A SUPERCONDUCTING 3.5 T MULTIPOLE WIGGLER FOR THE ELETTRA STORAGE RING

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Abstract

The superconducting 3.5 T wiggler was designed and fabricated for the ELETTRA storage ring (Italy) for the generation of synchrotron radiation with critical energy of 9.3 keV. The presented wiggler is a 49 pole superconducting magnet with maximum field of 3.5 Tesla inserted into a special liquid helium cryostat. The wiggler design and main parameters are presented in this article. Results of magnetic field measurements and wiggler testing in different modes of operation are discussed.

1. INTRODUCTION

The first multipole wiggler of this type with field of 3.5 Tesla and 9 cm period was fabricated and tested in Budker INP in 1979 for the VEPP-3 storage ring [1,2]. The present wiggler magnet consists of 45 full field poles with maximum field of 3.5 Tesla and 4 side poles to match the orbit. The first magnetic field integral along the wiggler can be adjusted using two power supplies. It can be set to zero at any field level. The pole gap is equal to 16.5 mm and the beam duct consists of a copper liner at 20 K and an internal vertical aperture of 10.7 mm which is surrounded by a stainless steel vacuum chamber that is part of liquid helium vessel. The main parameters of the wiggler are listed in Table 1.

Table 1: Main parameters of wiggler.

Maximum field on beam axis:	
Central 45 poles (T)	3.5
Side 2-nd and 48-s poles (T)	2.8
Side 1-st and 49-s poles (T)	1.0
Pole gap (mm)	16.5
Period length (mm)	64
Stored energy (kJ)	240
Total weight of cooled parts (Kg)	1000
Working temperature (K)	4.2
Crytical photon energy at 2 GeV (keV)	9.3
Total radiated power at 2 GeV, 100 mA (kW)	4.6

2. WIGGLER MAGNETIC SYSTEM

The wiggler magnetic field is produced by 98 NbTi coils assembled symmetrically above and below the vacuum chamber. The general view of the magnet is shown in Fig.1.

The main goal of the wiggler design was to obtain a magnetic field of 3.5 Tesla while keeping the period of the magnet structure as short as possible. The wiggler period is 64 mm. The shape of the central pole is elliptical with axes 140 mm and 7 mm. The 45 central coils consist of two different sections which are wound one over another. Each section is energised by different currents in order to obtain the optimal field-current characteristics of 90% of short sample limit of the used superconducting wire. Two independent power supplies feed the wiggler coils. The first power supply with a current of 196 A at a field level of 3.5 T feeds both the inner and the outer sections. The second one with the current of 261 A (for 3.5 T) is used only for outer sections.

Each superconducting section of the wiggler is protected by shunts with a resistance of 0.1 Ohm and cold diodes to prevent the coils from damage during a quench.

The ARMCO iron yoke is used to return the magnetic flux and to support the coils. The length of the magnet iron yoke is 1700 mm. The upper and lower wiggler halves are supported by non-magnetic stainless steel slabs located symmetrically between the halves. Additional iron plates between the upper and lower halves of the iron yoke are used to close the stray magnetic flux. The iron yoke is not saturated and provides very low level of stray field (several Gauss nearby the cryostat).

The coils are pre-stressed by a special bandaging system, consisting of 8 longitudinal bronze screwed rods. The pre-stressing is used to avoid movement of the wire forming the coils under the action of magnetic field and protects the wiggler from untimely quenches. This system allowed us to reach the maximum magnetic field of 3.57T after 5 quenches.

3. CRYOSTAT

The wiggler is inserted into a special liquid helium cryostat. The drawing of the cryostat is shown in Fig.2. The inner liquid helium vessel is surrounded by two copper screens to reduce the heat flux from outside. The screens with temperatures of 60 K and 20 K are cooled by two-stage cooling machines with a total cooling power on each stages of 330 and 30 Watt respectively.

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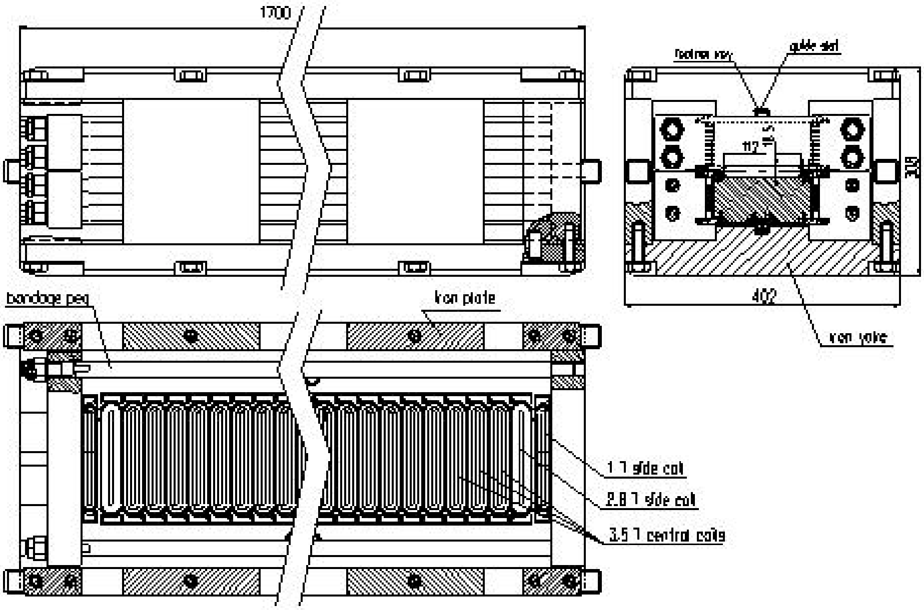

