Accelerator and Fusion Research Division

LBNL Superconducting Magnet Program Newsletter

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HD-1: Progress Report

Heading Toward 16 Tesla Dipole Fields

Our current project is the construction of HD-1, a high field, Nb_3Sn, "block" dipole magnet. The single-aperture magnet is a significant departure from our past dual-aperture Common Coil ("RD") Dipole Magnet series. It is still based on racetrack coils and utilizes the same mechanical support concepts as the RD-series; however, the coils are arranged in a horizontal configuration. The central dipole field can reach 16 Tesla in a 20x10 mm aperture using the highest performance Nb_3Sn available, and can be further increased in subsequent models by grading the outer turns of the coil. If fully successful, HD-1 will eclipse the previous dipole field record of RD-3 by more than a Tesla. At the same time, the conductor area and the demands on the outer support structure are a fraction of what would be required for a high field common coil design, and the required yoke diameter is significantly smaller. Integration of new coil support structural components and improved processes utilized and tested in our Subscale Magnet Program have been injected into the HD-1 design. The forces generated by HD-1 are quite different from that of the RD-series and pose challenges in applying bladder and key technology in our aluminum shell and iron yoke loading structure.

Studies are underway to determine the field quality that could be achieved in such a structure, and its implications on the maximum dipole field. The single aperture configuration halves the coil volume, electromagnetic forces, stored energy and inductance. In addition, shorter coil length and reduced transverse size are possible with additional savings on magnet fabrication and testing. Other new elements in this design (with respect to the RD series) are the high load on the cable's broad face (the more compliant direction) and the absence of a central island. Subsequent steps in the HD series will aim at increasing the dipole field using a combination of improved conductor, saddle coils with no midplane gap, and graded coils, and possibly the use of high-temperature superconductor inserts as a means of achieving fields over 17 Tesla. The coils have been reacted and the first coil is ready for impregnation. Testing is scheduled for the fall.

HD-1 coil ready for impregnation.

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DOE Advanced Technology R&D Program
Senior Program Officer, Dr. David Sutter

Program Highlights

New Applications for Nb3Sn Technology

The main magnet program is extensively supported by conductor studies and work on sub-sized_model magnets. The sub-scale magnet program is now well underway with five tests completed and several more planned for this year. Sub-sized models are used to test support structure designs, investigate new coil geometries and evaluate cable designs. A test performed this spring in collaboration with the Fermilab Magnet Group was designed to investigate the effects of thermally induced stress on the strain sensitive Nb_3Sn coils. A specially instrumented coil was subjected to temperatures exceeding 400 K during quench with no degradation of performance. While this result is very encouraging, more work will need to be done in order to determine operating limits for full-scale magnets.

This year the group is working on two Laboratory Directed R&D (LDRD) projects; "Superconducting Magnet Systems for Ex-situ NMR Spectroscopy" and "Short Period Superconducting Undulator Development". Both projects benefit significantly from materials and techniques developed in the base program.

In ex-situ NMR, a mobile magnet is scanned over an otherwise inaccessible object or subject in order to acquire magnetic resonance information. The quality of the ex-situ NMR data, and the development of ex-situ NMR techniques, would greatly benefit from the availability of higher field strength provided by Nb_3Sn. A fully optimized superconducting magnet using advanced conductors can be expected to achieve an additional increase of the field strength by a factor of at least 2-3 compared to other options.

Development of short-period, narrow-gap superconducting insertion devices is critical to applications in both future synchrotron radiation sources and in existing rings. The LDRD is addressing this requirement by developing and implementing beyond state-of-the-art Nb_3Sn superconductor/copper matrix technology, pushing the copper current density in excess of 5,000 A/mm^2 in order to design undulator-compatible superconducting coils with the highest possible fields for the appropriate undulator geometries. Focusing early R&D efforts on these issues will enable timely design and development of full-scale insertion devices [IDs] with fully integrated cryogenics and accelerator compatibility later on.

DOE Conductor Development Program

Record J_c Achieved!

About three years ago DOE initiated a conductor development program to focus on the needs of the HEP community. The program has several target specifications with the initial priority of attaining a non-Cu critical current density (J_c) of 3,000 A/mm^2 at 12T and 4.2 K. Dr. Seung Hong and his colleagues at Oxford Superconducting Technologies achieved this goal in November 2002. Our group was one of the first to be able to measure this high current conductor. A strand with a diameter of 0.8mm carried 776A (J_c=3,115 A/mm^2 at 4.2 K and 12.0 T with self-field). The emphasis of the program is now shifting to the second goal – reducing the effective filament size to 40 microns without sacrificing the gains in J_c. Using the new knowledge gained from this research as a base, the program will then move into a fabrication scale-up phase where the performance and cost-effectiveness can be demonstrated on production-size quantities.

