# Generation of 24 T with an all Superconducting Magnet

Jianhua Liu, Qiuliang Wang, Yinming Dai, Shouseng Song, Chenchen Gou, Lei Wang, Jianbo Zhou, Kun Chang, Lankai Li, Baozhi Zhao, Haoyang Liu

Institute of Electrical Engineering, Chinese Academy of Sciences (CAS), P.R.China

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

January 26, 2016 (STH39, HP105). The continuous improvement of performance of ReBCO coated conductor provides a feasible and economic approach to develop superconducting magnet capable of generating fields above the limit of NbTi-$Nb_3Sn$-based magnets, i.e. 23.5 T [1]. Many groups and laboratories have started high-field DC magnet projects based on ReBCO tapes. Up to now, the highest magnetic field ever achieved generated by superconducting magnets is 35.4 T, obtained at NHMFL, with a 4.2 T lay-wound ReBCO insert in a 31.2 T resistive magnet [2]. Another project at NHMFL is the 32 T/32 mm cold bore all superconducting user magnet. Presently, the prototype magnet of this project has obtained a central field of up 27 T, which is now the highest field generated by an all-superconducting magnet [3]. Another important project is a 1.3 GHz (30.5 T) NMR magnet project at the MIT Francis Bitter Magnet Laboratory [4], the 18.8 T ReBCO insert is still under construction. Another remarkable achievement is the generation of 26.4 T with an all ReBCO magnet at SuNAM [5]. The magnet was wound with non-insulated (NI) multi-width tapes. Most interestingly, the 26.4 T self-field, at 4.2 K is not only the highest field generated by a single ReBCO magnet, but also the highest field generated by an all superconducting magnet system until present.

The Institute of Electrical Engineering (IEE, CAS) started a 25 T/32mm cold bore all superconducting magnet project in 2013 [6]. The superconducting magnet, operating at 4.2 K, consists of a 10 T REBCO insert and a 15 LTS superconducting magnet. The LTS magnet, composed of NbTi and $Nb_3Sn$ coils, provides a 15 T background in a 160 mm diameter cold bore. The REBCO insert, designed with 16 Double Pancakes, will generate 10 T central magnetic field at 169 A, at 4.2 K, under 15 T background field. It has the inner diameter, outer diameter, and height of 36 mm, 104 mm, and 160 mm, respectively. The employed ReBCO-coated conductor provided by SuNAM, has a cross section of 4.1 mm×0.15 mm, and a minimum critical current of 150 A at 77 K, self-field. This conductor is strengthened by soldering a stainless steel lamination to the substrate layer. There was no insulation on the tape. The DPs were dry wound first and soldered last to maintain a solid structure. 16 DPs were wound and tested, and test results are as shown in Figure 1.

Since there was a defect occurring with winding DP 2# having low n-value, as can be seen in Figure1, we finally excluded DP 2# when assembling the magnet. DPs were stacked and electrically isolated by G10 slices. The outer diameters of all these 15 DPs are almost the same, so as to provide a rather flat base for soldering the splice joints. Resistance of each splice joint is around 100 nΩ. The insert in assembly is shown in Figure 2. After assembly, the insert was first tested at 77 K, and generated a 1.62 T central field, at self-field transport current of 32 A.

Finally, the insert was assembled with a 15 T background LTS magnet. Test was carried out in liquid helium at 4.2 K. The insert generated 9 T central field under a 15 T background field, to obtain a 24 T central field at an operating current of 167A. Figure 3 shows the excitation process. The quench started at the top DP of the insert, where the perpendicular field is about 3.6 T, which leaves no much safety margin for the ReBCO coated conductors. The next step is to increase the operation safety margin by reducing the current density at the top/bottom of the insert, so as to obtain a 25 T central field.

