SUPERCONDUCTING 16-POLE WIGGLER FOR BEIJING ELECTRON-POSITRON COLLIDER II

Minxian Li, Xiaojuan Bian, Fusan Chen, Wan Chen, Xianjing Sun, Haijing Wang, Jianli Wang, Miaofu Xu, Na Wang, Xiangchen Yang, IHEP, [100049] Beijing, China

Abstract

A superconducting 16-pole 2.6T wiggler with period 170mm of The High-Energy Photon Source and the Test Facility Project (HEPS-TF) designed and fabricating in the Institute of High Energy Physics (IHEP) in China is described. This wiggler will be installed in Beijing Electron-Positron Collider II (BEPCII). The main parameters and structure of the wiggler are presented. Besides, some vertical testing results are involved.

INTRODUCTION

A superconducting 16-pole 2.6T wiggler of The High-Energy Photon Source and the Test Facility Project (HEPS-TF) designed and fabricating in the Institute of High Energy Physics (IHEP) in China. This work will provide effective verification for the high energy monochromator. Meanwhile, the wiggler planned to replace the 3W1 permanent magnet of Beijing Electron-Positron Collider II (BEPCII), which will improve quality of synchrotron spectrum for users of BEPCII.

Until the submission of this paper, the fabrication of the magnet has been completed, and assembly of the cryostat, the magnet and beam chamber etc. will be carried out soon. In addition，vertical testing of the superconducting magnet has been finished, and the maximum peak field strength is 2.6T at an excitation current of 345A.

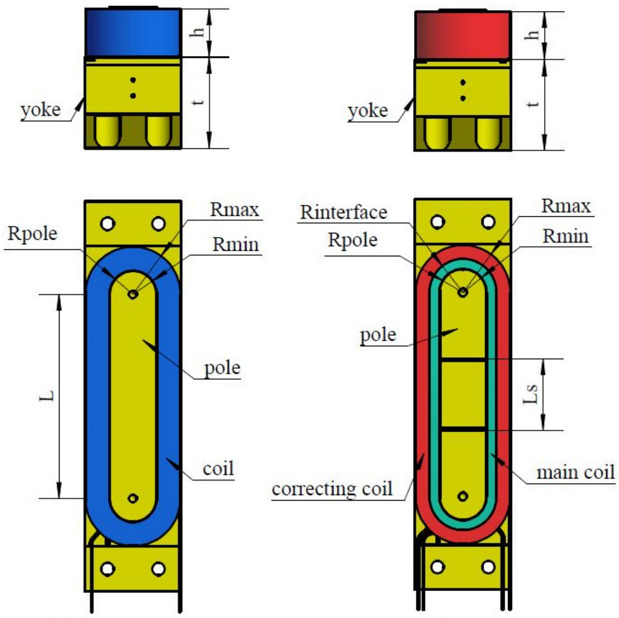
CONSTRUCTION AND PERFORMANCE OF THE WIGGLER

Design and construction of magnet

The superconducting 3W1 wiggler consists of 14 central poles and 2 side poles. The period length of the wiggler is 170 mm, the longitudinal length is 1430 mm. And the gap between up and down magnetic array which maintained by two support plates of stainless steel is 68mm. Table 1 lists the main parameters of the wiggler.

Table 1: The Main Parameters of Superconducting 3W1 Wiggler

Item	parameters
period length	170mm
Number of period	16
Pole gap	68mm
Magnet length	1430mm
Vacuum chamber (vertical)	39mm
Vacuum chamber (horizontal)	108mm
Maximum peak field	2.6T



(a) Central pole (b) Side pole

Figure 1: Schematic drawing of design coil, pole and yoke.

The wiggler magnetic field on the median plane is created by 28 central coils and 4 side coils. Each racetrack coil wound over the DT4 iron core with a continuous superconducting wire. Then the vacuum casting of the

Table 2: Principle Parameters That Govern the Design and Construction of the Magnet

Item	Central poles	Side poles
Number of turn	768	320+448
Total layer	24	10(main)+ 14(correcting)
Design current,I_0	400 A	400A(main)+ 20A(correcting)
L	180mm	180mm
Rmax	42 mm	41.87 mm
Rinterface	-----	29.62 mm
Rmin	21 mm	20.87 mm
Rpole	20.5 mm	20.37 mm
h	42 mm	
t	80 mm	
L_S	-----	63mm

coils on iron cores following the winding. Figure 1 shows the structures of the coil, pole and yoke of central poles and side poles. The total turn number of all central coils is 768 (see Table 2). The side coil composed of two parts: main coil and correcting coil, and the turn number of the main coil and the correcting coil is 320 and 448, respectively. Superconducting Nb-Ti wire with 1.28×0.83 mm^2 including of lacquer insulation was used to produce the wiggler coils. Specifications of superconducting wire in magnet indicate in Table 3.

