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Superconducting 63-pole 2 T wiggler for Canadian Light Source


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Available online 12 January 2007

Abstract

A superconducting 63-pole wiggler with the average period 34 mm designed and fabricated in the Institute of Nuclear Physics in Novosibirsk for Synchrotron Radiation Center Canadian Light Source (CLS) in Canada is described. The maximum field 2.2 T in the median plane has been achieved. The liquid helium consumption less than 0.03 L h in operating mode has been reached. It allows refilling liquid helium once a year. In January 2005, the wiggler was installed in the storage ring in CLS and now experiments are carried out. The main parameters of the magnet and the cryogenic systems as well as test results are presented.

PACS: 41.85.Lc; 85.25.L

Keywords: Superconducting magnets; Wigglers; Cryostats

1. Introduction

Superconducting 63-pole wiggler for Canadian Light Source (CLS) was designed and fabricated in Budker INP (Novosibirsk, Russia) according to technical requirements of the contract made between University of Saskatchewan and Budker INP in October 2003. A wiggler with the photon energy range 4–40 keV, the maximum field 2.2 T, and the period length as small as possible was required for the micro-XAFS beamline. In January 2005, the wiggler was successfully tested at CLS site and installed on the storage ring to improve quality of SR of CLS (see Fig. 1).

The main goals of multipole wigglers are shift of SR spectrum to X-ray rigid area and increase of photon flux [1]. The multipole wiggler represents magnetic system with transverse magnetic field, consisting of 63 bending magnets placed in a straight section of a storage ring. There are 61 main poles with the field amplitude of 2 T. The wiggler is installed on the straight section of the storage ring and is a magnetic element with compensated field integrals along beam trajectory. Two side poles with the field of 1/2 of the main pole field are used to close electron beam orbit.

Superconducting windings are made from Nb–Ti wires, that are inside liquid helium vessel at temperature 4.2 K during normal operation. Wiggler cryostat has four compact coolers used for cooling of shield screens and to prevent heat in-leaks into liquid helium vessel. During normal operation of the wiggler, the liquid helium consumption is close to zero. The presented wiggler has a rather complicated spectral structure with a transition from undulator radiation spectra to spectra of sign alternating bending magnets array (wiggler) depending on the energy of photons. XAFS experiments require smoothness of spectrum in range 4–40 keV. Effects of electron beam energy spread and final number of wiggler poles are not enough for spectrum smoothness in photon energy area 4–10 keV. To provide the required spectrum smoothness in low-energy range, it was decided to bring a casual disorder in the wiggler periodicity (see Fig. 2). The main wiggler parameters are presented in Table 1.

2. Magnetic system

The wiggler magnetic field on the median plane is created by 122 central and four side coils wound over the ARMCO-iron cores. The shape of the central pole is

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racetrack type with dimensions of $82 \times 16.6\,\text{mm}^2$ and height of 26 mm. All central coils consist of one section with total turns number of 105. Superconducting Nb–Ti wire with diameter of 0.91 mm including of lacquer insulation was used to produce the wiggler coils.

Wiggler central poles are energized by two independent power supplies with maximum current of 400 A. Both the currents are summarized at the coils so current in the coils is equal to 800 A. Additional 1/2 side coils are energized by only one of 400 A power supply. It enables to control the first field integral and adjust it close to zero with required accuracy. The windings are connected in series outside of the strong magnetic field region. Connections between all 126 coils are realized with using of low resistance superconducting technique to prevent Joule heating and liquid helium evaporation.

The load curves of the used superconducting wire are presented in Fig. 3. In the same figure are pointed the operation points that describe values of magnetic fields and currents in the points of the winding that are critical from the quench standpoint.

The ARMCO-iron yoke is used to return the magnetic flux and to support the coils (see Fig. 4). The length of the magnet yoke is 1120 mm. The yoke includes two parts that are placed symmetrically above and below of the median plane of the wiggler. The additional iron plates between the upper and lower halves are used to close the stray magnetic flux. There are several technological facilities for high-accuracy orientation and alignment of the coils on the yoke to minimize the second field integral. Block of the coils is pressed so that orientation of coils is perpendicular to the longitudinal axis of the wiggler. The dimension of the vertical magnetic gap between the coils is equal to 13.5 mm. Superconducting coils of the wiggler are protected from damaging during quench by shunts with resistance of 0.1 $\Omega$ and cold diodes.

