Florida State University • University of Florida • Los Alamos National Laboratory

NHMFL REPORTS

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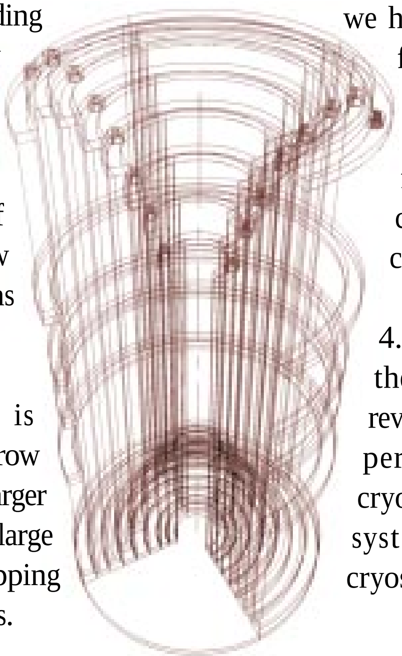
National High Magnetic Field Laboratory

Full Steam Ahead for the 900 MHz Project

The 900 MHz project has been getting a lot of attention lately—as well it should be. The 900 MHz and the 45 T Hybrid are two of the four centerpiece magnet systems to be operated at the NHMFL. The other significant deliverables were the 33 T resistive magnet (commissioned in February, 1996, with two additional 33 T systems delivered since then) and the 60 T Long-Pulse magnet (commissioned in August, 1998). The production of the 900 MHz and the 45 T magnet systems has been done in collaboration with Intermagnetics General Corporation (IGC) who have contributed essential manpower, technical assistance, and production efforts, and who now share in the technology required to build these cutting edge magnet systems. Now that the 45 T Hybrid is in its initial testing phase (see page 18), the focus has shifted to completion of the 900 MHz. This article discusses the major activities on the 900 MHz system over the past year including a brief summary of the recent external review committee report and production milestones achieved.

On May 6 and 7, 1999, an external review of the entire 900 MHz project was held. A few of their key comments and recommendations were as follows.

1. The NHMFL 900 MHz magnet is distinguished from presently competing, narrow bore commercial projects by its significantly larger bore (110 mm) and the potential that the large bore provides for serving as the essential stepping stone to 1 GHz or higher frequency systems.



2. The motivation to construct 900 MHz magnets has strengthened significantly since the present project was started. Four companies are now vying to offer narrow bore (52-63 mm) 900 MHz magnets to an eager NMR user community. Due to the high stored energy of the 900 MHz system and the associated large magnetic forces, however, the production of a successful system is challenging. Consistent with this, all of the companies attempting the 900 MHz challenge are approaching their projects with considerable care and caution and none have yet succeeded in delivering the next evolution in high field NMR magnets. For multiple reasons, the NHMFL wide bore 900 MHz magnet lies at the forefront of superconducting NMR magnet technology.

3. On the basis of the presentations made at this review, we have good confidence that there are no fundamental barriers to project success. Experimental verification should be pursued, however, for certain key features of the magnet prior to final commitment of the full scale components.

4. The principle recommendation is that the present aggressive schedule should be revised to include successful test of full scale persistent current joints and a bucket cryostat test of the superconducting magnet system before welding it into the user cryostat.

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Operated by Florida State University, University of Florida, Los Alamos National Laboratory

From the Director's Desk


Jack Crow

It has been nine years since the NHMFL was established, and we are now engaged in strategic planning for the upcoming five-year renewal and reevaluating the laboratory's vision and mission for the next ten- to fifteen-year period.

We are giving considerable thought to how we can more responsively and cost effectively serve the broad and interdisciplinary research communities and how we can maintain leadership with innovative instrumentation and facilities. To that end, the NHMFL and Sandia National Laboratory are co-sponsoring a small workshop on Innovative Measurement Technology on August 12-13. The workshop will be held in Albuquerque, New Mexico, and will focus on the applications of nano- and micro-fabrication technologies to new instrumentation that open new scientific opportunities or enhance existing methodologies. Of particular interest are:

- Magnetometers with improved sensitivities, high precision magnetization measurements on small samples, thin films and single crystals and increased dynamic range to address needs for high field magnetization measurements in pulsed field applications,
- Calorimetry on a chip with integrated thermometry and heater systems for rapid measurements in quasi-continuous pulsed magnets and DC magnets,
- The development of micro-scale amplifiers and other electronic components operating at low temperatures and high magnetic fields and the integration of these components with measurement techniques, and
- The development of micro-coil technology for nanoliter NMR measurements on biological and chemical systems.

We sincerely appreciate Sandia National Laboratory's interest in this important collaborative effort. Together, we believe this workshop will help us to identify opportunities to apply micro-electro-mechanical systems (MEMS) technology to new instrumentation, thereby further enabling new science and improving experimenters' productivity by increasing measurement sensitivity, decreasing noise or data acquisition time, or shrinking sample size.

In the same collaborative spirit, we look forward to continued cooperation with the other major high field magnet laboratories around the globe and building on the partnerships with the National Research Institute for Metals in Tsukuba, Japan, the CNRS/MPIF High Magnetic Field Laboratory in Grenoble, France, and the High Magnetic Field Laboratory at the University of Nijmegen, Netherlands. These partnerships are important so that all of us can provide exciting science and technology to researchers.

In addition, we are looking at ways to serve researchers at other venues. For example, the unique features of the Advanced Photon Source at Argonne National Laboratory (ANL) can be enhanced with the addition of high magnetic fields in the experimental area. The NHMFL and ANL are exploring ways to add several magnetic field configurations at ANL to exploit the capabilities of x-rays for elastic and inelastic magnetic scattering, time dependence of magnetism, and magnetic microscopy. In another collaboration, this one with Los Alamos National Laboratory and the Department of Energy, the NHMFL is building two 20 mm bore, split-pair magnets that will achieve fields up to 30 T. The magnetic field will be pulsed at a rate of 2 Hz, and will be synchronized with the Los Alamos Neutron Science Experiment (LANSCE) neutron source to provide a combination of high magnetic fields and neutron scattering unique in the world.

Suffice it to say that the laboratory is strongly committed to engaging with other laboratories, universities, and the private sector to open new science opportunities and enhance U.S. competitiveness. Readers might wish see page 10 of this newsletter for additional information on the extensive collaborative activities of the NHMFL.

From the Chief Scientist's Desk


Robert Schrieffer

Remarkable results are reported by Z. Fisk, J. Sarrao, and J. D. Thompson concerning the magnetic behavior of doped divalent alkaline earth hexaborides. For a doping by only 0.5% by La, they observe a metal insulator transition with the resistivity changing by a factor of 100. Even though there are no magnetic ions in these materials, they observe a weak ferromagnet moment with its magnitude peaking at 0.5% doping. In spite of a weak moment they observe a very high Curie temperature. They suggest that this might correspond to the ferromagnetic phase long predicted theoretically for a low carrier concentration by Felix Bloch and Eugene Wigner.

