SUPERCONDUCTING 119-POLE WIGGLER FOR ALBA LIGHT SOURCE

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Abstract

Budker INP of Siberian Branch of the Russian Academy of Science has designed, manufactured and tested 119-pole superconducting wiggler for ALBA CELLS Light Source. The period length and maximal field of the wiggler are 30 mm 2.27 Tesla correspondingly. A pole gap and vertical aperture for the electron beam are 12.6 mm and 8.5 mm, accordingly. The wiggler magnetic structure closely comes nearer to undulator structure as K-value is about 6. The wiggler cryostat is bath cryostat type with use of cryocoolers which provide zero liquid helium consumption for long period. In June, 2010 the wiggler has been successfully tested on ALBA site. Test results of the wiggler including magnetic measurement, quench training, cryogenic system behavior for various mode of operation are presented.

INTRODUCTION

A superconducting 119-pole wiggler (SCW) with 2.1 Tesla nominal field and 30 mm period (see Figure 1) for the 3 GeV storage ring ALBA (Barcelona, Spain) was designed and fabricated in Budker Institute of Nuclear Physics (Novosibirsk, Russia) in 2010. In June 2010 the SCW was successfully tested at ALBA site (outside of the storage ring). At present time the SCW is installed at the ring. The final tests (with the electron beam) are expected to be carried out in October 2011.

The SCW is supposed to be used as powerful synchrotron radiation source in photon energy range of 10-40 keV for the Materials Science and Powder Diffraction Beam Line. Photon spectrum is represented in Figure 2. The total radiation power is about 16 kW for the electron beam current of 0.4 A and the energy of 3 GeV. The main parameters of the SCW are represented in Table 1.

MAGNETIC SYSTEM

The magnetic field is created by 117 central sign alternating dipole magnets and 2 side dipole magnets. Each dipole consists of two superconducting coils assembled symmetrically above and below the vacuum chamber. The shape of the each coil is racetrack type with dimensions of 118 mm x 15.08 mm and height of 19.1 mm. All coils consist of one section with the total turn number of 138 wound over the ARMCO-iron cores.

The parameters of the superconducting NbTi wire are represented in Table 2. See also Figure 3 for the load curves of the wire.

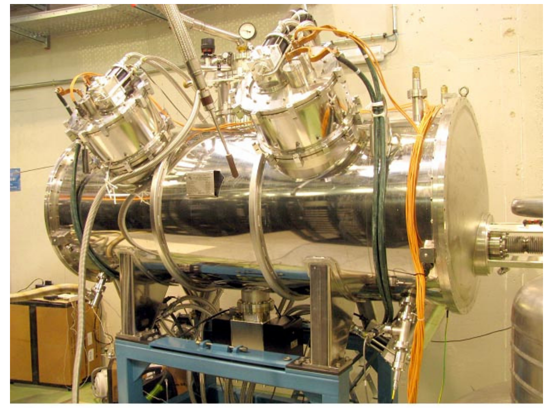

Figure 1: Overall view of the SCW.

Table 1: The Main Parameters of the SCW

Nominal peak on axis field, Tesla	2.1
Maximum peak on axis field, Tesla	2.27
Period length, mm	30
Number of pole pairs @ full field	117
Number of pole pairs @ ½ field	2
Magnetic gap, mm	12.6
Length of magnetic arrangement, mm	1892
Full vertical aperture, mm	8.5
Full horizontal aperture, mm	60
Stored energy, kJ	~19
Operation currents at 2.1 T	168 +238 A
Liquid helium consumption	≤0.05 l/h

The epoxy filled with Gd_2O_2S which has anomalous high heat capacity at 4 K is used for the “wet” winding to align the temperature contraction coefficient with superconducting wire and essential increase the heat capacity of the coil [1].

The ARMCO-iron yoke is used to return the magnetic flux and to support the coils. The yoke includes two parts which are placed symmetrically above and below of median plane of the wiggler. The upper and the lower wiggler parts are supported by the nonmagnetic stainless steel slab located symmetrically between the coils. The additional iron plates between the upper and lower halves are used to close the stray magnetic flux. Coil arrays are pressed by special bronze rods to avoid any movements inside the coils.

