AP1-1-INV

The Iseult Whole Body 11.7 T MRI System

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A new innovative Whole Body 11.7 T MRI magnet was manufactured as part of the Iseult/Inumac project, a French-German initiative focused on very high magnetic-field molecular imaging.
It will be the most powerful whole body MRI equipment at Neurospin, a neuroscience research center operating in France at CEA Saclay since November 2006.
This actively shielded magnet system, manufactured from NbTi superconductor, will generate a homogeneous field level of 11.75 T within a 90 cm warm bore. After 7 years of activities, the fabrication has been successfully completed at Belfort by GE Power. The Iseult magnet was delivered to CEA in May 2017 and the final commissioning has started.
The first part of the talk deals with the magnet design and the technical challenges addressed during the R&D phase. The second part presents a summary of the manufacturing and of the final factory tests. An overall status of the commissioning and tests of the ancillary equipment at the site is finally presented, as well as the next steps to reach the nominal field of 11.75 T.

AP1-2-INV

Design and technical development of a high-resolution 1.3 GHz (30.5 T) NMR magnet in a persistent current (PC) mode

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A Japanese research team succeeded in developing a 1.02 GHz (24.0 T) NMR in 2014. The next target is a 1.3 GHz (30.5 T) NMR and we have commenced designing a magnet operated in a persistent current (PC) mode, which is to be used for human brain amyloid beta protein analysis to address Alzheimer's disease.

The magnet is composed of series connected HTS inner coils and LTS outer coils including magnetic shielding coils. Layer-winding is employed in the HTS coils for achieving a homogeneous field and a PC mode operation. The HTS coils are operated in high current densities, 130 - 250 A/mm^2, to generate > 23 T, enabling a compact magnet as small as 800-900 MHz LTS NMR magnets. Major part of the magnetic field is generated by high-strength Bi-2223 coils for reducing the screening current-induced field effect as well as avoiding unexpected degradation frequently observed for a REBCO coil. Two designs have been examined; one comprises a REBCO insert and a Bi-2223 midsert and the other a Bi-2223 insert and midsert. From a viewpoint of magnet size, the former is preferred; while from a viewpoint of reducing degradation and screening current effects, the latter is better.

The stress of the HTS coils are designed to be <335 MPa (Bi-2223) and <400 MPa (REBCO) in hoop stress, and <50 MPa in axial compressive stress. The hoop stresses are lower than stresses at 99% recovery of I_c of the conductors measured at 77 K. We plan to perform hoop stress tests at 4.2 K for more reliable stress design. A numerical simulation of the screening current in the REBCO coil showed the drift and gradient of the magnetic field. However, they are not as large as we expected, since the REBCO insert geometry is long and thin; the resultant error field can be addressed with conventional technologies. A similar simulation is being made on the Bi-2223 coils. A newly proposed layer-wound no-insulation (LNI) method, giving a short field delay and self-protection behavior, can be employed for the REBCO insert. For a PC mode operation, the total coil circuit resistance has to be as low as 0.1 nΩ. As a model experiment, we have been developing a PC mode 400 MHz (9.39 T) LTS/REBCO NMR using a superconducting joint between REBCO conductors with a short processing time of <1 day [1].

[1] K. Ohki et al., *Supercond. Sci. Technol.* in press.

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AP1-3-INV

REBCO coated conductor layer winding for persistent current operation

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Following the recent report on the development of superconducting REBCO conductor joint, the much anticipated persistent current HTS-MRI magnet demands new technology to be developed. Our activities aim to contribute to this new technology by demonstrating a cryocooled REBCO-1T magnet with persistent current joints with resistances less than $10^{-12}\Omega$.

The main challenge here is the joint technology, however, it is also well known that a REBCO magnet fabrication itself is a challenge. The difficulty of layer winding a REBCO coated conductor is in its highly anisotropic tape form that handling process during helical winding may easily induce damages. Although the conductor with thick 75 µm substrate was successfully wound to generate then a record breaking 24 T [1], some difficulties with thinner conductors with 50 µm substrate have been reported [2].

We summarise here our ongoing development of layer winding and implementations necessary for constructing a layer wound REBCO magnet with a persistent current joint. The commercially available 4 mm and 6 mm width conductors are used to fabricate several test coils of different dimensions, as well as coil terminations that feed the wire to the joint. They are tested in gas cooled environment between 30 K and 77 K with applied field up to 12 T, and are compared against the short conductor sample performances measured separately.

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[1] S. Matsumoto et al., Supercond. Sci. Technol. 25, 025017, 2012.
[2] S. Matsumoto et al., IEEE Trans. Appl. Supercond. 22, 9501604, 2012.