Fig.1 : General view of the magnet.

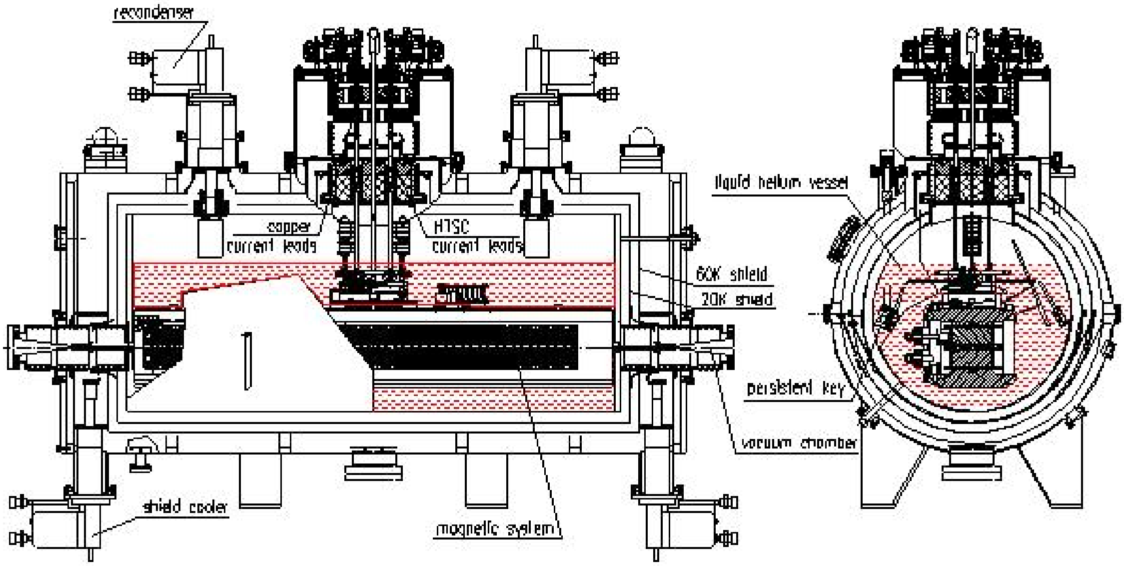

Fig.2 : Assembled cryostat with the magnet

Vacuum insulation with a value of 10^{-7} Torr is located between the helium vessel and an external room temperature stainless steel housing. This insulating vacuum of the cryostat is independent and completely separated from the vacuum system of the storage ring.

Special kevlar suspensions are used for supporting of the helium vessel and the screens in order to minimise heat in-leakage. The space between the helium vessel, the screens and the room temperature external housing are filled with many layers of aluminised Mylar insulation. To decrease heat flow into the helium vessel two pairs of high temperature superconducting ceramic current leads connected to the optimised copper current leads are used to energise the magnet coils. Heat flux flowing along the current leads from the upper flange due to thermal conductivity is removed by connecting the copper current leads to the cooler stages through the special ceramic contact. After energising, the magnet coils are closed by persistent current superconducting switches and the wiggler is set into "persistent current" operation mode. The copper current leads are then disconnected to reduce liquid helium consumption. In this operation mode the liquid helium refilling should be carried out 1 time per month.

To compensate the current decay in the "persistent current" mode the magnetic field is stabilised with an accuracy of 10^{-5} by a feedback system using current probes and special transformers called magnetic flux pumps. In order to keep the current decay as small as possible a special welding technique was developed to decreasing the contact resistance between the superconducting coils down to 10^{-11} Ohm.

4. WIGGLER MAGNETIC FIELD

The calculation of the magnetic field was made with the MERMAID code developed at BINP (see Ref. [3]). The magnetic measurements were made in a bath cryostat and in the wiggler cryostat. For magnetic measurements in the wiggler cryostat a special scanning ante-chamber system was fabricated. This ante-chamber is a metallic tube with a diameter of 8 mm and length of 2.5 m inserted into the wiggler vacuum chamber. Inside of this tube a Hall probe can be moved in longitudinal direction. The tube can also move in the transverse directions to provide magnetic field maps. The calculated and measured longitudinal distributions of vertical component of the magnetic field are shown in Fig.3.

