VIEWPOINT

A new no-insulation REBCO magnet of 32 T class

IOP Publishing
Superconductor Science and Technology
Supercond. Sci. Technol. **33** (2020) 080501 (2pp)
https://doi.org/10.1088/1361-6668/ab9686

Viewpoint

A new no-insulation REBCO magnet of 32 T class

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Received 21 April 2020
Accepted for publication 26 May 2020
Published 26 June 2020

Magnetic fields have always been an invaluable tool in all natural sciences. They have lead to the classical Hall effect, are able to accelerate and focus particle beams in high energy physics, and are able to confine hot plasma in fusion reactors. They are useful in testing the magnetic properties of materials and are capable of splitting energy levels, revealing the quantum nature of matter such as the optical Faraday, Zeeman and quantum Hall effects. Additionally, magnetic fields are used in technologies such as cyclotron, electron spin, and nuclear (NMR) resonances which are useful for research in physics, chemistry, biology and medicine. Scientists have always demanded stronger magnets, with the present goal of being to generate a $B = 60$ T steady (direct current) field.

When superconductivity was discovered in 1911, copper wire magnets could already reach a few teslas strength, limited by the maximum magnetization of the iron cores. Almost 30 years later F. Bitter [1] constructed a series of magnets made of circular copper discs rather than copper coils, which were stacked in a helical configuration without any core. The strongest Bitter magnet was then able to reach 10 T at a power of 1.7 MW. These resistive magnets were instrumental in the search for superconducting materials suitable for magnet fabrication [2]. The first such magnets made of Nb_3Sn and NbTi, were constructed 50 years after the discovery of superconductivity. The strongest magnets using these low temperature superconductor (LTS) technologies can reach 23.5 T [3]. NbTi magnets with $B = 9$ T are quite popular, while NbTi+Nb_3Sn magnets are used where fields above 10 T are needed and are affordable up to 15–18 T.

In practice, the strongest resistive magnets (RM) have always been stronger than superconducting (SCM) ones, so being invaluable for the development of better SC wires. The strongest user resistive magnet generates 41 T in the National High Magnetic Field Laboratory, USA (NHMFL) using 33 MW of power. The NHMFL hybrid magnet is a RM combined with the SCM around it, generating the world strongest steady field of 45 T. The cost of energy for RM is an important reason to build stronger SCMs, which are always cheaper in use.

With the discovery of high-temperature superconductors (HTS) in 1986 [4], new high-temperature superconducting (HTS) cuprate materials have been developed. The present day leading conductors for magnets are Bi-2223, Bi-2212, and REBCOs, with the latter being phenomenally robust to magnetic fields as high as 45 T. A record high steady field with a total of 45.5 T was shown in an experiment with a small test REBCO coil, producing 14.4 T in the center of a 31.1 T RM [5]. There are many efforts to build HTS and LTS+HTS magnets. In the USA, the 32 T REBCO user magnet [6] and Bi-2212 NMR prototype [7] have been tested at the NHMFL, while a REBCO NMR is under development at MIT [8]. Efforts in Japan led to the construction of a cryogen free 25 T magnet with a 10 T REBCO insert [9] and a 27.2 T Bi2223/REBCO SCM [10] while a 26 T no-insulation REBCO 26 T [11] and 25 T NMR [12] magnet have been constructed in Korea. In turn 4 T [13] and 7 T [14] REBCO coils are under construction to generate totals of 25 T and 27 T, respectively, in Europe

In China, there is a magnet program as a part of the Synergetic Extreme Condition User Facility initiative. Recently, Jianhua Liu and his team [15] from the Institute of Electric Engineering, Chinese Academy of Sciences, have reached 32.25 T in an all-superconducting magnet. This is a bit more than the old record of the 32 T user magnet in the NHFML. Importantly, this achievement proves the feasibility of reaching that strong field using the no-insulation [16] (NI) winding technique, so far tested up to 26 T [11]. The NHMFL 32 T magnet has insulation between turns. The NI technique is promising for quench protection but this is at a cost of very slow field sweeps and enhanced liquid helium use. The magnet is a combination of a 15 T LTS outer magnet and two inner REBCO coils. A positive result is that no quench happened during the test. On the other hand, there are no data concerning the quench survival and its novel mechanical protection performance. Since the charging of this NI magnet takes hours, the authors propose to use it as a NMR magnet rather than a general science magnet. I disagree a bit, as such a magnet would find a lot of users who measure in constant field when changing other parameters, such as specific heat, angular measurements and temperature sweeps. Especially when semiconductor structures are tuned by electric gates, it sometimes takes days and even weeks to explore all the parameter space.

The National High Magnetic Field Laboratory is supported by the National Science Foundation Cooperative Agreement No. DMR-1644 779 and the State of Florida.

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