Achievement of 24.6 T by Cryogen-free Superconducting Magnet at Sendai HFLSM

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June 15, 2016 (STH41/HP111). Cryogen-free superconducting magnets (CSMs) are operated without liquid cryogen such as liquid helium and nitrogen. Because of the easy operation and long-term magnetic field generation, CSMs are widely used nowadays. The magnetic fields generated by CSM were sustainably improved with time as shown in Figure 1. In 2013, the 20 T cryogen-free superconducting magnet was successfully developed by upgrading of the insert coil from a conventional $Bi_2Sr_2Ca_2Cu_3O_y$ (Bi2223) coil reinforced by co-windings of stainless steel tapes to a high strength Bi2223 coil [1]. It is now routinely available as a user magnet at the High Field Laboratory for Superconducting Materials (HFLSM). As a next step, we started, in 2013, to develop a 25 T cryogen-free superconducting magnet project [2]. It consists of an 11 T high temperature superconducting (HTS) insert and a 14 T low temperature superconducting (LTS) outsert magnet. The HTS and LTS magnets are cooled by two 4K-GM and two GM-JT cryocoolers, respectively. Two single stage GM-cryocoolers are also used for the radiation shield and high temperate ends of the HTS current leads. The LTS and HTS magnets are operated separately by two individual power sources. The magnet was installed at HFLSM on March in 2015 as shown in Figure 2.

For the LTS magnet, high strength Nb_3Sn and NbTi Rutherford cables with 16 strands are adopted. The high strength Nb_3Sn strand is bronze route Nb_3Sn wire, 0.8 mm in diameter, with a Nb-rod-processed Cu-20wt%Nb reinforcing stabilizer [3]. This wire has a high mechanical strength and large RRR values. In addition, the react & wind method combined with repeated bending process was used for the improvement of superconducting properties. It utilized the so called "pre-bending effect" [4]. We design the Nb_3Sn coil with the maximum hoop stress up to 251 MPa. This is a challenging design, but it could be confirmed by using R&D coils that the stress limit of the CuNb/Nb_3Sn Rutherford coil is above 300 MPa [5, 6]. It is well known that many training quenches would be necessary for Rutherford cable coils to achieve the maximum field. However, we reached the 14 T with an operation current of 854 A without any training quench [7]. Instead, many large spike coil voltages and rapid temperature rises were observed during the virgin operation only.

For the HTS insert two separate coils were assembled, a $GdBa_2Cu_3O_y$ (Gd123) and a Bi2223 coil. Fifty six (56) Gd123 pancake coils were stacked and impregnated with epoxy resin. All turns are decoupled through co-winding of Teflon coated polyimide tapes. The high purity Al sheets are mounted on all the pancake coils for good thermal conduction. The Al sheets are connected to the heat exchanger located at the top and bottom ends of the HTS insert coil. The Gd123 insert coil could generate 10.15 T by the operation current of 131.4 A without background magnetic field [8]. In this case, the calculated magnetic field is about 10.5 T. Hence the difference between the measured and the calculated central magnetic fields is about 0.4 T due to the shielding current effects. Unfortunately, the Gd123 coil quenched at 24 T during the combination test.

The Ni-alloy reinforced Bi2223 tape is used for the Bi2223 insert coil, which consists of 38 double pancake coils. The Bi2223 insert generated 11.0 T without the background field and 10.6 T with the background field of 14 T. A maximum field of 24.57 T was confirmed by the Hall probe as shown in the inset of Fig. 2 [9]. Furthermore, we also confirmed the one-hour charge and discharge of 24.6 T, for a 52 mm room temperature bore. The maximum temperatures are about 7.5 K for the HTS and about 5.0 K for LTS magnets during the one-hour charging. The detailed J_c measurements of RE123 films were performed using this 25 T cryogen-free superconducting magnet for trial use. The noise level of voltages is about one order smaller than that in the hybrid magnet at the HFLSM. Details will be presented at ASC2016 at Denver, CO, USA on September, 2016.

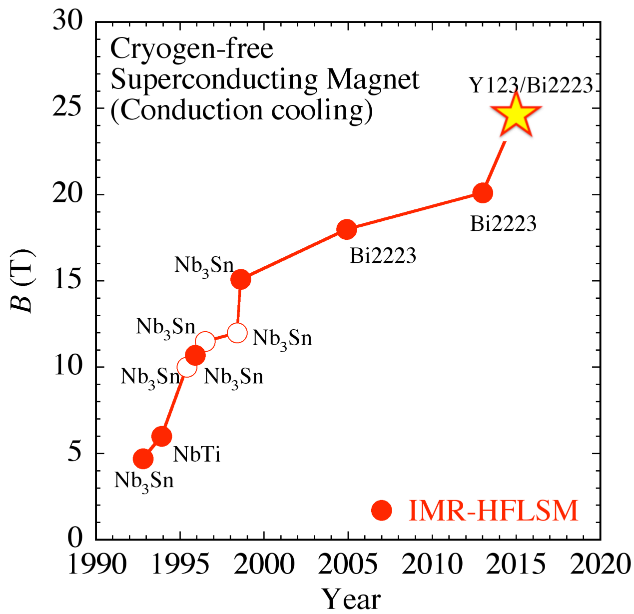

Fig. 1. Progress in cryogen-free superconducting magnet field *B*. The star indicates the 25 T CSM of the present work. Closed circles show the magnets developed by the HFLSM, IMR, Tohoku University. The materials shown in the figure are the materials for innermost coils.

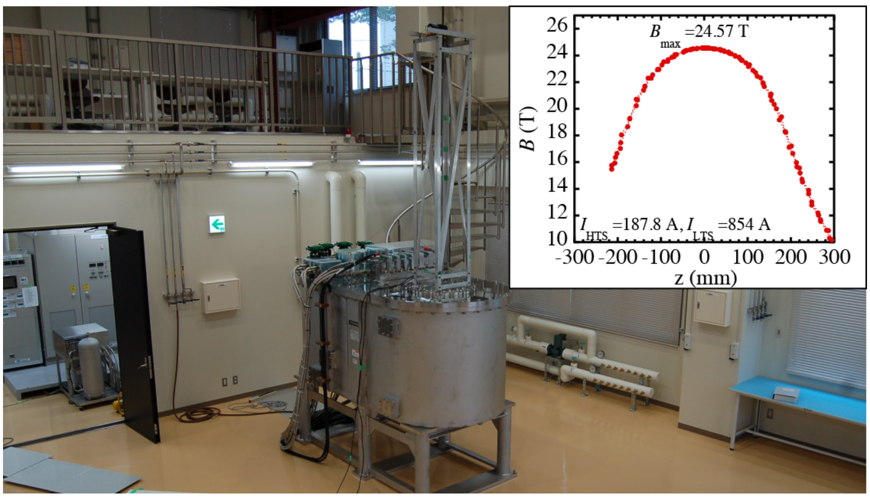

Fig. 2. 25 T cryogen-free superconducting magnet was installed at the HFLSM annex building. The machineries are put in the next room can be seen on the other side of the door. The balcony is for user experimental space. The inset shows the magnetic field distribution at the operation current of 187.8 A for the HTS coil and 854 A for the LTS one.

References

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