### 3. Cryostat

The superconducting magnet is placed into a special liquid helium cryostat with working temperature of 4.2 K (see Fig. 5). Inner liquid helium vessel with the magnet inside has useful volume of $\sim 330\,\text{L}$ of liquid helium. The liquid helium vessel is surrounded by two shield screens to reduce the irradiation heat flux from outside. The temperature on the outside shield screen is about 60 K, on the inner one is 20 K. Two cryo-collers Coolpower 10MD Leybold are used for cooling of 60 and 20 K shields. Two recondensers Coolpower 4.2 GM Leybold are used for maintenance of a working
temperature of current leads and liquid helium vessel during operation and for additional cooling of 60 K shield. Outside surface of the helium vessel is covered by high thermo-
 conductivity cooper net connected with 4K stages of recondensers. There is vacuum insulation with the pressure of $10^{-7}$ mbar between the helium vessel and external warm stainless steel vessel to reduce the heat flux.

The wiggler magnet is supported by the walls of the helium vessel face flanges with special projections of the magnet body. The helium vessel is hanged with four kevlar strips connected to the external cryostat vessel. These strips pass throughout the both shield screens and external housing walls and are used for precise alignment of the magnet position without disassembling of the cryostat.

Small vertical size of wiggler magnetic gap (13.5 mm) does not allow arranging room temperature beam vacuum chamber inside of the wiggler cryostat. So the vacuum chamber of liquid helium volume with the temperature of 4.2 K is used simultaneously as the beam vacuum chamber. To prevent liquid helium consumption owing to electron beam heating a special copper liner connected with 20 K radiation shield is inserted inside the vacuum chamber. Also the liner is used to reduce heat flux to the helium chamber from room temperature walls of the wiggler cryostat and from storage ring parts. At the both ends of the vacuum chamber there are bellow assemblies for separating of beam vacuum chamber from insulating vacuum of the cryostat and connecting with straight section vacuum chamber. The volume between liner and helium vacuum chamber is not separated and is connected with high vacuum of electron beam. The special elliptical shape adapters are used for smooth transition from the wiggler vacuum chamber to the storage ring.

The superconducting wiggler coils are connected permanently with the current leads. Two pairs of current leads are

![Fig. 3. Load curves of used wire and operation points.](image1)

![Fig. 4. Magnetic system of CLS wiggler.](image2)

![Fig. 5. Cross-section of CLS cryostat.](image3)

![Fig. 6. Current leads block.](image4)
used for feeding the magnet with current of 800 A. These current leads with 400 A per each pair are the main source of heat in-leak into liquid helium vessel due to both heat conductivity and Joule heat. Each current lead consists of two parts: normal conducting brass cylinder and high-temperature superconducting ceramics (HTSC). The junctions of normally conducting and superconducting parts of current leads are supported at temperature 50–65 K. The lower part of a superconducting part of the current lead is connected with superconducting Nb–Ti wiggler coils and supported at temperature below 4.2 K. The both ends of HTSC current leads are attached through electrical insulator (sapphire plate) to 4 and 60 K stages of the recondensers. The temperature at contact terminals of current leads is a critical parameter. So, the HTSC current leads temperature is measured by thermal probes and involved to the wiggler interlock system. Assembled current leads block is presented in Fig. 6.

4. Conclusion

A planar-type superconducting 63-pole wiggler with short period 34 mm was successfully tested and installed on the CLS storage ring in January 2005. The maximum magnetic field 2.2 T was achieved after 7 quenches, and 2 T magnetic field level is acceptable for routine operation. Average liquid helium consumption was defined as 0.03 L h. The wiggler has been developed as a powerful synchrotron radiation source in photon energy range 4–40 KeV. In May 2005, the Hard X-ray Micro-Analysis beamline staff obtained monochromatic X-ray using radiation from the wiggler.

Reference