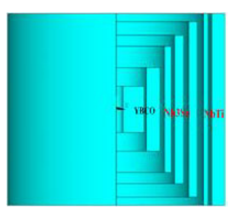
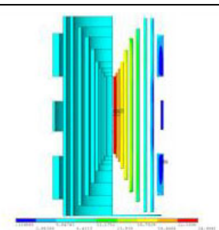
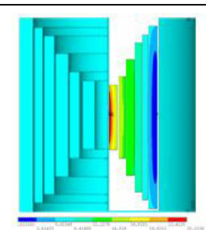
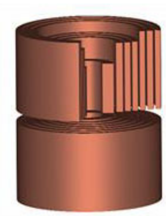
An 11 T HTS Insert for ExCES 25 T Superconducting Magnet

Qiuliang Wang, Junsheng Cheng, Jianhua Liu, Chunyan Cui
Institute of Electrical Engineering, Chinese Academy of Sciences (CAS), P.R.China

E-mail: qiuliang@mail.iee.ac.cn

March 29, 2014 (HP73). The extreme condition experimental science facility (ExCES), is an advanced science platform to be constructed by CAS. It should permit applying low temperature, high pressure and high magnetic field at or near the limits of current technology. The magnetic field of 25~30 tesla can be attained by combining HTS and LTS magnet coils. We report here on the progress towards such ultra-high magnetic field fully superconducting magnet with a center field of 25~30 T and warm bore size of 32 mm. The requirements for ExCES high field magnets are listed in Table 1.

Table 1 Superconducting Magnets for ExCES

Quantum oscillation	**Solid state NMR**	**STM magnet system**	**Split-pair system**
			
B_o=30-35 T/ 32-50 mm Homogeneity: 10^{-4} (10 mm)	B_o=25 T/ 54 mm δ B/B=10^{-5}, DSV=10 mm, dB/(dt$_B$)=10^{-5}	B_o=25 T/ 78 mm Homogeneity: 10^{-3} (10 mm) Small Vibration	Center field 23-25 T/ 80 mm separation: wedge Homogeneity: 0.2%
Operating mode: Zero boiling off LHe, Power supply Drive	Operating mode: Zero boiling off LHe, PCS mode or Power supply Drive	Operation mode: LHe cooling system, Power supply Drive	Operating mode: Zero boiling off LHe, Power supply Drive
1 mk-10 mk, 100 GPa	Solid state Sample	OMBE-ARPES-STM	Ultra-high intensity Light

The current carrying capacity at 4.2 K of NbTi and Nb_3Sn decreases sharply in high magnetic fields. The $Nb_3Al_{0.8}Ge_{0.4}$ wire has been developed over more than 30 years in Japan. This material has a critical field of up to 30~40 T, but fabricating long-length practical conductors still cannot be resolved. Since the target magnetic field for superconducting magnets has shifted to 32–35 T and even beyond, the development of practical HTS magnet technology is crucial. Nevertheless, the LTS magnet technology remains essential for outserts, as the current carrying capacity of LTS conductors in magnetic fields below 20 T exceeds that of HTS conductors at a much lower cost. Hybrid magnets with superconducting LTS outserts and Bitter-type inserts are a possible alternative, but it is not an economic choice, because of the high power consumption. Accordingly, a 25 T or still higher field magnet is typically designed as a set of graded coils with NbTi, Nb_3Sn, and HTS conductor sections.

Research on very-high-field magnets with various HTS inserts is progressing in the world. ISTEC developed a GbBCO insert coil to be installed in a 28.3 T hybrid magnet to generate a 29.3 T central field. The NHMFL is engaging in several HTS high-field magnet projects, including construction of a

7 T Bi2212 demonstration insert magnet for 25 T and an all-superconducting 32 T research magnet using ReBCO [1]. The ReBCO coil will contribute a 17 T field in the 32 T/ 32 mm cold bore magnet [2]. In March, 2013, a 25 T cryogen-free superconducting magnet (25 T-CSM) project has been budgeted by the Science Council of Japan [3].

At IEE CAS, our study of various Bi2223 tapes, Bi2212 wires, and YBCO coated conductors indicated good opportunities for their applicability in high-field magnets. The scope of our work has been generic and wider than the development of one particular magnet. We have now designed, fabricated and tested high-temperature superconducting YBCO and Bi2223 inserts operating at the temperature of 4.2 K to prove the technical feasibility of achieving the target of 25 T. The Bi2223 insert has the inner diameter, outer diameter, and height of 120 mm, 214 mm, and 250 mm, respectively. The YBCO insert has the inner diameter, outer diameter, and height of 22 mm, 65 mm, and 204 mm, respectively [4]. The central operating magnetic field of the Bi2223 insert can reach up to 5.8 T with operating current of 150 A (design value). In the central bore of the YBCO insert a 5.3 T central magnetic field can be obtained at the same operating current of 150 A. Figure 1 shows the assembly of Bi2223 and YBCO insert coils before test. Tests at liquid helium temperature show that the Bi2223 and YBCO inserts can generate a maximum center field of 5.71 T and 5.41 T, at the operating current of 158 A and 160 A, respectively. The assembly of the Bi2223 and YBCO insert coils can generate a center magnetic field of about 11 T when tested at the liquid helium temperature. Retest after quench showed that the performance of the HTS insert indicated no obvious degeneration, which also proved the technical feasibility of the protection circuit. This is a yet unpublished work. The center field versus current is shown in Figure 2.

Fig. 1. Configuration of assembled insert coils.

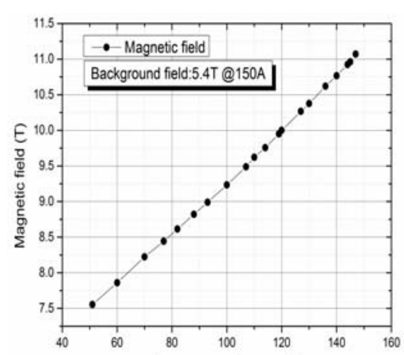


Fig. 2. Center magnetic field versus current in the YBCO insert at 5.4 T background field.

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