3.5 TESLA 49-POLE SUPERCONDUCTING WIGGLER FOR DLS

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Abstract

3.5 Tesla 49-pole superconducting wiggler with 16.4 mm magnetic gap and 60 mm period has been fabricated in Budker INP for DLS (Diamond Light Source). The maximum magnetic field, which can be generated on the central 45 poles, is 3.8 Tesla. To minimize magnetic gap the cold vacuum chamber with liquid helium temperature have been used. There is 20 K copper liner inside the vacuum chamber to prevent it of heating by electron beam. The inside cross section of copper liner is 10x80 mm. The irradiation power is 60 kW for electron beam current of 0.5 A and 1.9 GeV energy. The wiggler tests on DLS had been performed on May 2006. The main features of the wiggler design are presented in this paper.

INTRODUCTION

Superconducting 49-pole wiggler for Diamond Light Source (DLS) was designed and fabricated in Budker INP (Novosibirsk, Russia) according to technical requirements of the contract made between DLS and Budker INP in 2004. In 2006 the wiggler was successfully tested at DLS site and installed on the storage ring to improve quality of SR of light source (see Figure 1).

Figure 1: 3.5 Tesla 49-pole superconducting wiggler for Diamond Light Source.

The main goals of multipole wigglers are shift of SR spectrum to X-ray rigid area and increase of photon flux. The multipole wiggler represents magnetic system with transverse magnetic field, consisting of 49 bending magnets placed in a straight section of a storage ring. There are 45 main poles with the field amplitude of 3.5 Tesla. The wiggler is installing on straight section of the storage ring and is a magnetic element with compensated field integrals along beam trajectory. Four side poles with the field of 1/2 and 3/4 of the main pole field are used to close electron beam orbit.

Superconducting windings are made from Nb-Ti wires, which 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 main wiggler parameters are presented in Table 1.

Table 1: The main parameters of DLS wiggler

Working magnetic field	3.5 Tesla
Achieved magnetic field	3.8 Tesla
Period length	60 mm
Pole gap	16.4 mm
Number of poles:	
Main poles	45
Side poles 1/2	2
Side poles 3/4	2
Vacuum chamber (vertical)	10 mm
Vacuum chamber (horizontal)	80 mm
Magnet length	1600 mm
Electrical current in the main coils	800 A
Temperature vacuum chamber	20 K
Shield screens temperature	20, 60 K
Time between LHe refilling	6-12 months
LHe volume of the cryostat	~ 330 l
LHe consumption	~0.05 l/h
Ramping time 0-3.5 Tesla	3 min
Radiation power	60 kWatt

MAGNETIC SYSTEM

The wiggler magnetic field on the median plane is created by 90 central and 8 side coils wound over the ARMCO-iron cores. The shape of the central pole is racetrack type with dimensions of 88x16.6 mm^2 and height of 26 mm. All central coils consist of one section with total turns number of 156. Superconducting Nb-Ti wire with lacquer insulation was used to produce the wiggler coils. The parameters of the superconducting wire and coils are presented in Table 2.

Table 2: Main parameters of coils

Wire diameter with/without insulation	0.91/0.85 mm
Critical current at 7 Tesla	520 A
Number of layers in central coils	8
Number of turns in a layer	19,20
Number of turns in coil	156

Wiggler central and side 3/4 coils are energized by two independent power supplies with maximum current of 400 A. The both 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 photos of the central coils are presented in Figure 2. The windings are connected in series outside of the strong magnetic field region. Connections between all 98 coils are realized with using of low resistance superconducting technique to prevent Joule heating and liquid helium evaporation.

Figure 2: Central coil of DLS wiggler.

The load curves of the used superconducting wire are presented in Figure 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 Figure 4). The length of the magnet yoke is 1600 mm. The yoke includes two parts which 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 16.4 mm.

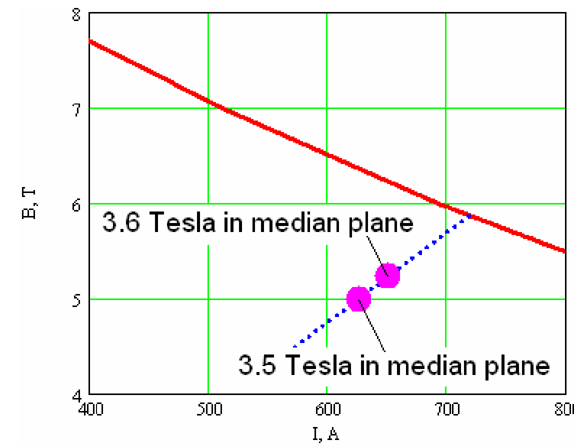

Figure 3: Load curves of used wire and operation points.