This work recently appeared in *Nature* (D.P. Young *et al*., *Nature* 397 (1999) p. 412-414) and was the subject of a News and Views article by David Ceperley (*Nature* 397 (1999) p. 386-387).

High-Temperature Weak Ferromagnetism in a Low-Density Free-Electron Gas

Z. Fisk, National High Magnetic Field Laboratory and Department of Physics, Florida State University; Los Alamos National Laboratory

J. L. Sarrao, Los Alamos National Laboratory

J. D. Thompson, Los Alamos National Laboratory

Abstract

In the course of studying correlated electron phenomena in cubic rare-earth hexaborides, we prepared crystals of divalent alkaline-earth hexaborides, e.g. CaB_6, electronically doped by substituting small amounts of non-magnetic La^{3+} or Th^{4+} for Ca^{2+}. Minute substitutions changed the temperature-dependent resistivity from semi-metallic to metallic-like and the low-temperature magnetization from paramagnetic to weakly ferromagnetic. Systematic study established that the saturated ferromagnetic moment reached a maximum value of about 0.07 μ_B /(La or Th), which was peaked sharply around an electron concentration of $7x10^{19}$ electrons/cm^3, irrespective of trivalent or tetravalent substitutions. Similar behavior was found for La substitutions into SrB_6 and BaB_6. Interestingly, the Curie temperature of 600 K at optimum La doping corresponded closely to the Fermi temperature of the electron gas, estimated to be 720 K at this electron density. The most plausible explanation for our observations is that these materials represent the first realization of a three-dimensional, spin-polarized low-density electron gas first predicted by Bloch in 1929.

The cubic rare-earth and alkaline-earth hexaborides have been a source of much interesting physics and many surprises despite their remarkable crystallographic simplicity. The crystal structure of these materials consists of a simple cubic lattice of rare-earth or alkaline-earth ions with a B_6 octahedron in the body-centered position of this lattice. Because the B_6 octahedron has a formal charge of -2, alkaline earth (A^{+2}) hexaborides should be semi-conducting while rare earth (R^{+3}) hexaborides should be metallic. Detailed band structure calculations (Massida *et al*., *Z. Phys. B* 102 (1997) 83-89), in fact, find that CaB_6, the subject of this work, is semi-metallic. Here we report the response of this seemingly simple semi-metal to heterovalent replacement of Ca^{2+} with La^{3+} and Th^{4+}.

Figure 1 (see page 6) shows the electrical resistivity of single crystals of $Ca_{1-x}La_xB_6$ as a function of temperature. With only 0.5% of the Ca ions being replace with La, we observe a change to a metallic-like temperature dependence and a 50x drop in resistivity at low temperature. The remarkable aspect of these La-doped borides is seen in Figures 2 and 3, where we plot magnetization versus field for a range of La-doped samples. Despite the absence of any magnetic ion in these materials, a weak ferromagnetic moment is evident, its magnitude peaking near x=0.005 and with no moment observed for x=0.20. Similar results have been obtained using doped alkaline-earth hexaborides BaB_6 and SrB_6. That this moment is an intrinsic function of carrier concentration is supported by the data for Th-doped CaB_6 (see inset, Figure 2). Because Th is tetravalent, it will contribute one more electron than trivalent La, and hence if the moment is a function of carrier count, compounds with $Th_{0.0025}$ and $La_{0.005}$ should have the same moment (as we, in fact, observe). In both cases this

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ATTENTION USERS

Timothy Cross
Director, NMR Program

NHMFL NMR Spectroscopy and Imaging Program

The NMR spectroscopy and imaging program at the NHMFL has two user missions for the Chemistry and Biological communities: the development of a premier high field NMR technology and application development facility, and an in-house NMR facility for a very broad range of NMR spectroscopy and imaging activities. This latter mission is closely associated with a number of academic units on the Florida State University and University of Florida campuses. In particular, the University of Florida Brain Institute has contributed a great deal of resources to this joint venture (see related article, page 9).

The former mission aims to attract science and technology investigators as users interested in advancing the frontiers of NMR technology and application science for spectroscopy and imaging. During the past 12 months, 42 external principal investigators used the facilities of the NHMFL NMR Spectroscopy and Imaging Program either as external users or as collaborators with NHMFL faculty.

The NHMFL's aggressive magnet development efforts will be matched by equally aggressive efforts to develop new NMR probes and instrumentation, both through in-house efforts and through partnerships with industry. The present NMR spectroscopy and imaging program at the NHMFL has several significant magnet systems around which a set of unique capabilities has been developed. Now we are looking toward the development and installation of very high field superconducting, resistive, and hybrid magnets for the continuing growth of this mission.

Present Major NMR Spectroscopy and Imaging Systems

- 25 T (1066 MHz for ^{1}H), 52 mm bore resistive magnet having 1 ppm stability and a homogeneity of 50 ppm over a 1 cm dsv (without shims). The shimmed goal is 1 ppm over a 1 cm dsv. Using first version ferroshims, homogeneity has been improved to 12 ppm over a 1 cm dsv. TecMag double resonance spectrometer with a separate channel for a field frequency lock; 500 watts at 1066 MHz available; single frequency static probe and single frequency MAS probes currently available.
- 19.6 T (833 MHz for ^{1}H), 31.6 mm bore superconducting magnet with approximately 1 ppm homogeneity over a 1 cm dsv without RT shims. With RT shims, 1 ppb over a microcoil is anticipated. Presently using the 25 T spectrometer system, but soon (see below) will have a triple resonance Avance Bruker console. Single frequency static probe and double resonance MAS probes currently available.
- 14 T (600 MHz for ^{1}H), 89 mm bore magnet with 1 ppb homogeneity. A triple resonance Bruker console is available with a double resonance MAS probe, double resonance *in vivo* and microimaging probes. Also single resonance static probe.
- 9.4 T (400 MHz for ^{1}H), 89 mm bore magnet with an HTS ^{1}H probe and a triple resonance Varian console.

NMR User Facility Capabilities

To be successful as an NMR facility, this NHMFL program is developing unique capabilities, both in technology development and applications development.

Technology Development

NMR Technology for Inhomogeneous Magnetic Fields. The highest fields attainable are substantially more inhomogeneous than chemists and biologists are typically accustomed to. At the NHMFL, we in cooperation with external users and visitors are developing methods to improve the homogeneity in these magnets or to circumvent the spectral problems such inhomogeneity causes:

- Improving homogeneity and stability in resistive magnets
- High resolution spectra in low homogeneity magnets
- Microcoils for solution NMR
- Stray field imaging
- Liquid chromatography NMR.

Increasing Sensitivity and Resolution. The primary challenges in NMR technology involve improving sensitivity and resolution. At the NHMFL, a variety of approaches are being used to address these challenges:

- High sensitivity probe development: A high temperature superconducting probe
- Hyperpolarized Xenon-129 facility
- Double rotation NMR for observing quadrupolar nuclei
- High field ^{19}F solid state NMR
- Magic angle turning at high magnetic fields.