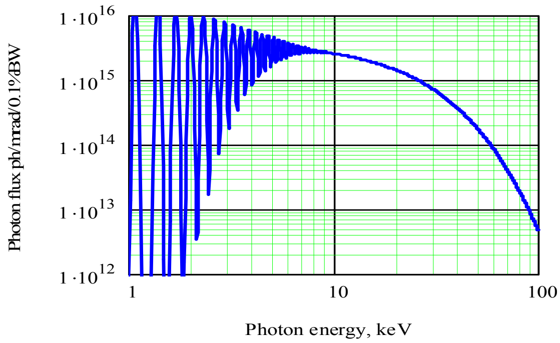

Figure 2: Photon spectrum.

Table 2: The Parameters of the NbTi/Cu Wire

Wire diameter with/without insulation, mm	0.55/0.5
NbTi/Cu ratio	1.4
Number of filaments	312
Diameter of filament, µ	37
Critical current at 7 Tesla, A	236

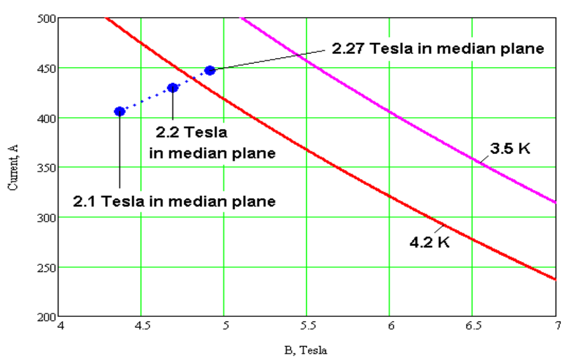

Figure 3: Critical curves of the NbTi/Cu wire.

Two power supply units (DANFYSIK MPS883) are used to feed the magnet. One power supply unit feeds all 119 poles and the other one feeds 117 central poles. This scheme enables to keep zero value of the first field integral by changing the ratio between two currents. Superconducting coils of the wiggler are protected from damaging during quench by shunts with resistance of 0.1 Ω and cold diodes. Overall view of the SCW magnetic system is shown in Figure 4.

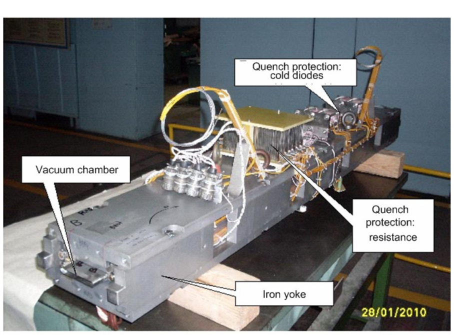

Figure 4: Magnetic system of the SCW.

CRYOGENIC SYSTEM

The main function of the SCW cryogenic system is to maintain the magnet at liquid helium temperature (4.2 K). The magnet is mounted inside a vessel with liquid helium which, in its turn, is placed into an external warm stainless steel vessel. Vacuum insulation between two vessels allows us to reduce the residual gas heat flux. The liquid helium vessel is surrounded by two shield screens with the temperature of 20 K and 60 K to reduce the radiation heat flux from outside. Two cryocoolers SUMITOMO SRDK-408S2 are used for cooling the both shields. Two cryocoolers SUMITOMO SRDK415 with cooling power of 1.5W at 4.2 K are used for interception of heat in-leak from current leads and for additional cooling of 60 K shield. Outside the surface of the liquid helium vessel is covered by copper net directly connected with 4 K stages of SRDK415 cryocoolers. In addition two special gilded copper heat exchangers located directly inside of the helium vessel are used to enhance the efficiency of gaseous helium recondensation.

