\Delta P/P \leqslant 5\%$ was taken into consideration. For this value one can obtain the following expression:

$$\Delta P/P \approx \alpha^2/2\alpha_0^2,$$

where α is the horizontal opening angle and $\alpha_0 = K/\gamma$ is the maximum wiggler deflection angle (K and γ are the undulator and relativistic factors, respectively). Here $\alpha \ll \alpha_0$ was assumed.

In our case, if the sample has a diameter of 55 mm and the distance from the source point to the stepper chamber is 12 m, then the deflection angle for half a pole has to be $\alpha_0 = 7.4$ mrad. For the maximum strength of magnetic field $H_{max} = 1$ T it gives a period length $\lambda_0 = 24$ cm.

Table 2
Design parameters of TNK multipole wiggler

Period [cm]	24	
Number of periods	5	(7)
Overall length [cm]	130	(180)
Gap height [mm]	32	
Maximum magnetic field [T]	1	
Critical wavelength at 1 6 GeV [Å]	7 3	
Current [A]	1000	
Voltage [V]	36	(45)
Power consumption [kW]	36	(45)

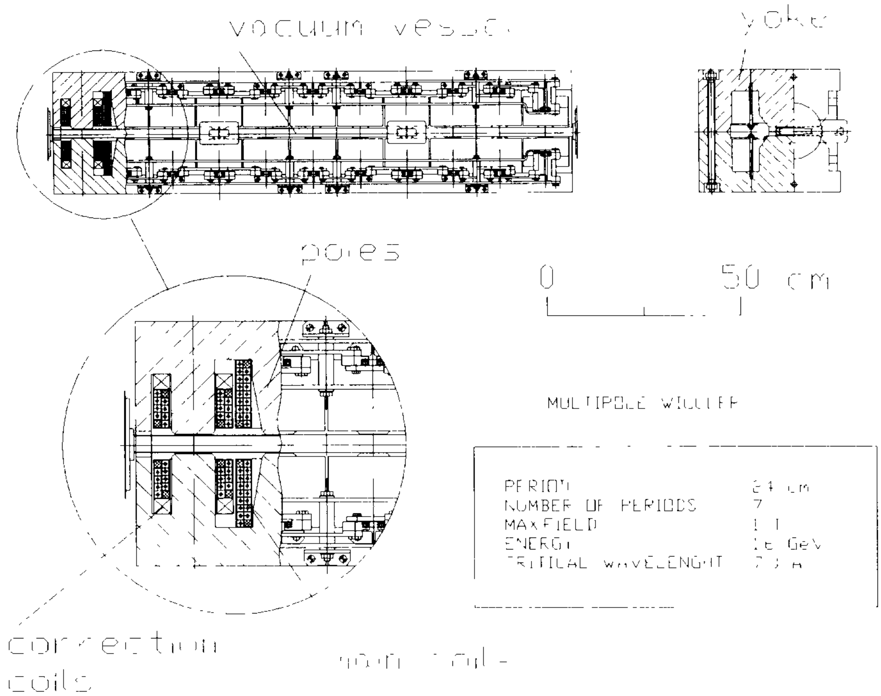

Fig. 2 Multipole wiggler layout.

3.2. Wiggler design

The general layout of the wiggler is shown in fig. 2; table 2 gives the main design parameters. The wiggler yoke has a C-shaped cross section and is made from ARMCO.

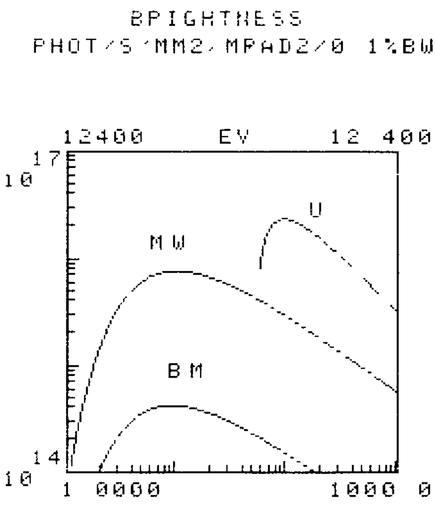

Fig. 3. Brightness (photons/(s mm^{-2} $mrad^{-2}$)/0.1% BW) of the various radiation sources. U – undulator, MW – multipole wiggler, BM – bending magnet ($H = 1.1$ T).