Application Development

High Fields for Sensitivity, Spatial and Spectral Resolution. The primary drivers for high field instrumentation include sensitivity, spatial and spectral resolution. At the NHMFL, we are taking advantage of these high field opportunities:

- Pulse field gradient NMR diffusion measurements
- High resolution velocimetry
- Spatially resolved electrophoretic mobilities and electroosmotic flow
- Single cell microimaging
- High field structural constraints for membrane proteins.

High Field Phenomena. High fields provide much more than improvements in sensitivity and resolution, and a number of important high field phenomena are being investigated:

- Orienting samples in magnetic fields
- ^{2}H wideline spectroscopy of short T_{2e} samples
- Observing low Gamma nuclei
- Dynamics in deuterated proteins
- GAMMA.

Facility Developments in Progress

The following new systems and instrumentation are being added to the NHMFL NMR Spectroscopy and Imaging Program, thereby expanding and enhancing our facilities for users. Three significant new facilities will be available in Gainesville (noted); the other systems will be housed in Tallahassee.

- 750 MHz, 17.5 T, 89 mm bore system with Bruker console in Gainesville at UF. Expected 10/99.
- The 600 MHz, 14 T, 51 mm bore spectrometer system in Gainesville at UF is being upgraded and a cryoprobe added. Expected 10/99.
- A Bruker console will be delivered with a phased array system for the 11.7 T, 400 mm bore, magnet system in Gainesville at UF. Expected 10/99.
- Double resonance solution NMR probe for the 25 T resistive magnet (Doty Scientific). Delivered 5/99.
- Double resonance H/X static probe for 89 mm bore 14 T (Doty Scientific). Delivered 6/99.
- Double resonance 5 mm MAS probe for 19.6 T (Doty Scientific). Delivered 7/99.
- Single resonance static ^{2}H probe for 19.6 T and 25 T (Doty Scientific). Delivered 8/99.
- Triple resonance H/X/Y MAS probe for 89 mm bore 14 T (Varian Associates). Delivered 8/99.
- Resistive shims for the 31 mm bore of the 19.6 T magnet (Doty Scientific). Expected 8/99.
- Double resonance static H/F probe for 19.6 T (Doty Scientific). Expected 10/99.
- Triple Resonance H/F/X MAS probe for 89 mm bore 14 T (Doty Scientific). Expected 10/99.
- Ferro- and resistive shims for the 25 T resistive magnet (Resonance Research). Expected 10/99.
- Single resonance double rotation (DOR) probe for 17.2 T and 25 T (Ago Samosan). Expected 10/99.
- Single resonance stray field imaging probe for 19.6 T (Andrei Samoilenko). Expected 12/99.

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New Resistive Magnet Available for Users

A 27 T, 50 mm bore magnet is now available to users. It replaces one of the original 20 T magnets with which the NHMFL first opened for business. The Resistive Magnet Group deserves congratulations for creative reuse of existing parts to put together a low cost, useful magnet in a short time. Further information, including drawings and a calibration sheet are available at *http://www.magnet.fsu.edu/user/facilities/dcfacilities/cell5/index.html*
or by contacting Dr. Bruce Brandt, director of the DC Field Facility User Program (850-644-4068 or *brandt@nhmfl.gov*).

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corresponds to a carrier density of 7x10^{19} electrons/cm^3. Measurements of the temperature dependence of the magnetization of $Ca_{0.995}La_{0.005}B_6$ reveal a loss of magnetization near the Curie temperature, T_c~600 K.

Two suggestions for the origin of the weak ferromagnetism that we have observed are (1) ordered defect moments and (2) ferromagnetic polarization of the low-density electron gas. Because no obvious source for a strong coupling giving rise to a Curie temperature as high as 600 K presents itself, and because of the experimental robustness of the result, the coupling of unspecified impurities on this scale seems implausible. A more likely candidate for the origin of magnetic polarization comes from theoretical studies of electronic correlations in the low-density electron gas. This is a topic of theoretical speculation with a long history dating to the 1920's with the work of Felix Bloch and Eugene Wigner. More recent calculations have been made by Ceperley and Adler (*Phys. Rev. Lett*. 45 (1980) 566-569), and by Gerardo Ortiz and collaborators at Los Alamos (G. Ortiz, M. Harris, and P. Ballone, cond-mat/9810126). These calculations predict that a polarized ferromagnetic state is energetically favored over an unpolarized one for $r_s \sim 20\ a_B$, where r_s is the radius of a sphere containing one conduction electron and a_B is the Bohr radius. For $Ca_{0.995}La_{0.005}B_6$, we find $r_s = 15.0$ Å $= 28.4\ a_B$, using the Bohr radius for the free electron. Furthermore, these calculations predict a partial ferromagnetic polarization of the order of 10%, again in quantitative agreement with our result of 0.07 μ_B per carrier. The natural energy scale for such a phase is the Fermi energy, E_F; for free electrons we have $E_F = 0.062$ eV = 720 K, of the order of the observed Curie temperature. Thus, although the observation of weak ferromagnetism in doped alkaline-earth hexaborides is at first glance quite surprising, in reality it appears to be simply the first experimental observation of a theoretically long-predicted result.

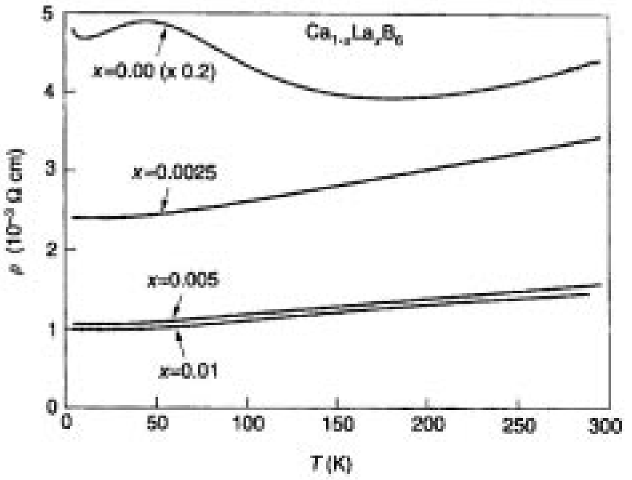

Figure 1. Temperature dependences of the electrical resistivities of La-doped CaB_6. Note that the resistivity for pure CaB_6 has been re-scaled to fit the figure.

