DESIGN OF AN IN ACHROMATIC SUPERCONDUCTING WIGGLER AT NSRRC

C. H. Chang[#], C. S. Hwang, H. H. Chen, T. C. Fan, M. H. Huang, F. Y. Lin and G. Y. Hsiung,
NSRRC, Taiwan

Abstract

A 15-pole superconducting wiggler with period length of 6.1 cm is designed for National Synchrotron Research Center (NSRRC) in Taiwan. The compact superconducting wiggler will be installed near the second bending magnet of the triple bend achromatic section in the 1.5 GeV storage ring. This wiggler magnet with maximum peak field of 3.1 T at pole gap width of 19 mm is operated in 4.2 K liquid helium vessel. A 5-pole prototype magnet is tested and measured to verify the magnetic field performance in the testing dewar. The cryogenic considerations and thermal analysis in the wiggler magnet and the 77 K cold bore beam vacuum chamber are also presented in this work.

INTRODUCTION

The Taiwan light source is a 1.5 GeV energy synchrotron radiation source optimized to produce soft X-rays. Recently, the increasing demands for high fluxes of X-rays are growing at NSRRC. Superconducting wigglers are used to expand the spectrum of photons into the harder X-ray range and promote the flux by a factor of ten at 10 - 20 KeV photon energies.[1,2] Currently, a 5 T superconducting wavelength shifter was installed between the two kicker magnets in the injection section and a 3.2 T superconducting wiggler was installed in downstream of the RF cavities section. [3,4,5] All long straight sections are already occupied. The possibility of installing short insertion devices into achromatic sections of the machine lattice has been studied to increase the number of insertion devices in the storage ring.

An in achromatic superconducting wiggler (IASW) with a maximum length of 1 m is design and will be installed near the second bending magnet of the triple bend achromatic section in the storage ring, as shown in Fig. 1, because space between the bending magnets is limited. These in achromatic wigglers are not responsible the main elements of the electrons circulation in the storage ring. The advantage is not to reduce the reliability of the machine. A 15-pole compact superconducting wiggler with a periodic length of 6.1 cm is designed to generate a maximum peak field of 3.1 T at a pole gap width of 19 mm in the 4.2 K liquid helium vessel. Table 1 lists the main parameters of IASW6 wiggler.

Table 1: Main parameters of the IASW6 wiggler magnet

Magnetic period	61 mm
Pole gap width	19 mm
Vertical aperture	11 mm
Horizontal aperture	98 mm
Total length of magnetic assemblies	500 mm
Number of full size poles	13
Total number of poles	15
Total length of wiggler	960 mm
Peak field	3.1 T
K, deflection parameter	17.7
Beam chamber temperature	90 K
LHe boiling off	2 l/h

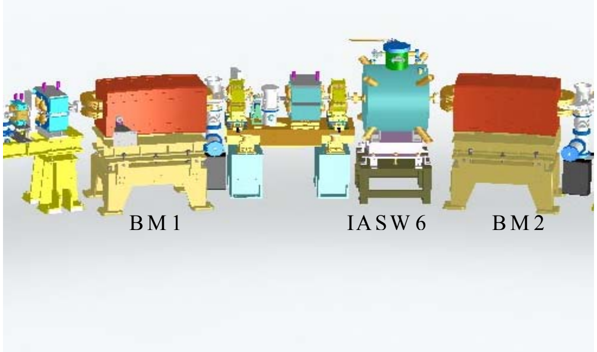

Figure 1 Schematic view of the IASW6 wiggler is be installed near the second bending magnet of the triple bend achromatic section in the storage ring.

SUPERCONDUCTING MAGNETIC DESIGN

The superconducting wiggler is designed to generate the maximum magnetic field strength of 3.1 T with periodic length of 6.1 cm in a gap width of 19 mm. Fig. 2 shows a cross sectional view of the wiggler magnet. In the 74 mm high aluminum mole, one can see the 25 mm high gap for return yoke and the rectangular 30 mm high coil cross sections of the conductors. Each Superconducting racetrack coil consists of 473 turns of windings by using the NbTi superconducting wire with 0.64 mm diameter. At the maximum field strength of 3.1 T of the soft iron of the pole plates and the yoke near the superconducting coils are fully saturated. The vertical height of the yoke is large enough not to be saturated at outside boundaries. The magnetic field strength inside of the superconducting coil cross section varies considerably. There is a clearance of 0.1 mm between the pole and the coil to prevent the maximum field close to the quench limit on the coil, whereas the radius of coil reaches values as high as 6.38 T.

---

*This work was supported by the National Science Council of Taiwan under Contract No. NSC 92-2213-E-213-001
[#] chang@nsrrc.org.tw

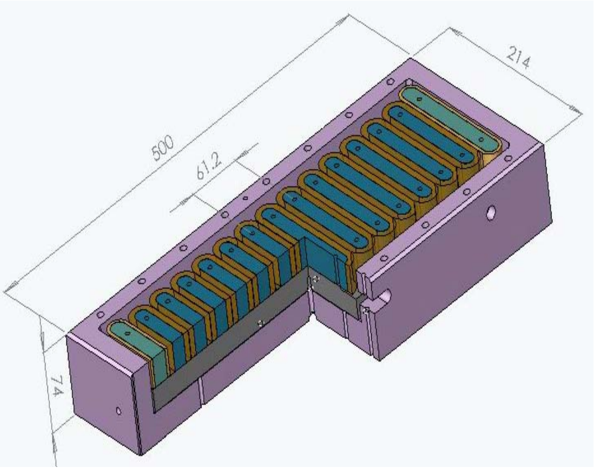

Figure 2 The cross sectional view of the wiggler magnet.

