SUPERCONDUCTING 63-POLE 2 TESLA WIGGLER FOR CANADIAN LIGHT SOURCE

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A superconducting 63-pole wiggler with the average period 34 mm designed and fabricated at the Institute of Nuclear Physics in Novosibirsk for Synchrotron Radiation Center (CLS) in Canada is described. The maximum field 2.2 Tesla in the median plane has been achieved. The liquid helium consumption less than 0.03 liters per hour in operating mode has been reached. In January 2005, the wiggler was installed in the storage ring in CLS and now experiments are already underway. The main parameters of the magnet and the cryogenic systems as well as test results are presented.

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1. INTRODUCTION

The superconducting 63-pole wiggler (SCW) for CLS was designed and fabricated at Budker INP (Novosibirsk, Russia) according to technical requirements of the contract made between University of Saskatchewan (Canada) and Budker INP in 2003. In 2005 the wiggler was successfully tested at CLS site and installed on the storage ring (see Fig.1). The wiggler represents a magnetic system with a transverse magnetic field, consisting of 63 bending magnets with the field amplitude of 2 Tesla. Superconducting windings are made of Cu/Nb-Ti wires, which are placed inside a liquid helium vessel at a temperature 4.2 K during normal operation. The wiggler cryostat has four compact coolers used for cooling of shield screens and to prevent heat in-leaks into the liquid helium vessel. During normal operation of the wiggler, the liquid helium consumption is close to zero. The wiggler has been developed as a powerful synchrotron radiation source in photon energy range 4…40 keV for the experimental micro-XAFS beamline.

2. WIGGLER MAGNET SYSTEM

A superconducting NbTi wire with lacquer insulation was used to produce the wiggler coils. The parameters of the superconducting wire are represented in Table 1.

***Table 1**. Wire parameters*

Wire diameter with/without insulation, mm	0.91/0.85
Ratio of NbTi : Cu	1.4
Number of filaments	312
Critical current at 7 Tesla(Amp)	510…550

The magnetic field on the wiggler median plane is created by 122 central and 4 side coils wound over the ARMCO-iron cores. The shape of the central pole is racetrack type with dimensions of 88×16.6 mm^2 and height of 23.85 mm. The central coils are fed by two independent power supplies with maximum current 400 A each where currents are summarized. Additional 4 side coils are fed by one power supply giving a possibility to adjust the first field integral to zero. The photos of the coils are presented in Fig.2.

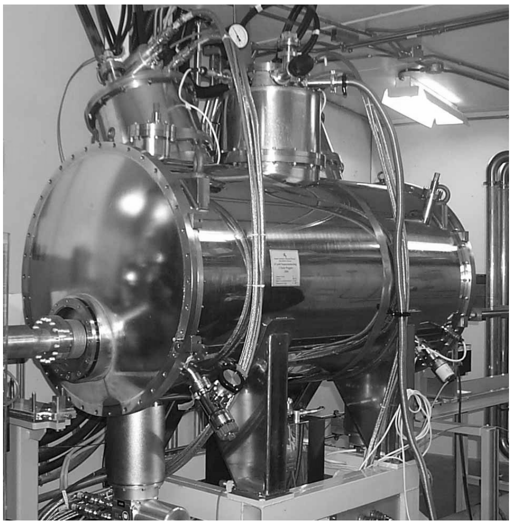

Fig.1. 2 Tesla 63-pole superconducting wiggler for Canadian Light Source

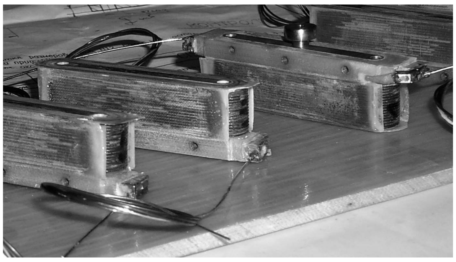

Fig.2. Photo of the magnet coils

The ARMCO-iron yoke is used to reverse the magnetic flux and to support the coils (see Fig.3). The length of the magnet yoke is 1120 mm. The yoke includes two parts which are placed symmetrically above and below the median plane of the wiggler. The upper and the lower wiggler parts are supported by a non-magnetic stainless steel slab located symmetrically between the halves. The additional iron plates between the upper and lower halves are used to close the stray magnetic flux. There are several technological facilities for orientation and alignment of the coils on the yoke. Block of the coils is pressed so that the coils are oriented perpendicular to the longitudinal axis of the wiggler. The dimension of the vertical magnetic gap between the coils is equal to 13.5 mm.

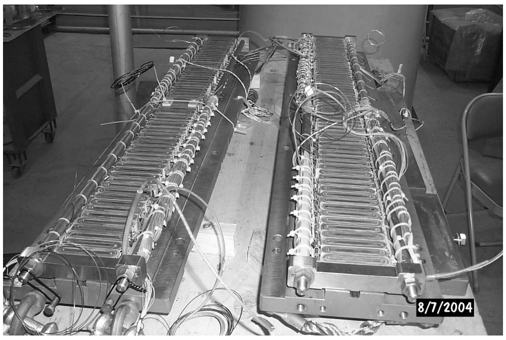

Fig.3. Two assembled halves of the CLS wiggler

Training of the wiggler coils by quenches was carried out during the wiggler test. Magnetic field of 2.2 Tesla in the median plane was achieved after 7 quenches. The quench history is shown in Fig.4. The further magnet training was stopped due to power supplies saturation.

