

Superconducting 7 T wiggler for LSU CAMD

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A superconducting 7 T wiggler is under fabrication in a collaboration between Budker INP and LSU CAMD. The wiggler magnet has been successfully tested inside a bath cryostat and a maximum field of 7.2 T was achieved after six quenches. The main parameters of the wiggler and the method of the wiggler installation onto the storage ring are discussed.

Keywords: superconducting wigglers; cryostats; magnets.

1. Introduction

A superconducting 7 T wiggler is destined for the 1.5 GeV storage ring at the Center for Advanced Microstructures and Devices (CAMD) which is operated by Louisiana State University (LSU), USA. The wiggler contract was awarded to Budker Institute of Nuclear Physics (BINP) in open tender in May 1996 and the wiggler will be installed at the CAMD site in December 1997. The main purpose of the superconducting wiggler is to shift the synchrotron radiation spectrum to the hard X-ray region on an existing 1.5 GeV radiation source. The wiggler is a three-pole superconducting magnet with a maximum field of 7 T at the central pole. Two side poles are used for compensation of the magnetic field integral along the wiggler. The magnetic field at the side pole is 1.55 T in order to suppress the second sources in the hard spectral region.

2. Conception of the wiggler design

The wiggler will be installed into a 3 m-long straight section. The main feature of this wiggler is that the orbit in the centre of the wiggler is fixed on the axis of the straight section and does not

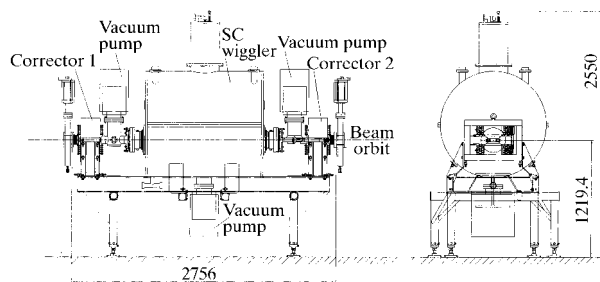


Figure 1
Layout of the wiggler installation in the straight section.

Table 1
Main parameters of the wiggler.

Maximum field on beam axis	
Central pole	7.0 T
Side poles	-1.55 T
Pole gap	51 mm
Vertical aperture of vacuum chamber	32 mm
Horizontal aperture of vacuum chamber	~100 mm
Stored energy	~100 kJ
Total weight of cooled parts	~1000 kg
Working temperature	4.2 K

depend on the wiggler field level. This feature permits experiments to be conducted under different field levels in the wiggler without changing the geometry of the experiments. A view of the wiggler installation at the storage ring is presented in Fig. 1.

The horizontal deviation of the electron beam orbit at the central pole is zero due to compensation of the beam trajectory. The compensation of the trajectory is realized by the superconducting magnet together with two normal conductivity correctors with a field of 0.6 T which are located at both ends of the wiggler 'non-dispersive' straight section.

Thus the radiation point emitting synchrotron radiation from the centre of the wiggler has the same position at any magnetic field level. There is a possibility of changing the magnetic field of the wiggler during an experiment by changing the spectral features and keeping the source at the same position.

The first field integral of the superconducting part of the wiggler is not equal to zero and corresponds to orbit angles energized by the correctors. The superconducting magnet is inserted into a special liquid-helium cryostat. The pole gap is 51 mm and the vertical aperture of the room-temperature beam vacuum chamber is 32 mm. The main parameters of the magnet are listed in Table 1.

3. Superconducting magnet

The superconducting magnet design is based on three superconducting dipoles. The wiggler magnetic field is produced by six Nb-Ti coils assembled symmetrically above and below the vacuum chamber. A general view of the magnetic system is shown in Fig. 2.

The central coils consist of two different windings which are wound one over the other. The current density at the windings

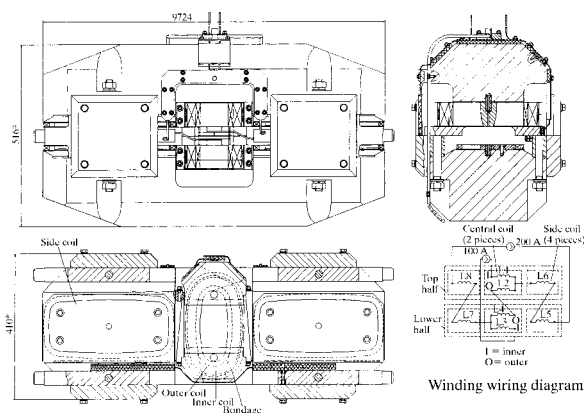


Figure 2
General view of the superconducting wiggler magnet.

of the central coils is optimized to obtain optimal field-current characteristics. The magnetic field at the coils reaches 90% of the short sample limit of the superconducting wire used. A stainless-steel wire bandage is used as a mechanical restraint of the coils.