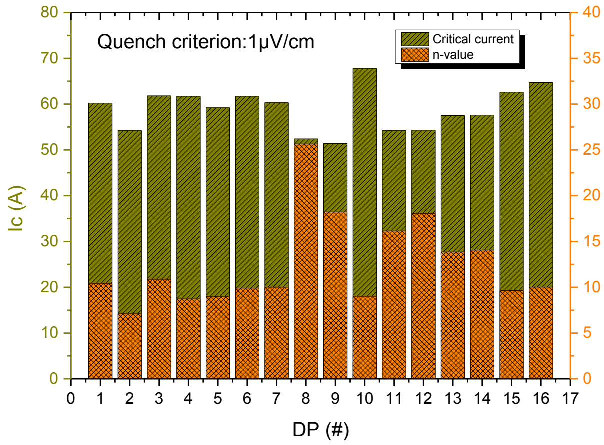


**Fig.1.** Critical currents and n-values of 16 DPs

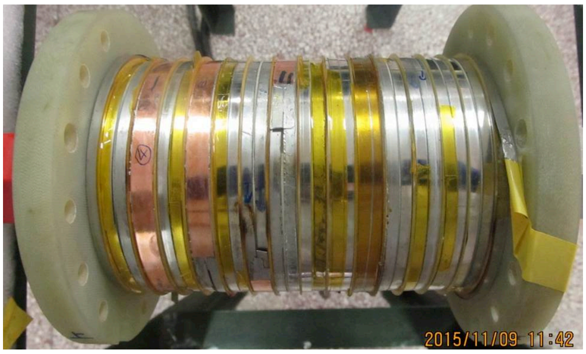


**Fig.2.** ReBCO insert in assembly

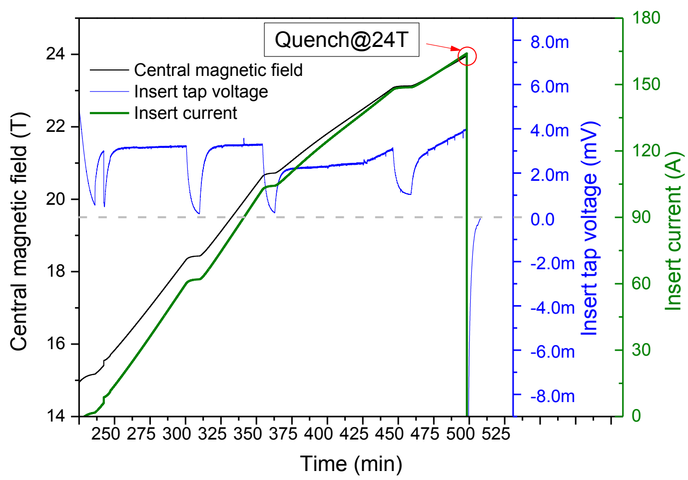


**Fig.3.** Excitation process of ReBCO insert under 15 T background magnetic field

This work was supported by the National Science Foundation of China, Grants 51307163 and 51477167.

## References

[1]. Carmine Senatore, Matteo Alessandrini, Andrea Lucarelli, Riccardo Tediosi, Davide Uglietti and Yukikazu Iwasa, “Progresses and challenges in the development of high-field solenoidal magnets based on RE123 coated conductors,” *Supercond. Sci. Technol.*, **27**, 1-26, (2014).

[2]. U. Trociewitz, M. Canassy, M. Hannion, D. Hilton, J. Jaroszynski, P. Noyes, Y. Viouchkov, H. Weijers and D. Larbalestier, “35.4 T field generated using a layer-wound superconducting coil made of (RE)$Ba_2Cu_3O_{7-x}$ (RE= Rare Earth) coated conductor,” *Appl. Phys. Lett.*, **99**, 202506 (2011).

[3]. Hubertus W. Weijers, W. Denis Markiewicz, *et al.*, “Progress in the Development and Construction of a 32 T Superconducting Magnet,” *IEEE Transactions on Applied Superconductivity*, accepted for publication, (2016).

[4]. J. Bascunan, Y. Hahn, Y. Kim and Y. Iwasa, “An 18.8 T/90 mm bore all-HTS insert (H800) for 1.3 GHz LTS/HTS NMR magnet: insert design and double pancake coil fabrication,” *IEEE Trans. Appl. Supercond.*, **24**, 4300904, (2013).

[5]. S. Yoon, J. Kim, K. Cheon, H. Lee, S.Hahn, and S. H. Moon, “26-T 35-mm All-REBCO Multi-width No-Insulation Superconducting Magnet,” *Supercond. Sci. Technol.*, submitted for pulication, (2015).

[6]. Qiuliang Wang, Yinming Dai, et al., "High Magnetic Field Superconducting Magnet System up to 25 T for ExCES," *IEEE Trans. Applied Superconductivity*, **23**, no.3, 4300905, (June 2013).