The quench current of a superconductor depends critically on the magnetic field strength at that conductor. The conductor for the wiggler coils is k55/1.3/60 wire type with an equivalent diameter of 0.6 mm with NbTi filaments of 53 um and a Cu to NbTi ratio of 1.3:0. At a temperature of 4.2 K quench are 299 A at B=5 T, 245A at B=6T. The current density in each coil was calculated to obtain optimal field current characteristics. The currents in the end coils should be adjusted such that the integrated field value over the whole wiggler is zero. [7]

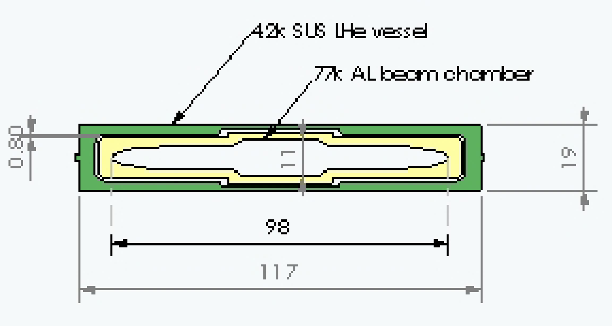

Figure 3 Schematic view depicts the 77 K beam vacuum chamber and the 4.2 K liquid helium vessel.

The one meter long wiggler assembly will be in a liquid helium vessel. The wiggler is 500 mm long, 214 mm wide, and 167 mm high with a vertical gap width of 19 mm which accommodates a vacuum chamber with horizontal and vertical apertures of 98 mm and 11 mm. The "cold" wiggler vacuum chamber will have vertical outside dimensions of 17 mm and inside apertures of 11 mm total. It is to install scrapers in front of the wiggler chamber to prevent beam particles from hitting the chamber walls. In the wiggler the electron beam will change horizontally. Irradiation from IASW6 and the bending magnet hits the vacuum chamber downstream. This make it necessary to have a wiggler vacuum chamber with an inside width of at least 98mm, such that irradiations from IASW6 and bending magnet cannot hits its cold walls at end of the wiggler. An aluminum vacuum chamber with 2 mm thickness was designed for guiding the electron beam. The beam duct chamber was intercepted with liquid nitrogen to reduce the heat load. However, a critical clearance 0.8 mm leaves between the 4.2 K vessel and the 77 K beam duct for thermal shielding. Cryogenic considerations are incorporated into the thermal analysis of the wiggler magnet and the 77 K cold bore vacuum chamber. Figure 4 presents the front view of vacuum chamber and magnetic structure in the cryostat. Moreover, the stainless liquid helium vessel yields a maximum stress of 210 Mpa and maximum deformation of 0.5 mm at the center of the vessel in a 3 atm pressure difference.

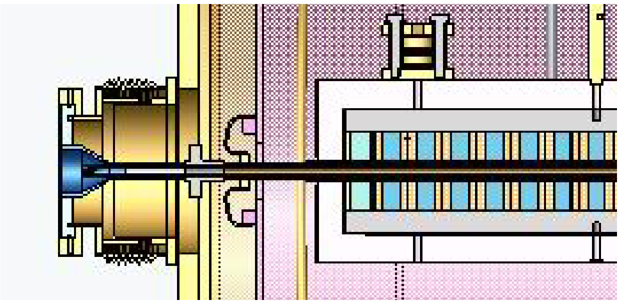

Figure 4 The front view of vacuum chamber and magnetic structure in the cryostat of IASW6 magnet.

CONSTRUCTION AND TESTING OF PROTOTYPE

The IASW6 wigglers are in house construction magnets as shown in figure 7. A coil-winding machine and winding fixtures are designed to produce continuous 15-pole coils in series for reducing the superconducting winding joints. A prototype of wiggler with five-pole was fabricated to examine the mechanical and magnetic field performances. The use of Vanadium-Permendure pole makes it possible to produce higher field than the iron pole. After winding, 5 winding coils were assembled with the iron return yoke in an aluminum mold. Each of the pole assemblies was accurately pinned by two dowel pins on the base plate to ensure the periodicity. Consequently, flatness of all poles within 20 microns on base plate was measured. The superconducting coils were impregnated with epoxy to glue the coil and cured at higher temperature of 50^{o} C in exactly aluminum molds. The compress forces from aluminum mold against to both end coils after the magnet cooling down. Compress force clamps at the ends will restrict coil motion in the beam direction. It is important that all restraining forces will be such as to prevent any appreciable coil motion, otherwise quenches may occur and training may become necessary.