The central pole is attached to an iron yoke by using two pairs of invar wedges. At the first stage the coils are pre-stressed by the wedges inside the iron yoke at room temperature. Final clenching and bandaging of the coils takes place during the cooling of the magnet due to low thermal contraction of the invar wedges. The thickness of the wedges is selected to provide the required restraint forces inside the coils.

The ARMCO iron yoke is used to return the magnetic flux and to support the coils. The length of the magnet yoke is 972 mm. The upper and lower wiggler halves are supported by the non-magnetic stainless-steel slabs located symmetrically between the halves. Special projections at the slabs are used for attaching the magnet body to the walls of the helium vessel. Thus, support of the wiggler is just at the magnet median plane.

The additional iron plates between the upper and lower halves are used to close the stray magnetic flux. The magnetic field from the superconducting magnet is clamped, shielded and does not exceed 10 G at nearby quadrupoles of the CAMD ring. The iron yoke is not saturated and provides a very low level of stray field (several gauss near the cryostat).

The simulation of the wiggler magnetic field was made using the three-dimensional *MERMAID* code and three-dimensional *MASTAC* code developed at BINP (Grudiev *et al.*, 1995; Dubrovin & Simonov, 1993).

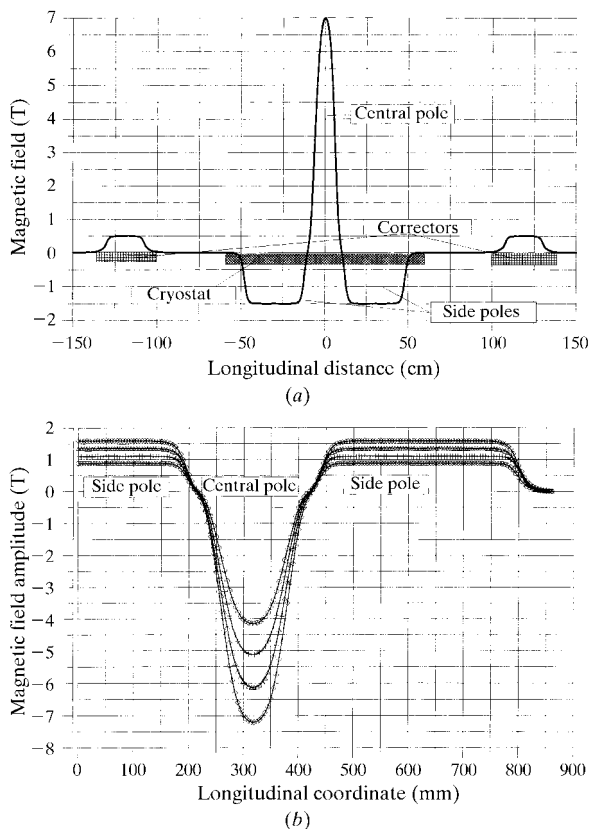


Figure 3
(a) Magnetic field distribution along the straight section at maximum magnetic field. (b) Results of magnetic field measurements for different field levels.

The longitudinal distribution of the field component, B_z , in the median plane for the superconducting magnet along the straight section is shown in Fig. 3(a). Fig. 3(b) shows the results of the magnetic field measurements for different field levels.

The maximum orbit displacement and angle deviation inside the wiggler are ~ 19 mm and ~ 82 mrad, respectively, for an electron energy of 1.5 GeV and $B_{\max} = 7.0$ T (see Figs. 4a and 4b). The angle distribution of the photon flux for various spectral ranges is shown in Fig. 5.

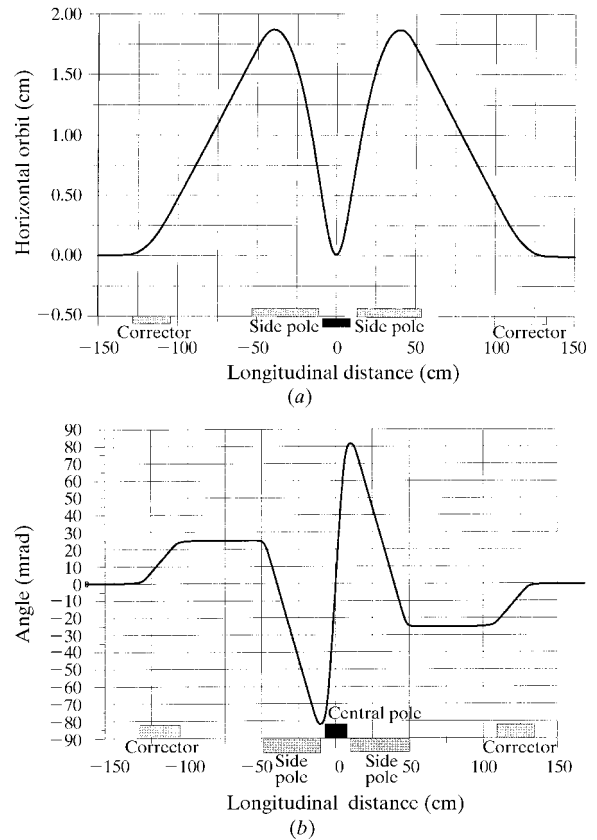


Figure 4
(a) Orbit deviation along the straight section. (b) Angular orbit deviation along the straight section.