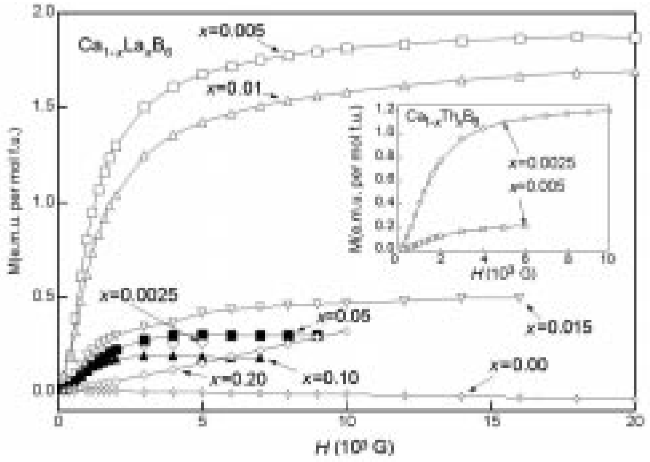

Figure 2. Magnetization per mole of compound versus applied field for La-doped CaB_6 measured at 5 K. The inset shows similar data for Th-doped CaB_6 in which the maximum in saturated magnetization occurs at one-half the nominal doping of that of La-doped CaB_6.

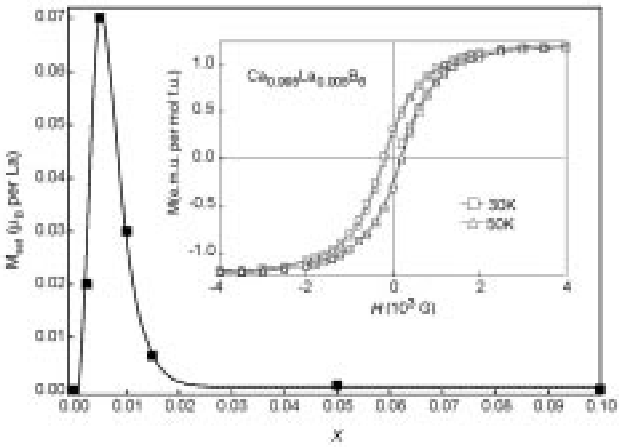

Figure 3. Saturation moment per mole La at 5 K as a function of La concentration in CaB_6. The line is a guide to the eye. The inset shows hysteresis loops at 30 K and 50 K for $Ca_{0.995}La_{0.005}B_6$.

Conference and Workshop Activity

Workshop on Innovative Measurement Technology
August 12-13, 1999
Albuquerque, New Mexico

This workshop will focus on the application of nano- and micro-fabrication technologies to new instrumentation. Its goal is to identify opportunities to apply micro-electro-mechanical systems (MEMS) technology to new instrumentation that enables new science and enhances experimentation opportunities by increasing measurement sensitivity, decreasing noise, decreasing data acquisition time, or shrinking sample size. The workshop is being co-sponsored by Sandia National Laboratory and the NHMFL. (See *From the Director's Desk*, page 2, for further details.)

16th International Conference on Magnet Technology (MT-16)
September 26-October 2, 1999
Sawgrass Marriott Resort, Ponte Vedra Beach, Florida

Early Registration Deadline: August 15, 1999

Hits to the MT-16 web site and incoming faxes reached record numbers on June 15—the deadline for abstracts for the 16th International Conference on Magnet Technology. The conference abstract review committee has been so impressed by the cutting edge science reported in the abstracts—as well as the numbers—that they have increased the number of oral contributors to approximately 150. MT-16 is shaping up to be extraordinary science and engineering experience, with 350 attendees expected and proceedings to be published by IEEE.

MT-16 will bring together scientists, engineers, and experts from around the world to focus on the latest developments in technology, operation, applications of research and industrial magnets, and magnet materials. The program will feature a range of topics such as magnets for accelerators and fusion and the generation of high fields. A major emphasis will be on industrial applications, such as magnets for NMR and MRI, energy storage, levitation, and separation. Several sessions will be dedicated to new developments in high and low temperature superconductors and other magnet materials for reinforcement, impregnation, and insulation.

The meeting will combine technological and scientific aspects of magnet technology. Basic investigations involving magnet materials, electrodynamics, stability of superconductors, heat transfer, He II cooling, cryogenics, etc., will be an integral part of the conference program. System optimization, magnet analysis, design strategies, new instrumentation, and related issues also will be included.

Industrial & Scientific Exhibition. A special exhibition will be held at the conference that will display a wide range of products in the field of magnet technology, achievements in magnet technology, and services offered by industry, academia, and research laboratories. Organizations interested in participating in the exhibition should contact conference organizers.

Complete information and registration is available online at *www.magnet.fsu.edu/mt16*. Interested individuals or organizations may also contact Jo Ann Palmer (850-644-1933, *mt16@magnet.fsu.edu*, fax 850-644-8350).

30th Southeastern Magnetic Resonance Conference (SEMRC)
November 4-6, 1999
DoubleTree Hotel, Tallahassee

The NHMFL is pleased to host this conference again—for the third time in five years! Following its traditional format, SEMRC will feature invited

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and contributed papers and posters in NMR, MRI, EPR, and ICR. Topics will include:

- Improving Sensitivity
- High Field Spectroscopy
- New NMR Methods
- Isotope Labeling Strategies

In addition, there will be a special event: *A Celebration of the Life and Work of Gitte Vold*.

Registration forms are available on line (see NHMFL web site *www.magnet.fsu.edu*). For information, contact Jo Ann Palmer (850-644-1933, *palmerj@magnet.fsu.edu*, or fax 850-644-8350).

Physical Phenomena at High Magnetic Fields (PPHMF-IV)
October 19-24, 2001
Santa Fe, New Mexico
Hotel Headquarters: Hilton Santa Fe

The purpose of PPHMF-IV is to bring together experts to discuss advances in areas of science and applications in which high magnetic fields play an important role. This conference was initiated in 1991 by the NHMFL and has grown in interest, significance, and attendance each recurrence. After three meetings in Tallahassee, the NHMFL is excited to be hosting this fourth conference in Santa Fe, New Mexico, near the NHMFL Pulsed Field Facility at Los Alamos National Laboratory.

For information, contact Dr. Alex Lacerda (director of the NHMFL–Los Alamos Users Program), 505-665-6504, *lacerda@lanl.gov*, fax 505-665-4311.

Applied Superconductivity Conference (ASC04)
October 4-8, 2004
Tentative site: Jacksonville, Florida

The NHMFL will host the Applied Superconductivity Conference in 2004. This is the premier conference in applied superconductivity and occurs in even numbered years only. The past two conferences have had over 1500 attendees; less than half of the attendees have been from the United States. Justin Schwartz (Associate Professor of Mechanical Engineering and NHMFL Magnet Science & Technology Group Leader) is the conference chair; John Miller (head of the NHMFL Hybrid Project) is the program chair. Further details will be reported as they become available. In the interim, Dr. Schwartz may be contacted at 850-644-0874, *schwartz@magnet.fsu.edu*.

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- A research small animal facility has been funded and is being constructed. Expected 1/00.

NMR User Facility Faculty

The NHMFL has an excellent group of faculty who are available to help users from training on the instruments to collaborating in a wide range of scientific disciplines. Bill Brey and Peter Gor'kov joined the laboratory recently to initiate our RF program for the development of unique NMR probes and console capabilities.

