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Superconducting 7 T Wave Length Shifter for BESSY-II

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Abstract

A superconducting 3-pole Wave Length Shifter (WLS) with a maximum field of 7 T was fabricated and tested by BINP in collaboration with BESSY-II. The radiation point is fixed in the center of WLS at any field level by using two correctors. The magnetic field is stabilized with an accuracy of 10^{-4} at 7 T by a feedback system based on NMR probes and magnetic flux pumps. Persistent current operation mode is enabled by using superconducting persistent keys. The magnetic field homogeneity of 10^{-4} at 7 T is obtained as a result of shimming in the aperture of the magnet. A protection system based on cold diodes and dump resistors prevents the destruction of superconducting coils during the quench. Two screens with temperatures of 20 and 60 K cooled by cooling machine, two recondensers, HTSC current leads and cevlar suspensions of helium volume are used to decrease liquid helium consumption. The main features and operating mode of the WLS are described. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

A superconducting 3-pole Wave Length Shifter (WLS) with a maximum field of 7 T at the central pole was designed, fabricated and tested by Budker Institute of Nuclear Physics in collaboration with BESSY-II. The superconducting 7 T magnet located at the center of "non-dispersive" straight section is the main part of the WLS. Two normal conducting correcting magnets placed at the ends of the straight section create, together with the superconducting magnet, a compensated orbit deviation at any field level so that the radiation point is fixed in the center of the WLS. The first field integral of the superconducting magnet is not equal to zero and corresponds to orbit angles defined by the correctors. The distribution of the magnetic field and electron beam orbit along the WLS straight section is presented in Fig. 1. The maximum angle deviation and the orbit displacement inside the WLS are 65 mrad and 15.5 mm, respectively, for an electron energy of 1.9 GeV and the field of 7 T. The total radiated power from the WLS at an energy of 1.9 GeV and beam current of 500 mA is equal to

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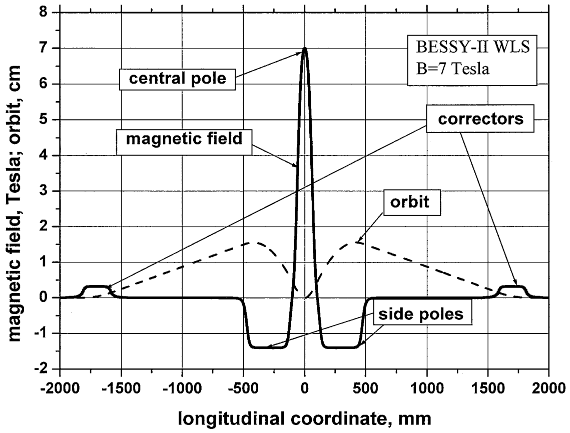

Fig. 1. Distribution of magnetic field and deviation of electron beam orbit along 7 T BESSY-II WLS straight section.

Table 1
The main parameters of 7 T superconducting WLS for BESSY-II

Maximum field at central pole (required/reached), T	7.0 (7.54)
Field at side pole, T	1.5
Magnetic length, mm	972
Pole gap, mm	52
Stored energy, kJ	140
Aperture of vacuum chamber:	
Vertical, mm	32
Horizontal, mm	90
Weight of cooled parts, kG	1000
Orbit deviation, mm	0 (15)
Orbit angle, mrad	$\pm$ 65
Consumption of liquid helium, l/h	0.2
Total radiation power, kW	13
Electron energy, GeV	1.9
Beam current, mA	500
Field stability at 7 T	10^{-4}
Field homogeneity at central pole	10^{-4}
Currents in windings, A	150, 250

13 kW. The main parameters of the WLS are presented in Table 1.

