Development of a 1.3 GHz (30.5 T) LTS/HTS NMR Magnet in the Persistent Mode

Yoshinori Yanagisawa

RIKEN Center for Biosystems Dynamics Research, Yokohama, Japan

Email: yoshinori.yanagisawa@riken.jp

Abstract – **A Japanese collaborative team, including the present author, commenced a project under the JST-Mirai Program in late 2017 [1]. One of the major development goals is a persistent-mode high-resolution 1.3 GHz (30.5 T) NMR magnet to be used for NMR measurements of various samples such as amyloid beta protein. The magnet comprises a REBCO inner coil, a Bi-2223 middle coil, and LTS (NbTi/Nb_3Sn) outer coils. The coils are with liquid helium at 4.2 K. Layer-winding is employed for the HTS coils since it can allow us to install the joints in low magnetic field areas over the coil windings. From the viewpoint of a persistent-mode operation and quench protection, all the coils are connected in series, forming a single persistent current circuit.**

For fulfilling the typical drift rate of the magnetic field for the high-resolution NMR magnet, < 0.01 ppm/h, the permissible circuit resistance of the 1.3 GHz NMR magnet has to be < 3 x 10^{-9} Ω. The magnet requires several tens of superconducting joints (10^{-12} Ω per joint) between HTSs and several low resistnace joints (10^{-10} Ω per joint) between HTS and LTS [2,3,4]. As a partial demonstration of the 1.3 GHz NMR magnet, a 400 MHz (9.39 T) NMR magnet with a REBCO inner coil with superconducting joints between REBCO conductors was developed and operated over two years, showing that the joints functioned for the stable persistent-mode operation [5].

For demonstrating a 30 T-class high field generation and protection from a quench of the REBCO coil, we developed and tested a LTS/Bi-2223/REBCO model magnet [6]. The magnet reached a center field of 31.4 T and a quench occurred in the REBCO coil. The stored energy of the HTS coils was consumed mainly inside the REBCO coil, owing to the nature of the intra layer no-insulation winding. After the test, the voltage-current performance of the REBCO coil was unchanged.

Based on the technical developments, we have made the basic design of the 1.3 GHz LTS/HTS NMR magnet, which will be developed and tested in the fiscal year 2024.

[1] Maeda et al., *IEEE TAS* 29 (2019) 4602409, [2] Ohki et al., *SuST* 30 (2017) 115017, [3] Takeda Y et al 2019 *APEX* 12 (2019) 023003, [4] Banno et al, *SuST* 32 (2020) 053001, [5] Yanagisawa et al. accepted for publication in *SuST*, [6] Suetomi et al *SuST* 34 (2021) 064003

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