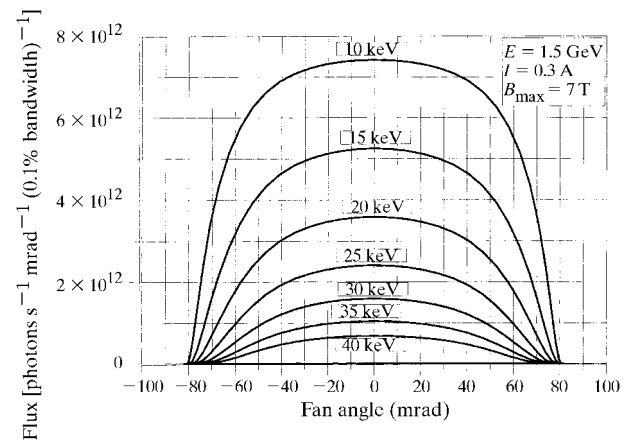


Figure 5
Angular photon flux distribution of synchrotron radiation from the wiggler for various spectral ranges for $E = 1.5$ GeV and $I = 0.3$ A.

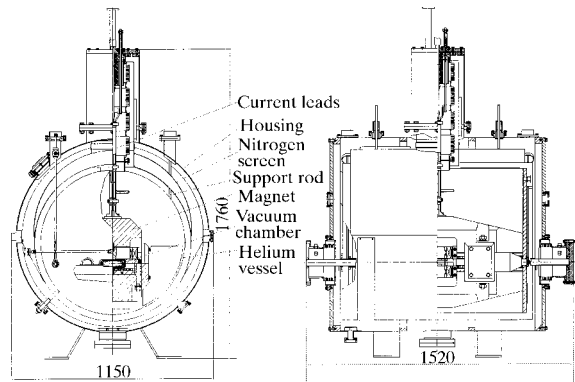


Figure 6
General view of the superconducting wiggler magnet assembled inside the cryostat.

4. Cryostat

The wiggler is inserted into a special liquid-helium cryostat. A general view of the cryostat is shown in Fig. 6. The inner liquid-helium vessel is surrounded by a nitrogen screen coating with multilayer aluminized mylar film to reduce the heat flux from outside. There is vacuum insulation between the helium vessel and the screens as well as between the screens and an external warm stainless-steel vessel. The space between the helium vessel and radiation screens is also filled with multilayer aluminized mylar insulation. Liquid nitrogen is used for cooling the screen.

The wiggler is supported by the walls of the helium vessel with special projections of the wiggler body. The helium vessel is hung with four fibre-kevlar ribbons connected to the external cryostat housing. The ends of these ribbons pass through the external vessel walls and are used for precise alignment of the wiggler.

Four optimized current leads for a current of 250 A cooled by evaporated helium streams are passed through the upper flange and are connected to the superconducting coils.

The stainless-steel vacuum chamber of the superconducting magnet is connected to the vacuum chamber of the storage ring. The chamber is at room temperature. To reduce the heat flux from the warm vacuum chamber to the wall of the wiggler helium volume a copper screen and insulating vacuum are used.

There are two stages in the process of cooling the cryostat. Firstly it takes 40 h and 450 l of liquid nitrogen for pre-cooling to 100 K. Then it requires 250 l of liquid helium and 4 h to cool the wiggler to 4 K. The liquid-helium consumption of the cryostat is estimated as $1.5\text{--}1.8\text{ l h}^{-1}$.

The power supplies are intended for current control and stabilization in the superconducting windings of the magnetic

system. The power supply to the superconducting wiggler consists of two independent power sources. The first one provides current control in the first wiggler circuit within 0–200 A. The second provides current control in the second circuit within –30–150 A.

The quench protecting system is destined to fast extract the energy stored in the wiggler magnetic system at superconductivity quenches. The quench protecting system consists of a fast electromechanical switch, quench detector and magnet energy absorber.

5. Results of the wiggler testing

Each high-field central coil of the wiggler after manufacturing was tested separately inside a small special immersed cryostat to obtain maximum current at the coils. Both sections of the central coil were connected in series and were energized by one power supply. There were several quenches during the process of training the superconducting coils, and maximum currents of 214 and 223 A were obtained.

After assembling the wiggler magnetic system, it was trained inside a large immersed cryostat to reach a maximum magnetic field at the centre of the wiggler. After six quenches, a maximum field of 7.2 T was achieved on 16 March 1997. The results of the magnetic field measurement along the wiggler axis are presented by Borovikov *et al.* (1998).

After assembling the common wiggler, the training will be continued to increase the maximum magnetic field. Measurement of the residual magnetic field of the wiggler and matching of currents in the coils for setting the field integrals to zero will be carried out. The wiggler will be installed in the LSU CAMD site in December 1997.

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