- Dr. Nagarajan Murali: expertise in macromolecular solution NMR, pulse sequence development and theory
- Dr. Scott Smith: expertise in spin system simulations, relaxation phenomena, and theory, developer of GAMMA
- Dr. Zhehong Gan: expertise in solid state NMR, pulse sequence and hardware development, and theory
- Dr. Riqiang Fu: expertise in solid state NMR, pulse sequence development, biological and chemical applications
- Dr. William Brey: expertise in high temperature superconducting probes, cryogenic probes and *in vivo* spectroscopy and imaging
- Mr. Peter Gor'kov: expertise in probe development for imaging and *in vivo* spectroscopy.

For further information about the NMR user facilities at the NHMFL, contact Dr. Timothy Cross, 850-644-0917, cross@magnet.fsu.edu, who contributed this article.

AMRIS Progress & Research Report #1, Summer, 1999

The primary science driver of the Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) facility in the University of Florida Brain Institute (UFBI) is the increased B_0 provided by the new instruments that will result in improved temporal/spatial/spectral resolution. These issues will be explored with the new instruments over the next few years. The AMRIS facility will operate as a national facility with support from the UFBI, the Department of Defense, the University of Florida, the NHMFL/National Science Foundation, and the National Institutes of Health.

Over the next few NHMFL newsletters, Steve Blackband, an associate professor in the University of Florida Neuroscience Department and an NHMFL-affiliated faculty member, will provide brief reports on progress in the development of the AMRIS facility, followed by short descriptions of ongoing research studies where improved hardware is having an impact. There will be no order to the reports, and they will encompass the wide range of research on all the AMRIS equipment in terms of hardware and technique development and applications.

AMRIS Progress, July, 1999.

The AMRIS facility at UF continues to develop more or less on schedule. Within the facility the 4.7 T/33 cm instrument is almost completely functional, with studies on, for example, spinal cord research and rat models of epilepsy and hydrocephalus proceeding successfully. The most significant hardware yet to be installed and developed is the phased array capability of the instrument. Two receiver channels are now operating with two more (enabling full phased array capability) on order. A Bruker representative is coming to UF in August to give a programming course.

The 600 MHz narrow bore has been moved into AMRIS and is presently being tested. We are expecting delivery of the 500 MHz narrow bore next month, with delivery of the 11.7 T/40 cm and the 750 MHz wide bore on schedule for the fall. Funding has also been secured to upgrade the 3 T/80 cm instruments with a state-of-the-art GE console that will facilitate integrated echo planar capabilities particularly essential for the ongoing growth of functional MRI (fMRI) studies at UF. This upgrade is expected in the first half of next year.

We also have now fully equipped a radio frequency (rf) laboratory and have hired Barbara Beck as a full-time rf engineer, and David Peterson at 50 percent effort. Barbara and Dave are presently exploring rf coil designs for the upcoming world first instruments. We are also exploring new gradient coil designs to give stronger gradients for the facility. To accomplish this we are collaborating with Dr. Richard Bowtell at Nottingham University, England, who has designed novel multi-layer gradient coils, prototypes of which are being constructed by Dr. Stuart Crozier at the University of Queensland in Australia. It is anticipated that this hardware will facilitate stronger and faster switching gradients that will be particularly important for strong and rapid diffusion weighting for a variety of applications.

AMRIS Research Report #1
Quantitation in MRI: Studies on Single Cells and Brain Slices

Blackband, S.J., Buckley, D.L., Bui, J.D., Phillips, M.I., University of Florida

The last decade has seen a quiet revolution in magnetic resonance imaging (MRI). Higher fields and better rf coils (e.g. phased array) offer improved signal-to-noise ratio (SNR), and instrument stability has greatly improved through the introduction of shielded gradient coils. Sensitive techniques such as angiography, diffusion MR and EPI are now routine. Even T_2*, that latter-day scourge of the imager that we endeavored to eliminate, is now measured, resulting in fMRI. With improved sensitivity and stability

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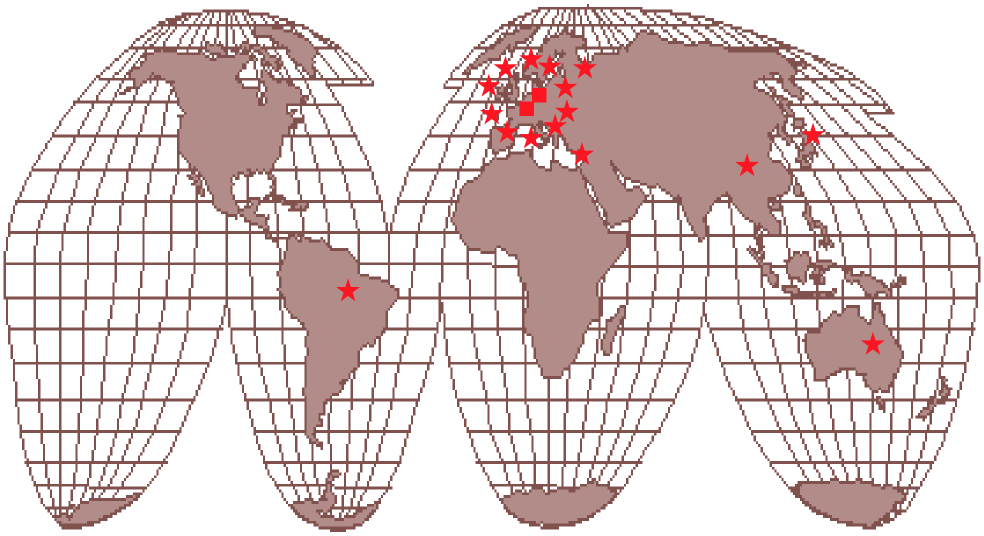
The NHMFL—A National Resource for the World of Magnet Science, Technology, and Engineering

The laboratory recently prepared its 1998 annual report of program activities, and in doing so, we gathered an enormous amount of information from all three sites and numerous groups and departments. One of the most striking "discoveries" was the extensive breadth and scope of collaborative activities undertaken by the researchers and staff of the laboratory. The technological expertise and the critical mass of human scientific capital resident at the NHMFL is attracting an increasing number of collaborators each year and at all levels. These collaborations are an excellent means of fulfilling the laboratory's mission to advance magnet-related science and technologies and to promote U.S. economic competitiveness while advancing NHMFL user facilities.

Formal collaborations with the private sector increased by about 60 percent this year, but that is just the beginning. The NHMFL is sought out regularly to advise and work with industry to advance new technologies and test prototypes. Hardly a week goes by that the laboratory is not meeting with corporations and other research institutions to explore common interests and problems.

The laboratory is also engaged in significant collaborations with almost all of the Department of Energy national laboratories and is working with the Office of Naval Research on a long-term research and development program for the electrification of naval ships. Likewise, with regard to



The technological expertise and the critical mass of human scientific capital resident at the NHMFL is attracting an increasing number of collaborators each year and at all levels.