A stainless steel vacuum chamber of the liquid helium vessel with the temperature of 4.2K is used simultaneously as a beam vacuum chamber. A special copper liner connected with 20 K radiation shield is inserted inside the vacuum chamber. The liner absorbs heat which is raised by electron beam moving inside the copper liner (synchrotron radiation, heating by image currents, etc.). The vacuum between the liner and the vacuum chamber and inside the liner is the same.

The superconducting wiggler coils are connected permanently with the current leads. Two pairs of current leads are used to feed the magnet. These current leads are the main source of heat in-leak into the liquid helium vessel due to heat conductivity and Joule heat. Each current lead consists of two parts: normal conducting brass cylinder and high temperature superconducting (HTSC) ceramics stick. The junctions of normally conducting and superconducting parts of current leads are supported at temperature 50–60 K. The lower end of the HTSC part connected with the magnet is supported at temperature below 4.2 K. Both ends of the HTSC current leads are attached to 4 and 60 K stages of SRDK415 cryocoolers through electrical insulator (sapphire plate).

TEST RESULTS AND CONCLUSION

The wiggler test procedure was carried out in 3 steps: (i) Bath cryostat test (BINP), (ii) Factory acceptance test (BINP), (iii) Site acceptance test (ALBA). Bath cryostat test included the magnetic system test only (field training procedure & Hall probe measurements). All other systems (cryogenic, vacuum, control etc.) as well as the magnetic system (long term stability, field integrals etc.) were checked during Factory and Site acceptance tests. The results obtained have shown that all SCW parameters are in accordance with the requirements.

The quench history of the magnet is shown in Figure 5. Maximum field of 2.277 Tesla was achieved after 6 quenches during Site acceptance test.

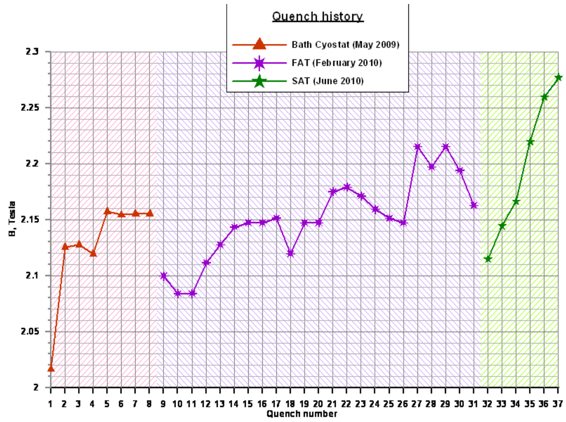

Figure 5: Quench history.

The cryostat design allowed one to decrease the magnet temperature up to 3.5 K, that is a guarantee of the reliable system operation and zero liquid helium consumption. The gas helium pressure behaviour inside the helium vessel during SCW operation is shown in Figure 6.

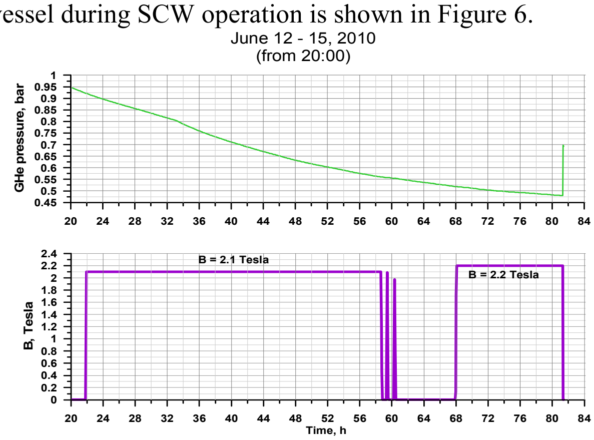

Figure 6: The gas helium pressure behaviour.

To simulate SCW operation with the electron beam a special heater with power of 20 W was inserted into the copper liner. The results of this test (see Figure 7) allow us to hope that the real electron beam will not affect for liquid helium consumption considerably.