2. Magnet design

The key elements of the three-poles shifter magnetic system is the central high-field superconducting dipole and two side weak-field ones which are placed above and below the beam duct (see Fig. 2). The central and side dipoles generate the magnetic fields of 7 and 1.5 T, respectively, at the shifter median plane. The coils are produced from superconducting Nb–Ti wire with diameter of 0.85 mm impregnated with epoxy compound. The critical current of the wire used is equal to 360 A in a field of 7 T. The values of magnetic field and maximum current at inner and outer sections of the central coils are equal to 7.7 and 6.5 T and 130 and 330 A/mm^2, respectively. The maximum current of about 90% of short sample current was achieved. The iron yoke is designed so that the whole magnetic flux is closed inside the magnet and there is no influence of the stray fields upon another element at the storage ring. Second field integral is defined by fabrication precision and correspondents to orbit deviation on the ring less than 5 μm. Each of the central coils are divided into two sections to optimize field–current relationship and reach the maximum field. To feed the coils, two independent power supplies are used. The inner and outer sections of the central coils and all side coils are powered by the first power supply with the current of 150 A. The second power supply with the current of 100 A feeds the outer section of the central coils. In this way, the currents are summarized at the outer sections and the value of current is equal to 250 A. Thus each section is energized by the optimal current and there is a possibility of easy control of first field integral to zero at any field level. The magnetic field homogeneity of 10^{-4} at 7 T is obtained at the central pole as a result of shimming in the aperture of the magnet by special iron plates with the thickness of 1.7 mm [1]. For the computation of such parameters of the magnetic system as saturation of yoke, optimization of the currents for maximum field, shimming of the aperture and zeroing of the field integral a 3D MASTAC code [2] was used.

3. Cryostat design

The WLS magnet is inserted into a special liquid helium cryostat. The schematic view of the cryostat is shown in Fig. 3. The inner liquid

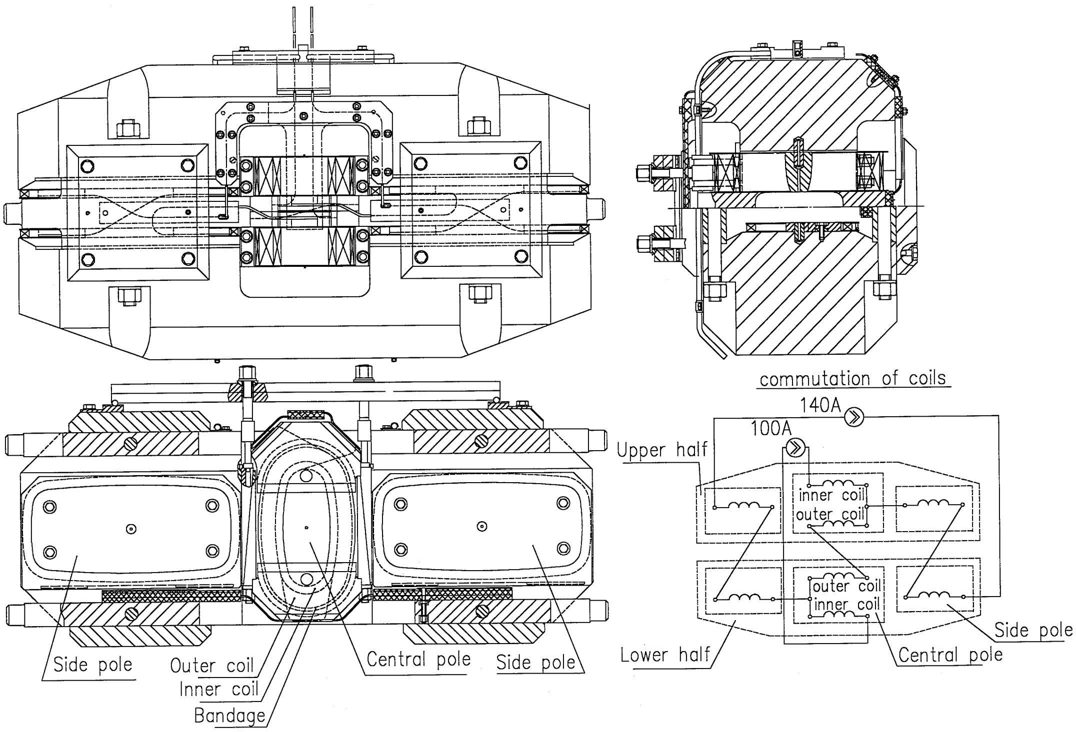

Fig. 2. Magnetic system of 7 T BESSY-II WLS.