International Activities

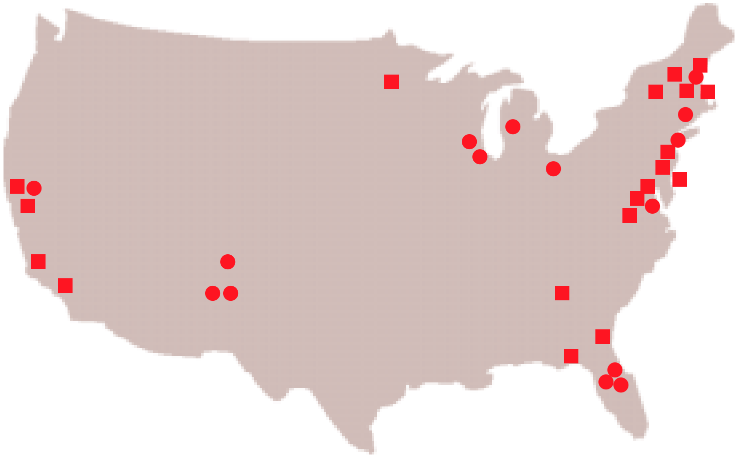
- ★ A.A. Bochvar Institute, Moscow, Russia
- ★ ALCATEL, France
- ★ Deutsches Elektronen-Synchrotron, Hamburg, Germany
- ★ High Magnetic Field Laboratory, Grenoble, France
- ★ High Field Magnet Laboratory, University of Nijmegen, The Netherlands
- ★ Institut für Experimentalphysik, Technische Universität, Wien, Austria
- ★ Institut für Technische Physik, University of Braunschweig, Germany
- ★ Institute of Low Temperature Physics, University of Sao Paulo, Brazil
- ★ Institute of Materials Research, Charles University, Prague, Czech Republic
- ★ Institute of Plasma Physics, Academia Sinica, Hefei, China
- ★ Institute of Solid State and Materials Research Dresden/Research Centre Rossendorf, Germany
- ★ National Pulse Magnet Laboratory, University of New South Wales, Sidney, Australia
- ★ National Research Institute for Metals, Tsukuba, Japan
- ★ Physics and Engineering Research Institute, Ruppin Institute of Higher Education, Ruppin, Israel
- ★ Physikalisches Institut, Johann-Wolfgang-Goethe Universität, Frankfurt, Germany
- ★ The Versaille Project on Advanced Materials and Standards (VAMAS)

international collaborations, the NHMFL has interactions with every active high field magnet laboratory. Since the NHMFL has set the benchmark for advanced research magnets, other laboratories have entered into agreements with the NHMFL to share materials and magnet design technology so that all the laboratories can maximize its impact on their respective user committees. The NHMFL is eager to continue pursuing these collaborations so that we may better serve magnet-related research communities.

We are particularly pleased about one international collaboration this year, as it will expand high magnetic field research facilities and capabilities for users around the world. During the last year, the NHMFL built on its cooperation with sister laboratories around the world by signing a cooperative agreement with Catholic University at Nijmegen. As many may be aware, the Netherlands has decided to modernize the very successful High Magnetic Field Laboratory at Nijmegen and has funded a new 20 megawatt (or more) power supply, cooling system, and pulsed field facility, all to be housed in a new facility. The NHMFL looks forward to working with our Nijmegen colleagues as they develop their new laboratory, and we would also like to acknowledge the fine spirit of international cooperation that has been characteristic of our relationship with the High Magnetic Field Laboratory in Grenoble, France, and the National Research Institute for Metals in Tsukuba, Japan.

Private Sector Activities

- Biospace International, College Park, MD
- BWX Technologies, Lynchburg, VA
- Conductus Inc., Sunnyvale, CA
- Carpco, Jacksonville, FL
- DuPont Superconductivity, Wilmington, DE
- EURUS Technologies, Inc., Tallahassee, FL
- General Atomics, San Diego, CA
- Intel Corporation, Santa Clara, CA
- Intermagnetics General Corporation, Latham, NY
- Lucent Technologies/Bell Labs, Murray Hill, NJ
- Maxdem Inc., San Dimas, CA
- Minnesota Mining and Manufacturing Company, Saint Paul, MN
- Nikon Instrument Group, Melville, NY
- Nordic Superconductor Technologies, Denmark
- Oxford Instruments, Inc., Superconductor Technologies, Carteret, NJ
- Physical Sciences Inc., Alexandria, VA
- Resonance Research Inc., Billerica, MA
- Southern California Edison, San Diego, CA
- Sempco Incorporated, Nashua, NH
- Stonehenge, Ltd., New York, NY
- Supercon Inc., Shrewsbury, MA
- TSI, Inc., Atlanta, GA
- Vacuumschmelze, Hanau, Germany
- Varian Associates, Palo Alto, CA



Inter-Agency & Inter-Institutional Activities

- Advanced Photon Source, Argonne National Laboratory, Chicago, IL
- Center for Advanced Microstructures and Devices, Louisiana State University, Baton Rouge, LA
- Center for Advanced Transportation Systems, Department of Transportation, and University of Central Florida, Orlando, FL
- Clark University, Worchester, MA
- Department of the Navy, Office of Naval Research
- Fermi National Accelerator Laboratory, Batavia, IL
- Gulf Coast Alliance for Technology Transfer, Shalimar, FL
- Lawrence Berkeley National Laboratory, Berkeley, CA
- Los Alamos National Laboratory, Los Alamos, NM
- MAGLEV 2000, Brevard County, FL
- National Superconducting Cyclotron Laboratory, Michigan State University, Lansing, MI
- New York University and Brookhaven National Laboratory, Upton, NY
- Ohio State University, Columbus, OH
- Princeton Plasma Physics Laboratory, Princeton, NJ
- Sandia National Laboratories, Albuquerque, NM
- National Museum of American History, Smithsonian Institution, Washington, D.C.

PEOPLE in the NEWS

Tom Baldwin will join the NHMFL and the faculty of the FAMU-FSU College of Engineering (Electrical Engineering Department) at the end of the summer. Dr. Baldwin comes to us from ABB Power T&D Company, Inc., in Raleigh, North Carolina, where he has been a key member of their superconducting transformer program. He received his Ph.D. in Electrical Engineering from Virginia Polytechnic Institute and State University in 1993.

William W. Brey and **Peter Gor'kov** (see below) came to the NHMFL in early June to begin a program in radio frequency (RF) technology within the Center for Integrated Magnetic Resonance program of the NHMFL. Bill was previously a member of the Technical Staff at Conductus, Inc., where he helped to develop RF coils for NMR spectroscopy and MRI from epitaxial $Y_1Ba_2Cu_3O_{7-\delta}$.

