Development of Superconducting Wavelength Shifter

In order to enhance the hard X-ray source of the 1.5 GeV storage ring of TLS, a project to install several high field superconducting insertion devices in short straight sections, such as the injection section, the RF cavity section, and sections between the arcs, has been launched. The first of these insertion devices, dubbed the superconducting wavelength shifter (SWLS), has been developed with a warm bore for synchrotron radiation light source. The wavelength shifter consists of three pairs of racetrack superconducting coils and the magnet can generate a maximum magnetic field of 6 Tesla at the central pole.

A compact cryogen-free SWLS has been designed and constructed to fit inside the remaining limited space in the injection straight section. This SWLS, 610 mm in length, and with a warm bore gap of 20 mm and a coil gap of 55 mm, is comprised of three pairs of racetrack NbTi superconducting coils. Table 1 specifies the magnet design and construction parameters. A 1.5 W Gifford-McMahon cryocooler is used to simplify the operation and maintenance. The coil bobbin is made of 1 mm thick OFHC sheets and the superconducting wire is conduction-cooled. A flexible S-shaped OFHC multi-sheet assembly was constructed to connect the magnet to the 4 K stage of the cryocooler and thus avoiding vibration caused by the cold head of the cryocooler. Laminated return iron yokes with insulation epoxy and separated aluminum supporting blocks separated by insulation Kapton were constructed to reduce eddy currents. Fig. 1 depicts the cold mass assembly, consisting of the coil, the iron poles, the return iron yoke, the aluminum block with alignment pins, and the LHe vessel. The 1.4 mm gap between the coils and the aluminum block is filled with epoxy to reinforce and glue the coil onto the aluminum block. The aluminum block

Table 1: Design and construction specification of the SWLS.

Magnet field design		
Central pole dimension with racetrack shape	38×177 mm^2	
Side pole dimension with racetrack shape	23×197 mm^2	
Warm bore beam duct chamber dimension	610×100×20 mm^3	
Magnet pole gap	55 mm	
Roll-off range for $\triangle B/B \leq 0.1\%$	20 mm	
Integral quadrupole	$\leq$ 25 G	
Integral sextupole	$\leq$ 50 G/cm	
Integral octupole	$\leq$ 50 G/cm^2	
Conductor		
Cu/SC ratio	3:1	
Dimension including insulation	1.0×1.9 mm^2	
Filament size	40 μm	
Number of filaments	330	
Minimum twist pitch	26 mm	
Inductance	3.1 H	
Total stored energy	105 kJ	
Coil-winding construction data	Central pole	Side pole
Total ampere turns/pole	2086	1439
Operation current, I_0	283.51 A	284.76 A
Peak field at coil, B_m	7.2 T	6.0 T
Pole field strength	6.0 T	-3.85 T
Average current density	137.5 A/mm^2	138.5 A/mm^2
Coil cross section	61.73×69.5mm^2	42.57×69.5 mm^2

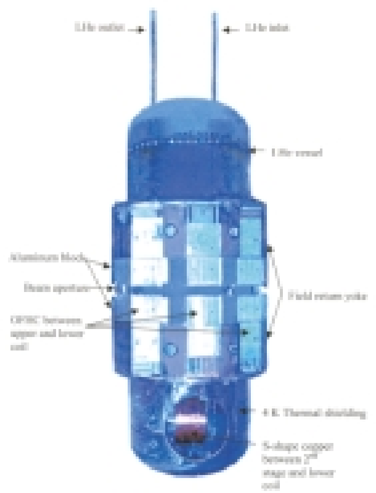

Fig. 1: Components of the 4 K cold mass inside the cryostat of the superconducting wavelength shifter.

consists of four individual parts (one upper, one lower, and two gap separation blocks) and was isolated by Kapton. The return yoke and the iron poles are carefully aligned, pinned, and bolted together very precisely. The aluminum block not only supports both the in-plane and the out-of-plane coil forces but also takes care of the thermal contraction of the coils. The return yokes are laminated into seven layers, which are glued together by epoxy and fiberglass to reduce eddy currents. Fig. 2 shows a photograph of the magnet.

When the magnet is cooled down by filling with liquid helium and liquid nitrogen, and by turning on the cryocooler, the temperature of the lower and the upper copper plates is 3.6 K and 4.7 K, respectively, under a 5 psig LHe vessel pressure. The temperature of the first and second stage of the cryocooler is 53 K and 3.5 K, respectively. However, the hot end of the HTS current lead is 70 K at an excitation current of 265 A. Therefore, LN_2 is under cryogen-free operation but LHe still has a boiling-off rate of 0.06 l/h. If the lower and upper OFHC copper plates are welded together to reduce the thermal contact resistance, the temperature of the upper plate will be under 4.2 K and the LHe boiling-off will be zero. Two bipolar power supplies with four HTS current leads charge and discharge the magnet system and nullify the first field integral. The

Fig. 2: Photograph of the SWLS magnet and the Hall probe magnetic field measurement system.