Keywords: REBCO coated conductor, layer winding

AP1-4-INV

Highly Compact, High Magnetic Field, High Performance Fusion Reactors Using REBCO Conductor Technology

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High-field, high-temperature superconductors (HTS) would enable a new generation of compact fusion experiments and power plants, dramatically speeding the development path and improving the overall attractiveness of fusion energy. All design concepts for power producing commercial fusion reactors rely on superconducting magnets for efficient and reliable production of the magnetic fields. HTS, particularly Rare-Earth Barium Copper Oxide (REBCO) superconductors, represent a new game changing opportunity that could significantly advance the economic and technical status of magnetic confinement physics experiments and fusion reactors. It could revolutionize the design of magnetic fusion devices leading to very high performance in compact devices with simpler maintenance methods and enhanced reliability. The most revolutionary aspect of REBCO superconductors is maintaining high performance at very high magnetic fields. Historically, the maximum field on coil (limited by achievable current density in the superconductor) has been a primary driver for designing a magnetic fusion device. In this talk we describe how a tokamak fusion device using REBCO allows an increase in toroidal field at the plasma from ~5.5 T for LTS technology to 10-12 T for HTS conductors. (The field at the coil increases from 12T to ~20-25 T). In this talk we present a conceptual design for fusion reactor based on REBCO conductors, showing the physics performance and technological advantages to be gained over LTS conductor technology [1].

[1] B. N. Sorbom*et al.*, ARC: A compact, high-field, fusion nuclear science facility and demonstration power plant with demountable magnets. *Fusion Engineering and Design*.100, 378–405 (2015).

Keywords: REBCO, Fusion Reactor, Superconducting Magnet, High Field

AP1-5

High Field Magnets for Future Circular Colliders

Presented by S. Izquierdo Bermudez on behalf of HL-LHC project and the FCC design study

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The upgrade of the Large Hardon Collider (High Luminosity LHC) relies on the installation of a new generation of superconducting magnets. The resulting peak field, in the range of 12 T, requires the use of Nb_3Sn as superconductor. A next step of energy increase of hadron colliders beyond the LHC requires high-field superconducting magnets capable of providing a dipolar field in the range of 16 T to 20 T with accelerator quality. This presentation summarizes the activities and plans for the development of these magnets at CERN, assessing the critical technical challenges and required R&D.

Keywords: High Field Magnet, LHC, FCC

AP1-6-INV

Progress of Fundamental Technology R&D toward Cryocooler-Cooled Accelerator Magnets

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We report the current status of an R&D project of fundamental technology for cryocooler-cooled HTS accelerator magnets funded by JST under its S-Innovation Program as well as some associated R&D. The topics of the recent progress are as follows.
1) Design and construction of a 2.5 T-class magnet for beam-line test
2) Three-dimensional design and ac loss evaluation technology of cosine-theta magnets wound with coated conductors
3) Quench behavior of conduction-cooled coated conductors subject to transient and localized thermal disturbances
With respect to the first topic, we designed a magnet consisting of racetrack coils and cold iron and are winding the coils. With respect to the second topic, we developed a new scheme for large-scale electromagnetic field analyses, and the magnetic field quality and ac losses of a cosine-theta dipole magnet were evaluated. The third topic is related to the behavior of coils which is subject to the injection of a particle beam. We estimated the disturbance energy caused by beam injection, and quench behaviors of short samples of coated conductor subject to transient and localized thermal disturbances were studied.
The plan of beam-line test will be also reported in the presentation.

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Keywords: coated conductor, magnet, accelerator

AP1-7-INV

Technology priorities in large-scale HTS bulk devices

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Abstract- The design, alignment and the needs in research strategy of HTS bulk application to those of industrial and academic partners is identified and reported. A "Masterplan" for the next 10 years include an interdisciplinary development strategy with physics, material science, cryogenics - all are paired with engineering. We report practical current engineering problems as integrated cooling, vacuum insulation, and mechanical stabilization. Except the application-adapted REBCO bulk fabrication, single or multi-seeded in axial or radial geometry, cryostat design and fabrication technology are basic for application and commercialization. High –speed small rotational magnetic bearings with low hysteresis of less than 0.1 mm and 100 N load at 77 K are tested for He pumping. Journal superconducting magnetic bearings of 160 – 200 mm diameter handle and stabilize safely loads above 10 kN. Linear magnetic bearings operate in comparable lightweight portable cryostat modules. Magnetic forces of up to totally 6 ton load are obtained by assembling HTS bulk cryostats under the vehicles. Lightweight and flexible 500 mm axial HTS bulk bearings were developed for cosmic microwave background (CMB) radiation polarization detection. The key is a frictionless smooth rotational movement of a sapphire half-wave-plate (HWP) rotor which relies on the great magnet homogeneity of the PM rotor. Extremely safe conditions and requirements are the surrounding circumstances of manned spaceflight experiments. The space project Magvector/MFX in cooperation with Deutsche Luft- und Raumfahrt (DLR) and AIRBUS in Germany was built successfully within 15 month and launched to the International Space Station (ISS). Since two years the interaction of the Earth magnet field with a fast moving bulk superconductor has been measured systematically. The experiment is planned to continue within the next German Mission "horizons" in April 2018. By evaluating HTS devices and controlling the results the main technology priorities were identified for future industrialization. We estimate and report the necessary scaling of HTS bulk manufacturing process, the reliable and cost-efficient cryogenics including the fabrication of lightweight cryostats.

Keywords: Large-scale devices, space application, Magnetic bearings, Maglev devices