Table 3: Specifications of Superconducting Wire in Magnet

Item	**Result**
Cu/SC ratio	1.3
Bare dimensions	1.20×0.75mm^2
Dimensions including insulation	1.28×0.83mm^2
Peak field at 604A&408A	7T&8T

The central coils and the main coils of the side poles are connected in series and energized by a power supply with maximum current of 400 A. Furthermore, two correcting coils of one side pole series connected, and four correcting coils are energized by two independent power supplies of 20 A. The joints of the superconducting wires are welded and fixed on an insulative sheet.

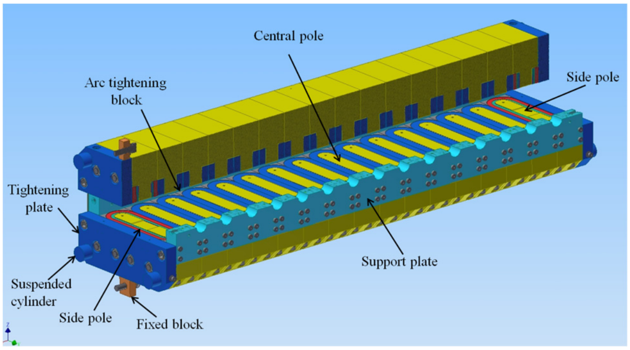


Figure 2: 3D structure of the 3W1 superconducting magnet.

Figure 2 shows the structure of the 3W1 superconducting magnet. Up and down magnetic array separated by two support plates of 316L stainless steel. The magnetic array impacted with four tightening plates and 32 arc tightening blocks in longitudinal direction and transverse direction, respectively. Therefore, the pre-tightening force applied on the coils. This magnet will working in the temperature of 4.2 K. The most conservative design would be to immerse the magnet in a bath of liquid helium [1]. The magnet designed to hang on two face flanges of liquid helium vessel though 8 suspended cylinders, and fixed with two fixed blocks on one flange.

Design and construction of beam chamber

Figure 3 shows the cross-section of the designed aperture of beam chamber, the duct of 60 K shield screen (60 K duct) and the duct of 4.2 K liquid helium vessel (4.2 K duct). The beam chamber of 316L stainless steel is operated in room temperature. Moreover, the aperture of one flange of the beam chamber is ellipse, but the other one is octagon. The 4.2 K duct is outside the 60 K duct, and the beam chamber is inside the 60K duct. The distance of the chamber and the 60 K duct is 2 mm. Besides, six G10 bumpers on the top of the chamber prevent the 60 K duct touching the chamber [2]. The two ducts and the chamber above-mentioned located in the 68 mm pole gap. So the design and fabrication of the two ducts and the beam chamber is a challenge work as the space constraining.

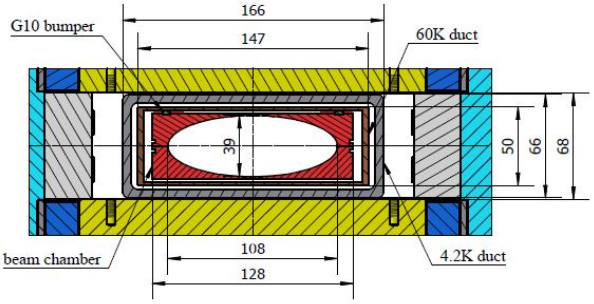


Figure 3: Cross-section of the beam chamber, 60 K duct and 4.2 K duct (unit: mm).

In consideration of beam power loss caused by resistive wall impedance of the beam chamber, the average beam power loss has been calculated as Table 4 presents. The beam power loss is 43 W under the conditions (I=910 mA, number of bunches =93, bunches length =15 mm) [3]. However, the beam power loss after copper plating is reduce to 6.4 W (bunches length =15 mm). Figure 4 shows the variation of the beam power loss with thickness of copper plating, the conclusion can be got that the surface effect depth of the copper is 1.2 um. Considering the processing technology, 10 um is selected for the thickness of copper plating for both internal and external surface of the beam chamber.

Table 4: The Beam Chamber Calculation Result of Beam Power Loss Caused by Resistive Wall Impedance

Material	**SUS 316L**	**Cu**
Power loss [W] (bunches length =15 mm)	43	6.4
Power loss [W] (bunches length =12 mm)	59.5	9.0

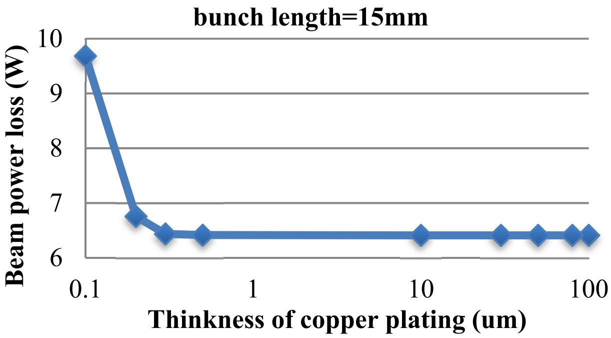


Figure 4: Variation of the beam power loss with thickness of copper plating.

