Design of a Superconducting Wiggler for the PLS *

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May 14, 1993

Abstract

The physical engineering design of a 7.5 Tesla superconducting wiggler for the PLS is described. The design is based on three parallel superconducting dipoles. The field is produced by six racetrack NbTi-coils assembled symmetrically above and below the vacuum chamber. The current density for the central pole was chosen to obtain optimal field-current characteristics within the conductor packages. The use of iron poles and return yokes makes it possible to produce higher fields than the corresponding values when no iron is used.

I Introduction

A strong field wiggler (wavelength shifter) will be installed in a straight section of the Pohang Light source (PLS) storage ring power [1] to enhance the performance of the machine for short wavelength users and to provide new possibilities for SR experiments. The wiggler is not one of the main elements of the lattice and does not reduce the reliability of the machine. However, lattice matching and compensation of wiggler effects on the electron beam dynamics are needed.

A superconducting wiggler is under construction now at the Budker Institute of Nuclear Physics [BINP], Russia and will be delivered to PLS at the end of 1994, which is also the expected completion date for the PLS.

In this article, the design of the Superconducting Wiggler and the radiation properties of the wiggler will be briefly presented.

II Wiggler Design

A view of the three-pole wiggler is presented in Figure 1. The wiggler design is based on three parallel superconducting dipoles. The magnetic field is produced by six racetrack NbTi-coils assembled symmetrically above and below the vacuum chamber. The conductor is insulated with Kapton film, and the completed coils will be impregnated with epoxy resin. The two central coil packages are split into two separate coils. The current density in each of the coils was chosen to obtain optimal field-current characteristics.

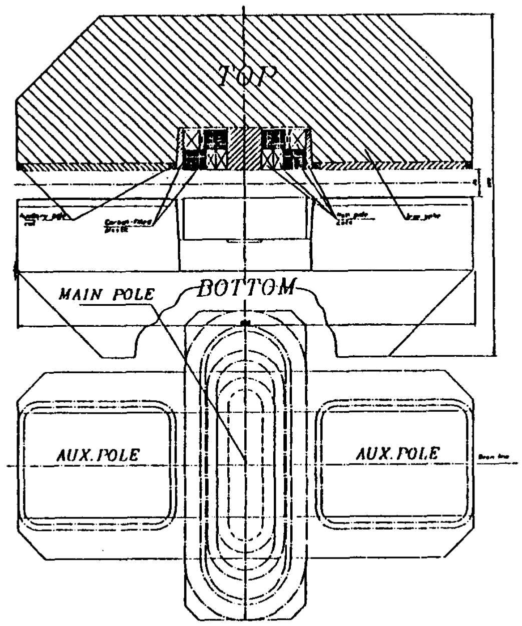

Figure 1: General view of the Superconducting Wiggler

The iron poles and yoke surround the coils, providing a flux path, and supporting the coils. The use of iron poles and yokes makes it possible to produce a higher field than is possible for similar geometries when no iron is used. In addition, the outer poles act as the mechanical restraint to the very large magnetic forces generated by the main pole coils. The non-magnetic stainless steel slab located between the upper and lower wiggler halves is simultaneously a part of the helium vessel and a support for the halves.

The magnetic field of the wiggler magnet was calculated with the MERMAID code developed at BINP. [2] The flux distribution is shown in Figure 2. The distribution of

*Work supported by Ministry of Science and Technology, Hyundai Electrical Engineering Co., Ltd. and the Budker Institute of Nuclear Physics