Jianming Cao, a physics experimentalist specializing in time resolved spectroscopy and ultrafast gas-phase electron diffraction, will be joining the NHMFL Condensed Matter/Theory group at the end of the summer. Dr. Cao earned his Ph.D. from the University of Rochester in 1996, and is just completing a postdoctoral position at California Institute of Technology. Dr. Cao's wife, Hong Li, is an outstanding young and promising scientist in structural biology (x-ray scattering) and has accepted a faculty position in the FSU Chemistry Department. The NHMFL would like to recognize and thank FSU for hiring both young faculty members.

Danny Crook joined the engineering staff of Magnet Science & Technology to provide needed design and engineering test capability. He most recently worked as a project designer/ engineer on the RICH detector project through the Nuclear Physics group at FSU. Prior to that, he worked for 16 years at Princeton Plasma Physics Laboratory.

Elliot Douglas, UF assistant professor of materials science and engineering and NHMFL faculty member, received a 1998 Presidential Early Career Award for Scientists and Engineers. Dr. Douglas was nominated for this award by the U.S. Army, and the $500,000 support (over the next five years) will enhance his research efforts on the "Structure-Property Relationships in Crystalline Thermosets." This project is expected to lead to the development of new stronger, lighter-weight composites for use in armor and helicopter structures. Our apologies to Dr. Douglas for the delay in recognizing this important award, which he received in November, 1998, at a special White House ceremony.

Lev Gor'kov, professor of physics at FSU and director of the Theory Program at the NHMFL, recently received the prestigious Humboldt Research Award for Senior U.S. Scientists. This award is given by the Alexander von Humboldt Foundation to recognize scholars "whose academic qualifications enjoy international recognition." Humboldt winners are entitled to stay for 12 months at a research institute in Germany, and Dr. Gor'kov's host institution will be the Max Planc Institute in Grenoble. Rather than an extended stay at one laboratory, however, Dr. Gor'kov looks forward to visiting a number of facilities over an extended period of time.

Peter Gor'kov joined the NHMFL in early June, following a position in Paul Lauterbur's Biomedical Magnetic Resonance Laboratory at the University of Illinois, Urbana-Champaign. There he designed instruments for magnetic resonance imaging studies of biological tissues and small animals. At the NHMFL, he will work in conjunction with Bill Brey to design custom

NMR equipment for solid state NMR as well as for magnetic resonance imaging experiments.

Ke Han, assistant scientist in Magnet Science & Technology, comes to the NHMFL in Tallahassee from Los Alamos National Laboratory where he worked as a postdoc in processing and applications of high strength/conductivity conductor materials for pulsed magnets. Dr. Han will expand MS&T's capabilities in materials development and interact with the pulsed magnet development group. He received his Ph.D. in materials science from the University of Oxford, and started his position with the NHMFL on June 28.

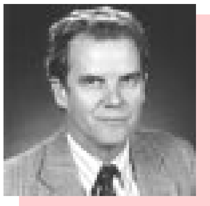
Cesar Luongo will join the faculty of the FAMU-FSU College of Engineering this fall as an associate professor in Mechanical Engineering and will also join the Magnet Science & Technology group and participate in various research activities. Dr. Luongo has 12 years of industrial experience with Bechtel and Stoner Assoc. in the San Francisco, California, area. He received his Ph.D. in Mechanical Engineering from Stanford University.

Jack Quine, professor of mathematics at FSU, will begin a one-year sabbatical at the NHMFL this fall thanks to a grant from NSF Interdisciplinary Grants in the Mathematical Sciences (IGMS) program. The objective of IGMS is to enable mathematical scientists to undertake research and study in another discipline in order to expand their skills and knowledge; to subsequently apply this knowledge in their research; and to enrich the educational experiences and broaden the career options of their students. Recipients of an IGMS award spend eleven months full time in a twelve-month period in a non-mathematical academic science department. Dr. Quine will spend the 1999-2000 academic year working with Timothy A. Cross, director of NMR, helping to develop techniques to find structures of membrane proteins using solid-state NMR. Dr. Quine is also supervising a mathematics graduate student and Institute of Molecular Biophysics Research Training Grant fellow, Jeffrey K. Denny, who is also involved in this collaborative effort.

UF Faculty Promotions

Three NHMFL physics colleagues in Gainesville were recently recommended for promotion:

Pierre Ramond, to Distinguished Professor
Peter J. Hirschfeld, to Full Professor
Hai-Ping Cheng, to Associate Professor



The NHMFL is also extremely pleased to announce the promotion of NHMFL Co-Principal Investigator **Neil Sullivan** to Associate Dean for Research in the College of Liberal Arts and Sciences at the University of Florida, as of August 13. At that time, Dr. Sullivan will step down as the chair of the UF Physics Department but will continue his leadership position with the NHMFL. Dr. Sullivan's new position should afford new opportunities for the laboratory to strengthen the consortium partnership, and to enhance science and engineering research activities and facilities for users. Congratulations!

Greg Stewart, UF professor of physics and member of the NHMFL Science Program, has been elected to the Executive Committee of the Topical Group on Instrument and Measurement Science of the American Physics Society. Dr. Stewart will serve on the committee until 2002.

Kun Yang, a physics theorist with interests in strongly correlated many-body systems and statistical physics (phase transitions and critical phenomena), will join the Condensed Matter/Theory Group in late summer. Dr. Yang comes to the laboratory from California Institute of Technology, where he has been a Sherman Fairchild Senior Research Fellow for two years.

AMRIS continued from page 9

quantitative MR procedures become reliable. We believe MR is no longer limited by instrumental signal instabilities, but by true biological heterogeneity, and that quantitative techniques offer great potential for improving the sensitivity and specificity of clinical MRI. Before this can be achieved, however, an understanding of the origins of MR signals in tissues is required.

Our studies work toward understanding MR signals at the cellular level through measurements on model systems, namely isolated single cells and perfused slices of tissues. Studies on isolated single neurons from the marine snail *Aplysia californica* demonstrate intracellular heterogeneity in that the T_2 and diffusion coefficient of water (D) in the nucleus are both several times longer than that of the cytoplasm.[1] Upon physiological perturbation the NMR characteristics in these compartments change,[2] indicating the potential for using this information to help generate models of intact tissues. Of course, these are marine creatures and not land animals, but it is expected that these observations can be suitably extrapolated. The problem with this data, however, is that the isolated cell does not have a realistic extracellular compartment. In order to bridge the gap between single cells and whole tissues, we have been examining isolated brain slices.[3] Thin slices of suitably prepared brain tissue can be maintained in a viable state for many hours, providing a well established and accessible neurological model. **Figure 1** shows an NMR microimage (20x20 microns) showing fine structural detail in a rat hippocampal slice, but it takes 14 hours to collect even at 600 MHz. By reducing the resolution to 120x230 microns, images can be obtained in a few minutes (Figure 1) facilitating the implementation of meaningful physiological studies. These images demonstrate dramatically the tradeoffs in MRI between spatial and temporal resolution that can be made. We have seen that the water diffusion coefficient measured in this tissue is multiexponential, fitting well to a biexponential function (**Figure 2**). This observation is only possible on high field machines with strong gradients since good SNR and heavy diffusion weighting (the so-called b-values) are required. We presently speculate that the two biexponentials correspond grossly to the intra and extracellular compartments of the tissue, and after correcting appropriately for the differing T_2s of the compartments, their relative sizes are in agreement with measurements made using alternative techniques.