Superconducting coils of the wiggler are protected from damaging during quench by shunts with resistance of 0.2 Ohm and cold diodes.

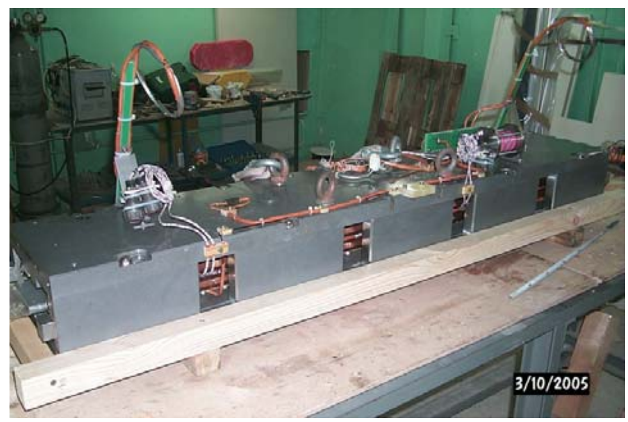

Figure 4: Magnetic system of DLS wiggler.

CRYOSTAT

The superconducting magnet is placed into a special liquid helium cryostat with working temperature of 4.2 K (see Figure 5). Inner liquid helium vessel with the magnet inside have useful volume of ~330 litters 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 K 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 (16.4 mm) doesn't 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 due to electron beam heating a special copper liner connected with 20 K radiation shield is inserted inside of 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.

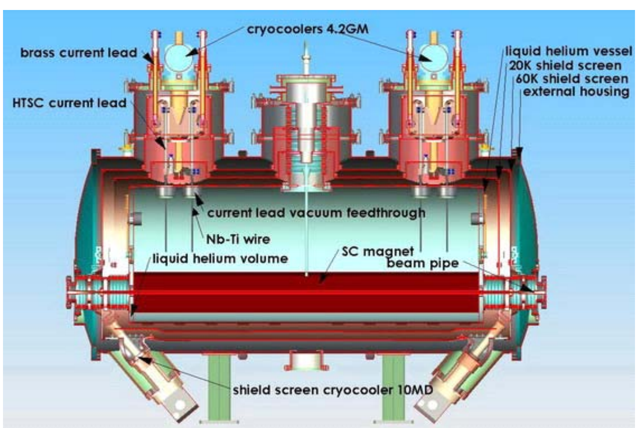

Figure 5: Cross-section of DLS cryostat.

The superconducting wiggler coils are connected permanently with the current leads. Two pairs of current leads are used for feeding the magnet with current 400A. These current leads 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 (HTSC) ceramics. 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 K and 60K 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[1]. Assembled current leads block is presented in Figure 6.

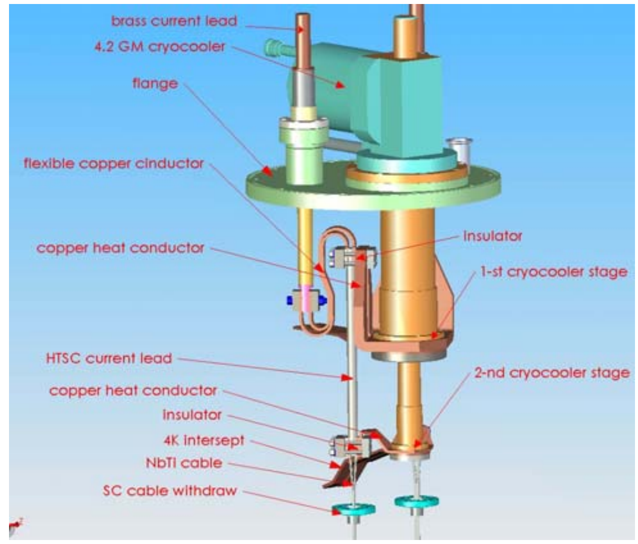

Figure 6: Current leads block.

CONCLUSIONS

Superconducting 49-pole wiggler with the period of 60 mm was successfully tested and installed on the DLS storage ring in August of 2006. The maximum magnetic field 3.8 Tesla was achieved after series of quenches and 3.5 Tesla magnetic field level is acceptable for routine work. Average liquid helium consumption was defined as 0.05 liters per hour. The wiggler has been developed as a powerful synchrotron radiation source in photon energy range 5-50 KeV.

REFERENCES

[1] E. Kuper et al., “Control system of the superconducting 63-pole 2-Tesla wiggler for Canadian Light Source”, Problems of atomic science and technology, (2006), N3, p. 157-159