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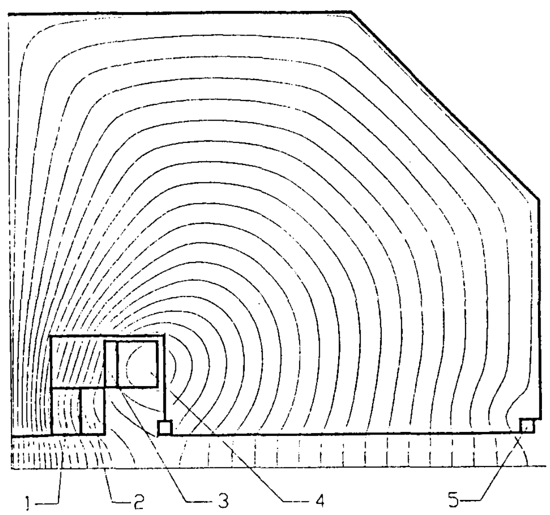

Figure 2: Magnetic flux distribution and overall current densities for each coil region

the magnetic field along the wiggler axis is presented in Figure 3. The maximum central field is 7.5 Tesla and the flux density along the side poles is about -1.7 Tesla. Calculated beam trajectories are also plotted in Figure 3. The maximum deviation from the equilibrium orbit is approximately 15 mm and the maximum slope of the trajectory is 65 mrad, or about 3.8°. The main parameters of the wiggler are summarized in Table 1.

For the central pole coils and the side pole coils, two high stability power supply units are used. Referring to Figure 2, Coil 1 and Coil 3 are connected in series with one supply, and Coils 2, 4, and 5 are excited by the other power supply. Such connection permits us to control the field integral and match it to zero within the required accuracy. We need only one type of superconducting wire which will

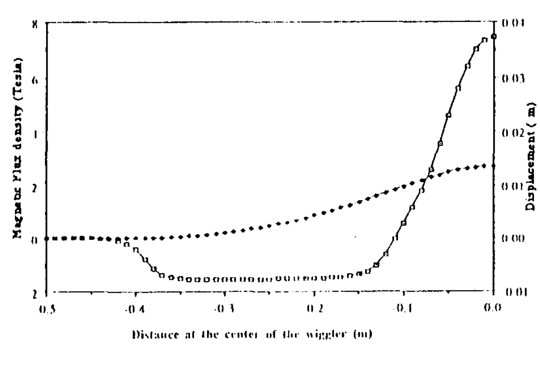

Figure 3: Magnetic field profile and reference orbit

Maximum field on beam axis	
Central pole (T)	7.5
Outer poles (T)	-1.7
Pole gap (mm)	40
Vert. gap of the vacuum chamber (mm)	24
Horiz. gap of the vacuum chamber (mm)	100
Stored energy (kJ)	150
Total weight of cooled parts (Kg)	~ 1000

Table 1: Main parameters of the 7.5 T wiggler

Diameter	0.85 mm (0.95 mm with insul.)
Ratio of Cu:NbTi	0.58:0.42
No. of NbTi filament	8910
Critical Current	360 A (at 7 Tesla)

Table 2: Properties of the superconducting wire

operate with different current density, depending on the coil. We will use the superconducting wire specified in Table 2.

III Radiation Characteristics

Here and below an electron energy of 2 GeV and an electron beam current of 100 mA are assumed. In Figure 4 the vertically integrated intensity for a 1 mrad horizontal opening angle and 0.1 % bandwidth is shown for a central pole field strength of 7.5 T and side pole field strength of -1.7 T. The spectral photon flux at the critical wavelength $\lambda_c = 0.62$ A° (critical energy $\epsilon = 20$ keV) is $I = 3.2 \times 10^{12}$ photon-s/sec/0.1% BW/mrad.

The total radiation power from the 7.5 T superconducting wiggler is approximately 3.4 kW.

The 7.5 T superconducting wiggler deflects 2.0 GeV electrons in the horizontal plane by a total angle of about ±3.8°. For the case when the wiggler is located in the center of a 6.5 m straight section, the design of the PLS vacuum chamber makes it possible to have a maximum horizontal angular aperture for radiation output approximately equal to $2\Delta\theta \simeq 20$ mrad. This is corresponds to an output power of nearly 0.5 kW, with the remainder of the total 3.4 kW emitted power being stopped by several water cooled copper absorbers installed in the vacuum chamber between the wiggler and the beamline port.