Construction of Cryostat

Reliability and maintainability are the key requirements of a cryogenic system. The superconducting magnet is placed into a cryostat with working temperature of 4.2 K. The three-dimensional overall structure of the wiggler is presented in Fig.5. The cryostat consists of 4.2 K liquid helium vessel, 60K shield screen and external vacuum housing from inside to outside. The magnet is immersed in a bath of liquid helium. Furthermore, it hangs on two face flanges of the liquid helium vessel though 8 suspended cylinders, and fixed on one flange with two fixed blocks. Contraction in cryogenic environment is allowed at the other end of the magnet. The 4.2 K liquid helium vessel is hanged with eight carbon fibre rods connected to the external vacuum housing. In addition, the rods pass throughout the both shield screen and vacuum housing walls. The 60K shield screen can reduce the irradiation heat flux from outside [4]. Besides，the cryostat is equipped with four refrigerators, two on the top and the others at the bottom [5].

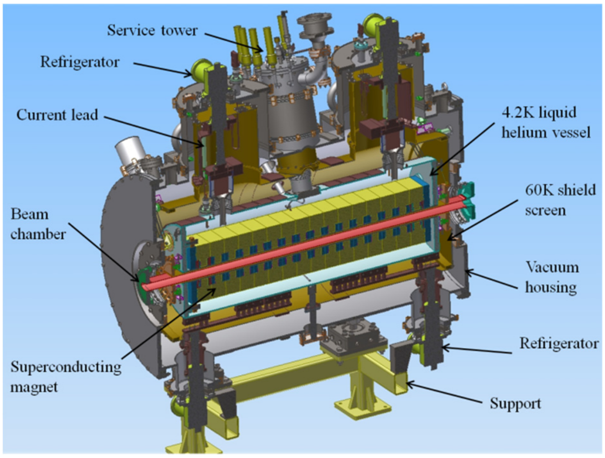


Figure 5: Overall 3D structure of superconducting wiggler, including the magnet, beam chamber, cryostat, current leads, service tower, etc.

MAGNET VERTICAL TESTING

The vertical testing of 16-pole superconducting magnet in Dewar has been finished in April 15th, 2018.

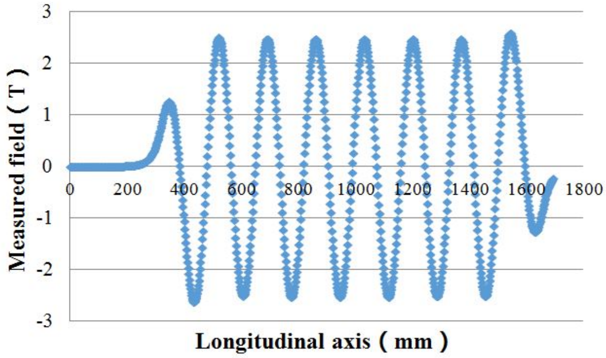


Figure 6: Measured magnetic field in longitudinal direction.

Before that, every pole has been trained and tested in several batches. In the vertical testing, the maximum quenching current of 350A reached after 17 quenches. Additionally, the measurement of the magnetic field is consistent with the simulation of the magnetic field. Figure 6 presents that the maximum peak field of the magnet is 2.6 Tesla at an excitation current of 345 A.

CONCLUSION

16-pole superconducting wiggler has been designed and fabricating in IHEP, and the assembly of the cryostat, the magnet and the beam chamber etc. will be carried out soon. In addition, the maximum peak field strength of the magnet is 2.6 T at 345 A in the vertical testing, and the measurement of the magnetic field is consistent with the simulation of the magnetic field. After the assembly and horizontal testing, the superconducting wiggler will be installed to enhance the storage ring performance of BEPCII during the next shutdown period.

REFERENCES

[1] C. H. Chang *et al.*, “In-achromatic superconducting wiggler in Taiwan Light Source：installation and test results”, *in Proc. EPAC’06*, Edinburgh, Scotland, 2006.

[2] C.-S. Hwang *et al.*, “Superconducting wiggler with semi-cold beam duct at Taiwan light source”, *Nuclear Instruments & Method in Physics Research A*, vol. 556, 2006, pp. 607-615.

[3] Alexander Wu Chao, Maury Tigner. “Impedances and wake functions”, in *Hand book of accelerator physics and engineering*, Singapore, New Jersey, London, Hong Kong: World Scientific, 1998, pp. 194-212.

[4] S. V. Khruschev *et al.*, “Superconducting 63-pole 2T wiggler for Canadian Light Source”, *Nuclear Instruments & Method in Physics Research A*, vol. 575, 2007, pp. 38-41.

[5] Miaofu Xu *et al.*, “Design and research of cryostat for 3W1 superconducting wiggler magnet”, *IEEE Transactions on applied superconductivity,* vol. 28, 2018.