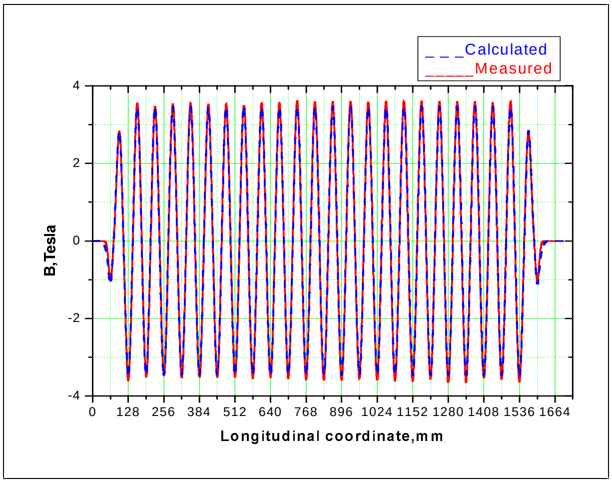

Fig.3. Computed and measured longitudinal distribution of the vertical magnetic field.

The remanent magnetic field after slowly decreasing the current to zero and after a quench are shown in Fig.4 and Fig.5 respectively. Zero integral current relationship for different field levels is shown in Fig.6 and has been obtained by using the stretched wire method.

5. CONCLUSION

Superconducting multipole wiggler was designed, fabricated and tested in its own cryostat. The results of these preliminary tests show good agreement between designed and real parameters. Following final functional tests and detailed magnetic measurements, the wiggler should be installed in the ELETTRA ring by the end of 2002.

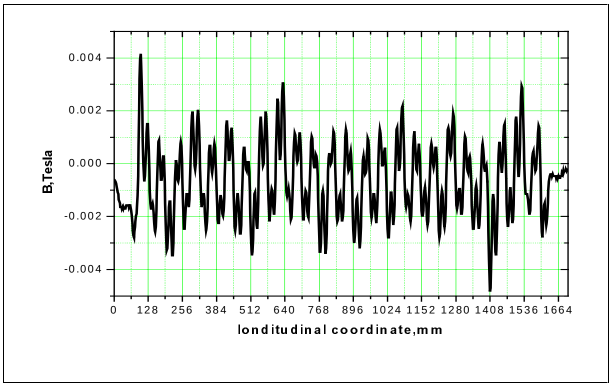

Fig.4: Remanent magnetic field in the wiggler after slow decreasing of currents to zero

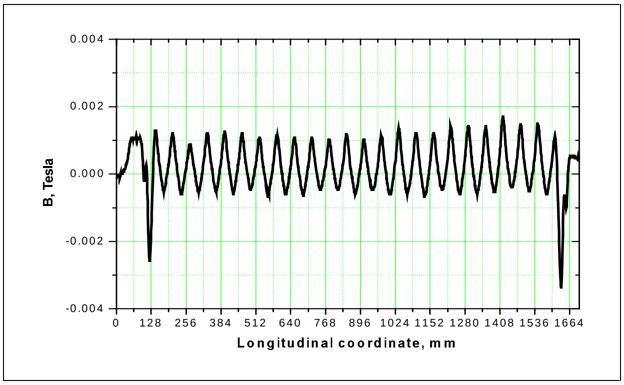

Fig.5. Remanent magnetic field in the wiggler after quenching

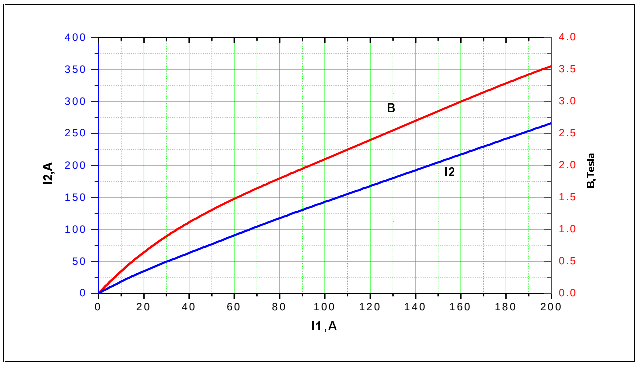

Fig.6: Currents relationship for different field level corresponding to zero first field integral.

6 REFERENCES

[1] A.Dubrovin, E.Simonov, Computer Code for Magnetic Field Computation preprint (Budker INP, 1993).

[2] A.S.Artamonov et al. First results on the work with a superconducting 'snake' at the VEPP-3 storage ring. NIM, 1980, V.177, N 1, P.239-246

[3] A.Dubrovin, E.Simonov, Computer Code for Magnetic Field Computation preprint (Budker INP, 1993).