Insertion of the special absorber units inside the PLS vacuum chamber will not result in a reduction of the horizontal aperture of the electron beam, which is ±35 mm.

The preliminary location of the absorbers has been computed and incorporated into the design of the vacuum chambers.

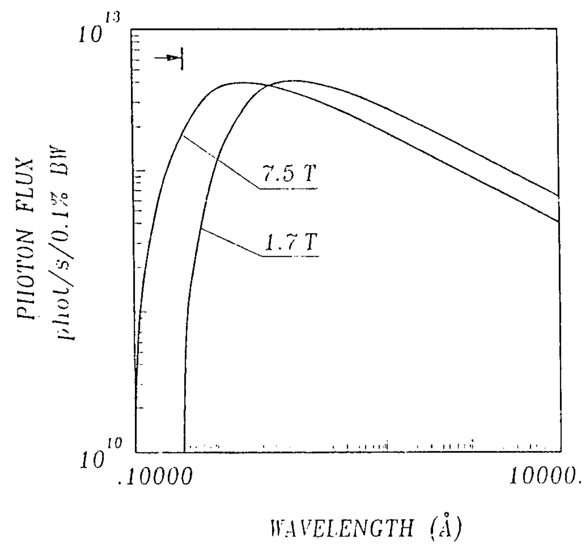

Figure 4: Photon flux integrated over the vertical opening angle.

Maximum output current	2 × 300 A
Maximum output voltage	12 V
RMS Stability	0.01 %
Line voltage	220/380 V–60 Hz
Cooling	water

Table 3: Parameters of wiggler power supply

IV Miscellaneous

Cryogenics

The inner helium filled vessel is surrounded by a nitrogen shield to reduce the heat transfer rate between the outside and the helium inner part. The space between the helium vessel and the nitrogen screen, as well as that between the nitrogen screen and the external warm stainless steel vessel, are filled with aluminized mylar insulation to reduce heat transfer rates.

The wiggler coil current inputs are cooled by boiled helium vapors. The vacuum pipe where electrons pass is at room temperature so as not to interfere with the machine. The approximate thermal inflow is 1.4 W, and the expected helium consumption rate is 46 liters/day. Detail design of the cryogenics system is now in progress.

Power Supply

Two separate power supply units are needed to feed the wiggler coils. Preliminary design parameters of power supply units are listed in Table 3. Each power supply has a three phase tyristor rectifier, a rectifier filter and electronics for the feedback system, as well as current control and monitoring. A zero-flux current transformer is used for high precision output current measurements. The power supplies are computer controlled using 16-bit digital to analog converters.

Control System

The wiggler control system has to provide for control and monitoring of the wiggler operation during cooling, ramping on and operation conditions. The main functions of the control system are:

- control and monitoring of the power supply.
- magnetic field ramping.
- control of the quench protection system.
- monitoring of cryogenic equipment.
- wiggler operation statistics.

V Summary

A superconducting wiggler is being built for the PLS storage ring. The design is based on three parallel superconducting dipoles. The field is produced by six racetrack NbTi-coils assembled symmetrically above and below the vacuum chamber. The current density for the coil about the central pole is optimized to obtain optimal field-current characteristics within the coils. The use of iron poles and yokes makes it possible to produce higher field than the corresponding values when no iron is used. The central field is expected to be about 7.5 T, giving a critical wavelength of $\lambda_c = 0.62$ A at an electron energy of E=2.0 GeV. This superconducting wiggler will enhance the performance of the PLS for short wavelength users and provide new possibilities for synchrotron radiation experiments.

References

[1] *Conceptual Design Report of Pohang Light Source*, Pohang, POSTECH Press, 1992.

[2] A. Dubrovin and E. Simonov, *Computer code for magnetic field computation*, preprint from BINP (in printing).