Conductor and Cable

Progress on Rutherford Cables

One of the key activities of our superconductor R&D program is the development of improved techniques and tooling for the fabrication of Rutherford-style cable. Our cabling machine greatly enhances our experimental program. It can produce cable with as many as 60 strands - about a third again as many as other cabling machines. Cable can be produced in a variety of cross sections, including keystoned and rectangular (and with or without a core). This capability provides our magnet designers with additional flexibility in their choice of superconducting materials and cable designs.

Our cabling activities this year have encompassed a wide variety of projects. LBNL continues to provide significant cabling support for other magnet and cable development programs. As part of our collaborative activities this year we supplied cables to six other groups. When a production cabling machine broke down at one of the LHC cable vendors, LBNL stepped in to provide 4.2 km of cable, maintaining a continuous supply of cable to keep LHC magnet production on track.

Another important activity is the development of new cables. At present, we are the only group developing the technology to make Rutherford type cables from the high temperature superconductors. Using Bi-2212 strands provided by IGC and Showa Electric, we have made cables with 18-20 strands that carry over 5000 A at 5 T, 4.2 K. This year we produced a single length of 300 m for Showa Electric. The critical current of the Bi-2212 wires has been improving steadily, and it may soon be possible to consider using these materials to generate dipole fields above 17 Tesla.

LHC Accelerator Research Program

New Opportunity for Technology Development

The U.S. Large Hadron Collider (LHC) Accelerator Research Program (LARP) is a follow on activity to the U.S. LHC Accelerator Construction Project, a collaboration of Berkeley, Brookhaven and Fermilab. Participation in this program will build on the previous investment in the construction project and ensure continued development of domestic accelerator science and technology, keeping U.S. accelerator scientists at the forefront of the field. The multi-year program includes participation in commissioning the accelerator and U.S.-provided components, design and construction of state of the art beam instrumentation, accelerator physics studies, and design and technology development required for an upgrade of the interaction region magnet systems to increase luminosity. The program was recommended for funding at a DOE review in June.

The challenging requirements, along with recent progress, has led to the choice of Nb_3Sn as the conductor material for the proposed LHC upgrades. The LARP will be an important application of Nb_3Sn technology, helping to drive it well beyond state-of-the-art, significantly enhancing U.S. options in accelerator technology and providing opportunities for new applications.

Selected Publications

"Calculating Quench Propagation with ANSYS," S. Caspi et al, to be published in Trans. on Applied Superconductivity June 2003, SC-MAG #763, LBNL-49906.

"Nb_3Sn Quadrupole Magnets for the LHC IR," S. Caspi et al, ibid, SC-MAG #764, LBNL-49901.

"Performance Comparison of Nb_3Sn Magnets at LBNL," L. Chiesa et al, ibid, SC-MAG #771, LBNL-49916.

"Progress and Plans for the U.S. HEP Conductor Development Program", R.M.Scanlan and D.R.Dietderich et al, ibid.

"An Approach for Faster High Field Magnet Technology Development," S. Caspi, et al, ibid, SC-MAG #773, LBNL-49918.

"Test Results for RD3-c, a Nb_3Sn Racetrack Dipole Magnet," A.F. Lietzke et al, ibid, SC-MAG #771, LBNL-49917.

"Post-LHC Accelerator Magnets", S.A. Gourlay, IEEE Trans. Appl. Supercond., Vol. 12, No. 1, March 2002, pp. 67 - 74, SC-MAG #766, LBNL-49903.

"A New Support Structure for High Field Magnets," S. Caspi et al, ibid, pp. 47 - 50, SC-MAG #738, LBNL-47796.

"*A Superconducting Undulator for 3rd-Generation Light Sources*", S. Caspi, et al, ibid, pp. 682 – 685, LBNL-47799, SC-MAG #739.

For more information contact:
Stephen A. Gourlay, Head
Superconducting Magnet Program
Lawrence Berkeley National Laboratory
MS 46R0161
Berkeley, CA 94720-8203
E-mail: sagourlay@lbl.gov
Web Site: http://supercon.lbl.gov/

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