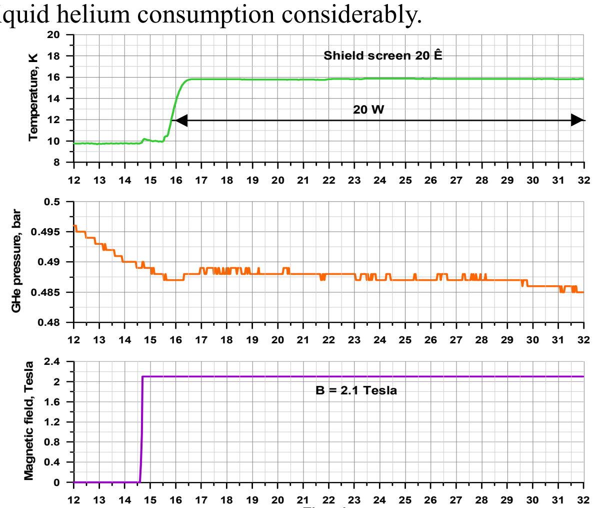

Figure 7: Simulation of 20 W beam heat load on liner.

Magnetic measurements with use of two Hall probes as perpendicular array was conducted at following field levels: B=0, 0.5 1.0, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.15, 2.2 Tesla (see Figure 8).

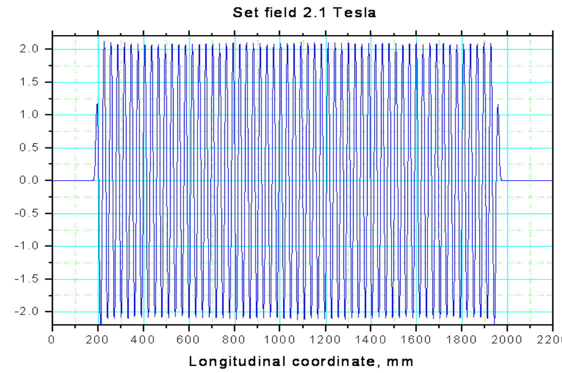

Figure 8: Longitudinal field distribution at 2.1 T.

Stretched wire method was used to find the ratio between two currents at field range 0-2.1 Tesla to zero 1st field integral. As a result the field ramping table was made. After that dynamical stability of 1st and 2nd field integral during field ramping was tested (see Figure 9). 1st field integral stability is defined by power supplies stability at low level of currents and ramping rate. The 2nd field integral show the value satisfied to wiggler specification. The time of field ramping from 0 up to 2.1 Tesla is near 5 minutes and this time may be decreased.

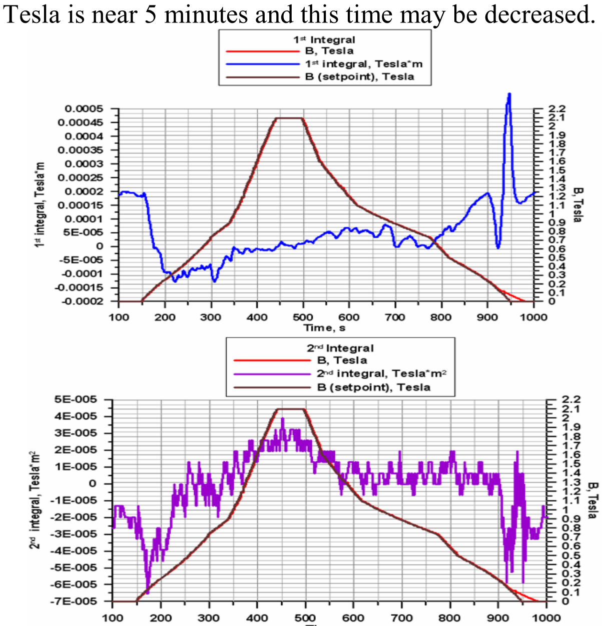

Figure 9: Dynamic behaviour of first and second field integrals during field ramping up and down.

REFERENCES

[1] V. E.Keilin, et al. Increasing thermomagnetic stability of composite superconductors with additives of extremely large heat capacity substances, Technical Physics Letters (2008), 34, pp. 418–420.