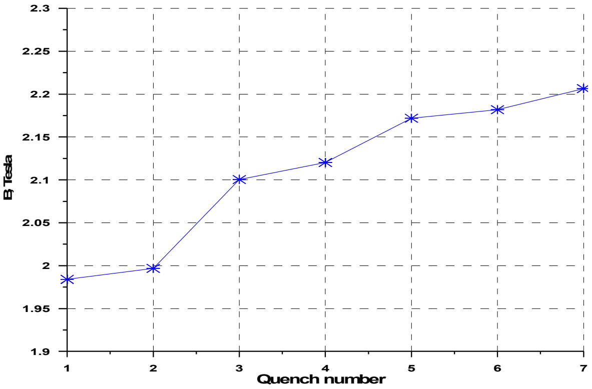

Fig.4. Quench history of wiggler magnet inside bath cryostat

3. WIGGLER CRYOGENIC SYSTEM

3.1. CRYOSTAT

The cryogenic system consists of external housing, 60 K shield, 20 K shield, liquid helium vessel, throat, vacuum chamber with copper liner, upper flange, filling tube, 2 Leybold 4.2GM One Watt System coolers, 2 shield Leybold Coolpack 10MD coolers and ion pump (see Fig.5). The SCW magnet is placed into a special liquid helium vessel having operational volume of 330 liters of liquid helium.

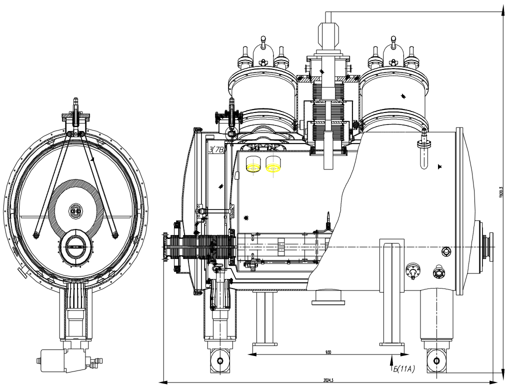

Fig.5. General view of CLS wiggler cryostat with magnet inside

To reduce the irradiation heat flux from the outside, two shield screens surround the inner liquid helium vessel. The temperature at the outside shield screen is about 50 K, at the inner one is 20 K. There is a vacuum insulation between the helium vessel and the 20 K screen as well as between the both screens and 50 K shield and an external warm stainless steel vessel to reduce the heat flux. The walls of the helium vessel face flanges with special stainless steel projections of the SCW body support the SCW magnet. The helium vessel is hanged with four kevlar strips connected to the external cryostat vessel. These strips pass through the external vessel walls and used for precise alignment of the magnet position.

3.2. CURRENT LEADS BLOCK

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 the 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. One pair of current leads is assembled into one block together with 2-stage cooler 4.2GM (Fig.6) which is placed into the insulating vacuum of the cryostat.

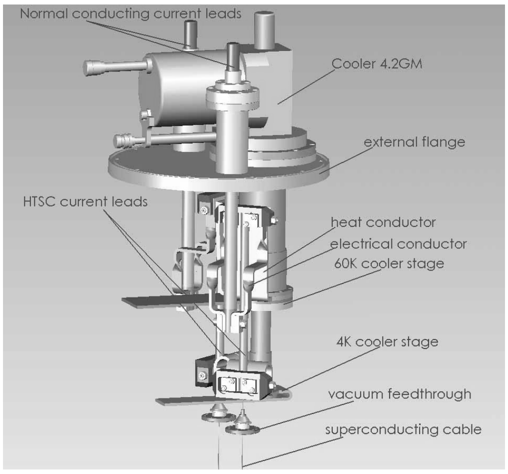

Fig.6. Assembling of current leads with cooler

The junctions of normally conducting and superconducting parts of current leads are supported at a temperature 50…65 K. The lower part of a superconducting part of the current lead is connected with a superconducting Nb-Ti cable and supported at a temperature below 4.2 K. Power of the 2nd stage of the coolers is approximately twice more than heat in-leak power at lower end of superconducting current leads and the rest cooler power is used for cooling the liquid helium vessel.

3.3. COPPER LINER

The wiggler vacuum chamber for an electron beam is a part of the liquid helium vessel and has a temperature of 4.2 K. To prevent the liquid helium consumption due to the electron beam heating, a copper liner is inserted to the vacuum chamber which is supported at a temperature of 20 K with the help of 2 Coolpack 10MD coolers and which determines the aperture of the electron beam.