The main coils are made from 10.5 × 10.5 mm copper bus with a central hole of 6 mm diameter for water cooling. For the beam sweeping system and to eliminate orbit distortions, there are additional correcting coils at both end poles.

The vacuum vessel of the wiggler, made from 1 mm thick stainless steel, is connected to the storage ring vacuum chamber by bimetallic flanges.

Five multipole wigglers are planned to be installed in both the dispersion-free straight sections (seven-period wigglers) and the nonzero dispersive straight sections (five-period wigglers).

3.3. Radiation properties

In fig. 3 the vertically integrated intensity for a 1 mrad horizontal opening angle is shown in comparison with dipole and undulator intensities. Fig. 4 gives the

Table 3
Parameters of TNK electron beam with/without wigglers

Parameter	Without wiggler	With wiggler
Horizontal betatron tune	7.717	7.717
Vertical betatron tune	7.698	7.745
Horizontal emittance [mm rad]	31.2	29 4
Loss per turn [keV]	114	125
Vertical damping time [ms]	10.8	9.8

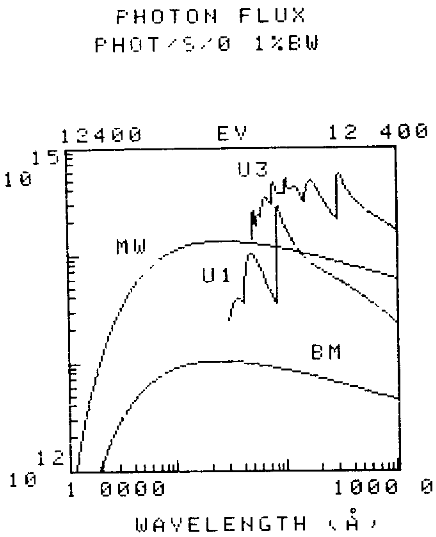

Fig 4 Total flux from the undulator integrated over all angles (U1: undulator parameter $K = 1$, U3: $K = 3$) compared with that from the bending magnet (BM) and the multipole wiggler (MW).

same but for radiation brightness. For both figures, the number of periods $N = 7$ and the field amplitude $H_{max} = 1$ T, while the electron beam parameters are: energy $E = 1.6$ GeV and current $I = 0.3$ A.

4. The effects of insertion devices on beam dynamics

In spite of a relatively weak magnetic field in the wiggler (undulator) its effects on beam parameters should be investigated. The main effects are: potential distortion of the closed orbit (caused by $\int_w^B ds \neq 0$), increase of the energy losses per turn, addition focussing, and hence a shift in betatron tunes. In table 3 some beam parameters are given with/without five multiple wigglers.

To compensate for the vertical tune shift there are gradient correction coils in each quadrupole lens adjacent to a straight section where an insertion device will be installed.

As estimations have shown, that the nonlinear effects due to the cubic component of the wiggler (undulator) magnetic field are weak and can be neglected.

References

[1] V.V. Anashin et al., these Proceedings (9th USSR Nat. Conf. on Synchrotron Radiation Utilization, Moscow, 1990) Nucl Instr. and Meth. A308 (1991) 45.

[2] V.N. Korchuganov, G N Kulipanov, E.B. Levichev, S.V. Sukhanov, V.A. Ushakov and A G. Valentinov, ibid., p. 54.

[3] N.G. Gavrilov et al., Proc. of the 8th USSR Nat. Conf. on Synchrotron Radiation Utilization, Novosibirsk, USSR, Nucl. Instr. and Meth. A282 (1989) 422.