helium vessel is surrounded by two screens to reduce the heat flux into helium volume. The radiation screens are connected to the neck of the helium vessel at corresponding places. The outer and inner screens are wrapped by 30 and 10 layers of super-insulation, respectively. The screens with temperatures of 60 and 20 K are cooled by a two-stage cooling machine with the cooling power on the stages of 115 and 15 W, respectively. There is a vacuum insulation with the value of 10^{-7} T between the helium vessel and an external warm stainless vessel. The special cevlar suspensions are used for hanging the helium vessel and the screens to minimize heat inleakage. The ends of the suspensions pass through the external vessel walls and are used for precise alignment of the magnet location. The liquid helium consumption after a quench at maximum field level is equal to 40 l during 5 min after the quench. Two pairs of HTSC ceramic current leads connected with the optimized copper current leads are used to energize the magnet coils. The use of ceramic current leads permits to decrease heat inleakage 5 times less compared to the optimized copper current leads. Heat flux coming along the current leads from the upper flange due to thermal conductivity is taken off by connecting the copper current leads to the cooler stages through the special ceramic contact. To decrease liquid helium consumption, there is the special system for mechanical disconnection of copper current leads from the ceramic ones inside the cryostat. The disconnection is controlled automatically by computer code.

4. Testing and measurements

The magnetic system of the WLS was tested after manufacturing and the maximum field of 7.54 T was achieved after 6 quenches. Each section of the superconducting coils is shunted by a cold diode and a dump resistor to protect the coil from

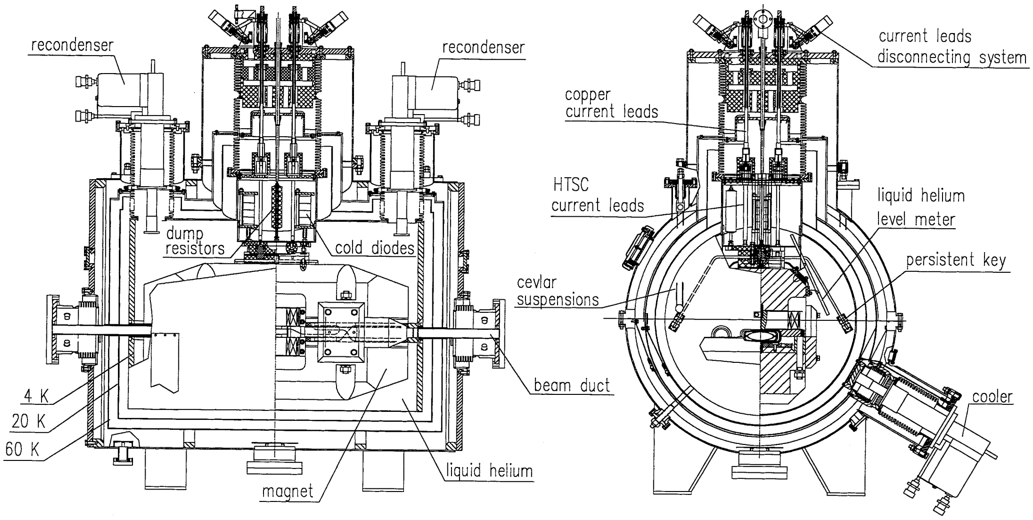

Fig. 3. View of the cryostat of BESSY-II WLS.

damage and to limit the voltage on the coils to not more than 60 V during quench. The numerous quenches demonstrate the high reliability of the quench protection system.

Persistent current operation mode is enabled by using superconducting persistent keys. The magnetic field is stabilized with an accuracy of 10^{-4} at 7 T by feedback system with the use of NMR probes and special transformers called magnetic flux pumps [3]. The secondary winding of the transformer is connected in series with the superconducting winding of the magnet and the primary transformer winding is energized by special power supply with the current of 1 A.

The consumption of the liquid helium at the mode of disconnected current leads is equal to 0.2 l/h It enables the refilling of liquid helium in the cryostat not more than once per month.

The WLS will be installed at the BESSY-II storage ring in September 2000 and will be used for calibration experiments.

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