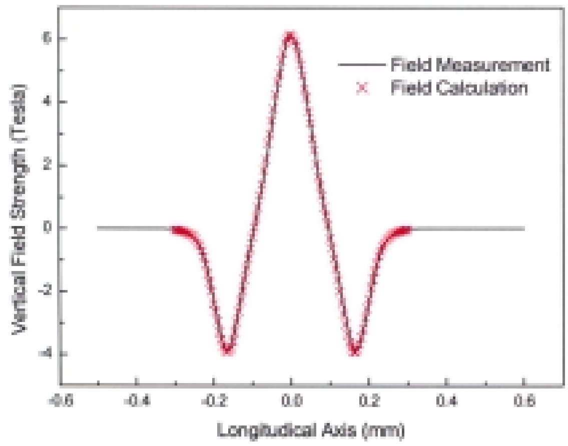

Fig. 3: Calculated and measured vertical field distribution along the longitudinal axis. The current was set at 260 A.

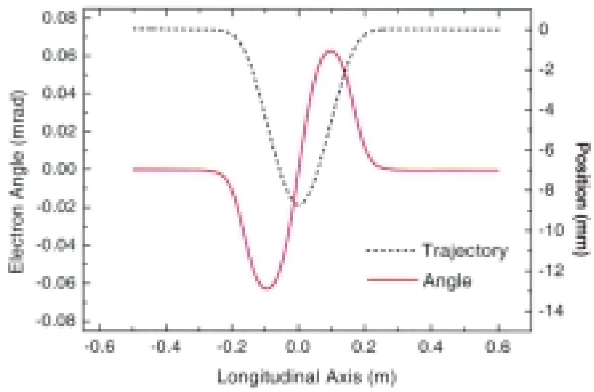

Fig. 4: Calculation of electron angle and position as functions of longitudinal distance when electrons pass through the superconducting wavelength shifter. The current was set at 260 A.

nominal current slew rate is set at 0.3 A/s. However, the maximum slew rate can exceed 0.5 A/s. The maximum field strength of 6.0 T can be obtained without magnet training. In addition, the field strength can be excited up to 6.5 T easily. In the cryoge-frre condition, the magnet can be operated at 5.5 T.

A high precision Hall probe and stretch wire systems are employed to measure the field roll-off, multipole components, and the longitudinal field distribution. Fig. 3 shows the field distribution along the longitudinal axis. Fig. 4 gives the angle and position of the electron beam trajectory inside the magnet. The maximum electron deviation is 8.8 mm at the magnet's center at a magnetic field

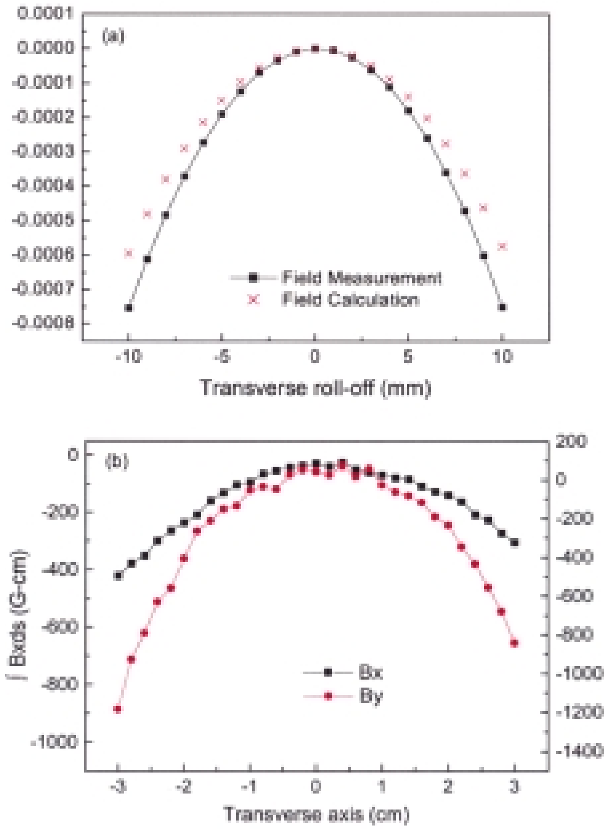

Fig. 5: (a) Roll-off of △B/B at central pole and (b) Integral field profile, as function of the horizontal transverse distance. The current was set at 260 A.

of 5.93 T. A pair of electromagnets is located at each end of the magnet for multipole shimming and for the trajectory correction. The upstream one is for horizontal correction and the downstream one is for vertical correction. Fig. 5 displays the integral field distribution along the transverse axis after multipole and trajectory shimming. The field distribution can be analysized to obtain the multipole components and the resulting normal (skew) multipole components, -20 (-20) G-cm, 40 (13) G, -70 (-40) G/cm, -4 (0.5) G/cm^2 are all closed to the specification. After detail multiple shimming, these components can reach much lower values.

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Publications:

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