A five-pole prototype magnet is tested and measured by using the Hall probe to confirmed its magnetic field performance in the vertical test dewar. A pair of R620 cold diodes is connected across the five coils to form the quench protection circuit. After many times of coils training and quench process, the magnetic field strengths were measured to achieve the maximum field of

3.2 T at excitation current of 270 A. Figure 5 reveals the measured magnetic field strength as a function of excitation current. Figure 6 plots the vertical field strength on-axis in the longitudinal direction. The magnetic structure design and field performance were confirmed by constructing five-pole prototype.

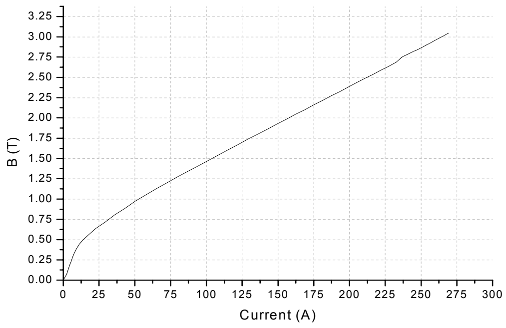

Figure 5 Measured magnetic field strength as a function of excitation current.

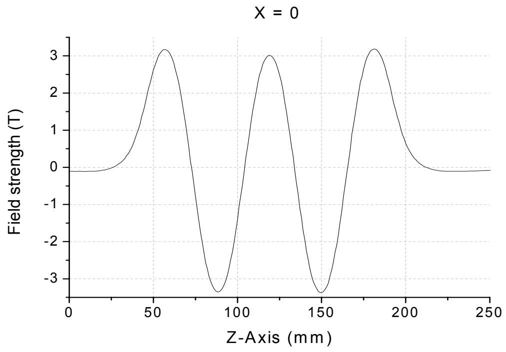

Figure 6 The on-axis vertical field strength was measured in the longitudinal direction.

CONCLUSIONS

The 3.1 T in achromatic superconducting wiggler with 19 mm gap width is being built in house at NSRRC. A prototype magnet with five-pole has been tested to verify its magnetic field performance in the vertical test dewar. The central field of 3.2 T is achieved at excitation current of 270 A. In the near future, three more superconducting wigglers will be built and installed in the storage ring. These superconducting wigglers will enhance the performance of the 1.5 GeV energy storage ring and provide more the hard x-ray photon beams for synchrotron radiation experiments.

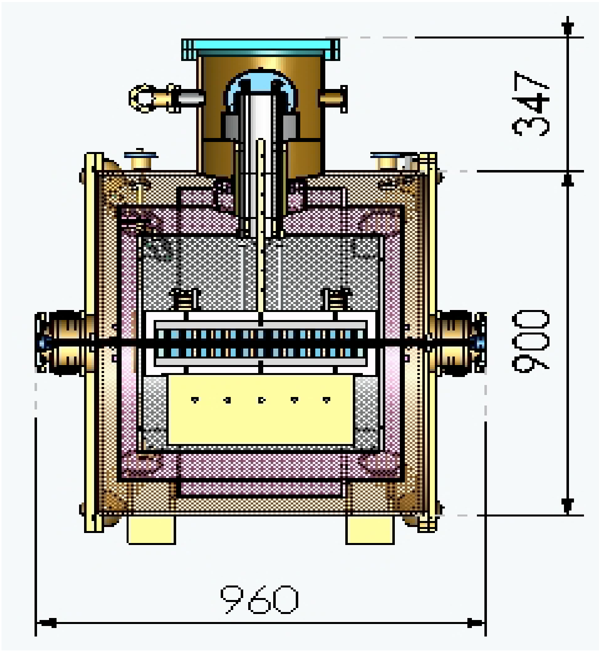

Figure 7 The IASW-6 wiggler magnet

REFERENCES

[1] C. S. Hwang, et al., "Superconducting insertion devices for synchrotron hard x-ray at SRRC", in Proceeding of EPAC2002, pp.2613-2615.

[2] E. Wallen, G. LeBlanc, M. Eriksson, "The MAX-wiggler, a cold bore superconducting wiggler with 47 3.5 T poles", Nucl. Instrum. Meth. A 467, pp. 118-120, 2001

[3] C. S. Hwang, et al.,"Design of a Superconducting Multipole Wiggler for Synchrotron Radiation"IEEE Trans. On Appl. Supercon. Vol. No. 2 2003

[4] T. C. Fan., et., "Magnetic field measurement on superconducting multipole wiggler with narrow duct" Orgen USA, May 12-16, PAC 2003.

[5] C. S. Hwang, et al., "Construction and Performance of a Superconducting multipole wiggler" pp 199-202, CP705, 2004 AIP

[6] C. S. Hwang, et al., "Design Concept of Superconducting Multipole Wiggler with Variably Polarized X-ray" Synchrotron Radiation Instrumentation: Eigth International Conference, 2004 pp195-198

[7] O. chubar, P. Elleaume, J. chavanne, "A 3-Magnetostatics Computer Code for InsertionDevices" J. Synchrotron Rad. (1998), 5, 481-484