4. INSULATING VACUUM SYSTEM

The insulating vacuum system purposes to reduce the heat flux from the warm external walls of the cryostat to the inner helium vessel through a residual gas. The common insulating vacuum occupies a volume between the internal part of the SCW housing and the external part of the liquid helium tank joined together. A required vacuum for cryostat operation is equal to $10^{-5}…10^{-7}$ Torr. In order to keep that vacuum level, an ion pump with productivity of more than 200 l/s is required. Behind the ion pump, the use of a turbo-molecular and rough pumping system is required.

5. TEST RESULTS

The main wiggler parameters are presented in Table 2.

***Table 2.** Main wiggler parameters*

Parameters	Required Value	Real value
Period length, mm	~33	34
Number of poles	63	63
K-value	~6	6.5
Vacuum chamber (vertical), mm	9.5	9.5
Vacuum chamber (horizontal), mm	50	50
Pole gap, mm		13.5
Temperature vacuum chamber, K		15…20
Shield screens temperature, K		20, 50
Electrical current in the coils, A		730
Time between LHe refilling, months	3…6	6…12
LHe volume of the cryostat, litres		330
Working magnetic field, Tesla	1.86	2
Achieved magnetic field, Tesla		2.2
Ramping time 0-2 Tesla, min	5	5

The tests of all the system include the procedures of cooling down and warming up, demonstration of field stability at maximum field value, fine tuning of currents in the magnet for zero field integrals in all range of working field, field mapping at several field levels, measurement of liquid helium consumption at various modes of the wiggler operation, etc. These measurements were done during the test inside bath cryostat, factory and site acceptance tests inside its own cryostat.

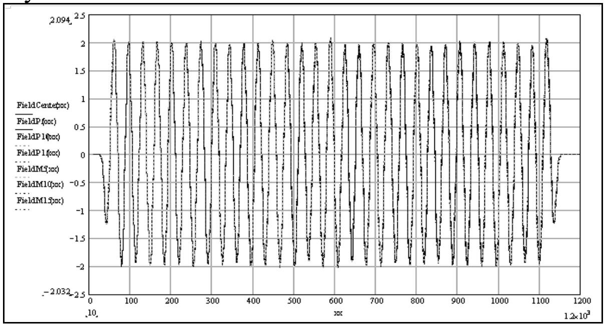

Fig.7. Hall probe measurements at 2 Tesla field

6. CONCLUSIONS

The planar type superconducting 63-pole wiggler with short period 34 mm was successfully tested and installed on the CLS storage ring. The maximum magnetic field 2.2 Tesla was achieved after 7 quenches and 2 Tesla magnetic field level is acceptable for the routine operation. An average liquid helium consumption was defined as 0.03 litres per hour.

In the first weeks of May, 2005 the Hard X-Ray Micro-Analysis beam-line staff obtained a monochromatic X-ray using the radiation from the wiggler.

REFERENCES

1. N.A. Mezentsev. *Superconducting magnet systems of Budker INP for generation of synchrotron radiation*. Workshop on superconducting undulators & wigglers. Grenoble. 2003, 1/11.
2. A.M. Batrakov et al. *Construction and Tests of the 49-pole 3.5 Tesla Superconducting Wiggler for ELETTRA Storage Ring. Proc. of SRI'03*, 2003, p.183.
3. D. Berger et al. *A superconducting 7T multipole wiggler for the BESSY II Ring.* Proc. of PAC"01, Chicago. 2001.
4. L. Barkov et al A proposal to install a superconductive wiggler magnet on the storage ring VEPP-3 for generation of synchrotron radiation // *Nucl. Instr. and Methods*. 1978, p.152.

СВЕРХПРОВОДЯЩИЙ 63-ПОЛЮСНЫЙ 2 ТЕСЛА ВИГГЛЕР ДЛЯ КАНАДСКОГО ЦЕНТРА СИНХРОТРОННОГО ИЗЛУЧЕНИЯ

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Описан 63-полюсный сверхпроводящий вигглер со средним периодом 34 мм, изготовленный в ИЯФ СО РАН для центра синхротронного излучения CLS в Канаде. Получено максимальное поле в медианной плоскости 2.2 Т. При этом расход жидкого гелия в рабочем режиме менее 0.03 литра в час. Вигглер установлен на накопительное кольцо CLS и ведутся эксперименты с СИ. Приведены основные параметры магнитной и криогенной систем.

НАДПРОВІДНИЙ 63-ПОЛЮСНИЙ 2 ТЕСЛА ВІГГЛЕР ДЛЯ КАНАДСЬКОГО ЦЕНТРА СИНХРОТРОННОГО ВИПРОМІНЮВАННЯ

С.В. Хрущьов, Е.А. Купер, В.Х. Лев, М.А. Мезенцев, Є.Г. Мігінський, В.В. Репков, В.А. Шкаруба, В.М. Сироватін, В.М. Цуканов

Описаний 63-полюсний надпровідний вігглер із середнім періодом 34 мм, виготовлений в ІЯФ СО РАН для центра синхротронного випромінювання CLS у Канаді. Отримано максимальне поле в медіанній

площині 2.2 Т. При цьому витрата рідкого гелію в робочому режимі менш 0.03 літра в годину. Віґглер установлений на накопичувальне кільце CLS і ведуться експерименти із СІ. Наведено основні параметри магнітної й криогенної систем.