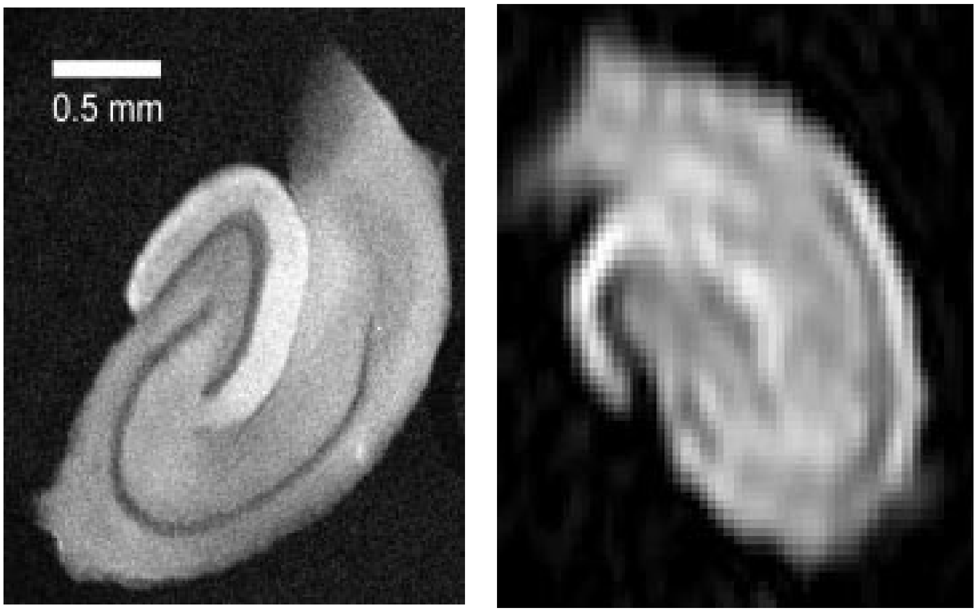


Figure 1. Left: Microimage of isolated perfused slices of hippocampal rat brain, resolution of 20x20x300 µm collected in 14 hours. Right: for dynamic physiological studies we collect lower resolution images (120x230 µm) in a few minutes (4.3 mins). The slice is maintained in a perfusion chamber constructed to fit within a standard 10 mm diameter NMR tube in a 600 MHz instrument.

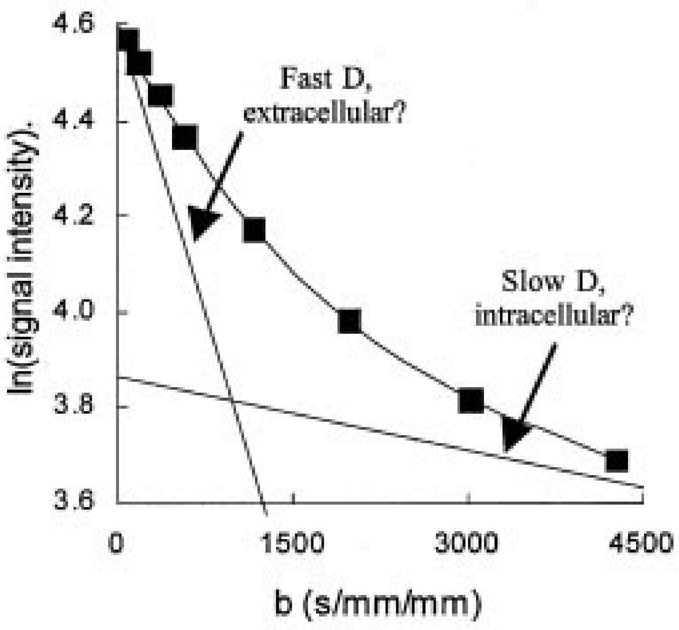


Figure 2. Plot of the signal intensity dependence on the diffusion weighting (the b-value) from a brain slice. On such a log plot a monoexponential would be linear. The two straight lines represent a fit to a biexponential and potentially to intra/extracellular compartments.

Additional studies look at the effect of a variety of perturbations on the cells, either by changes in hypertonicity,[3] sodium pump disruption by ouabain application,[4] or neurotoxic effects with neurochemicals[5]. In all cases, the ratio of the size of the two cellular compartments changes but now the values of D themselves are all consistent with cell swelling and the previously described observations on single cells. The exact origins and the signal changes observed have yet to be unequivocally confirmed, however similar results have been reported by Mareci *et al.* on spinal cord tissue[6] (to be reported in a later newsletter) and in perfused heart slices[7]. It is anticipated that similar data may be obtained in intact animals and humans and studies are ongoing in this and other groups.

In summary, compartmentation of MR signals at the cellular level can be investigated through studies on single cells and isolated tissues undergoing meaningful physiological perturbations. Thus coarse working models of MR signals and their changes can be constructed, and we are in the process of evaluating such models. These models can then be tested in normal and diseased tissues, for example in stroke and hydrocephalus. The disease states can be selected and controlled to test various aspects of the working models. The clinical utility and impact of these quantitative techniques can then be investigated. MRI is thus now able to probe biological samples from man through animals through isolated tissues and now down to the single cell level, making it one of the most versatile and sensitive techniques available today.

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2 Hsu, E.W.; Aiken, N.R. and Blackband, S.J., NMR *Microscopy of Single Neurons Under Hypotonic Perturbation*, Am. J. Physiol., 271:C1895-C1900 (1996).

3 Blackband, S.J.; Bui, J.D.; Buckley, D.L.; Zelles, T.; Plant, H.D.; Inglis B.A. and Phillips, M.I. *MR microscopy of perfused brain slices*, Magn. Reson. Med., 38:1012-1015, (1997).

4 Buckley, D.L.; Bui, J.D.; Phillips, M.I.; Zelles, T.; Inglis, B.A.; Plant, H.D. and Blackband, S.J., *The effect of ouabain on water diffusion in the rat hippocampal slice measured by high resolution NMR imaging*, Magn. Reson. Med. 41:137-142 (1999).

5 Bui, J.D.; Buckley, D.L.; Phillips, M.I. and Blackband, S.J., *Nuclear magnetic resonance imaging measurements of water diffusion in the perfused hippocampal slice during N-methyl-D-aspartate-induced excitotoxicity*, Neuroscience 93:2 487-490 (1999).

6 Bossart, E.L.; Inglis, B.A.; Wirth, E.D. and Mareci, T.H. *Multiexponential diffusion imaging of normal and 1 month post-injury rat spinal cords*, International Society for Magnetic Resonance in Medicine 7th Annual Meeting, Philadelphia, May (1999).

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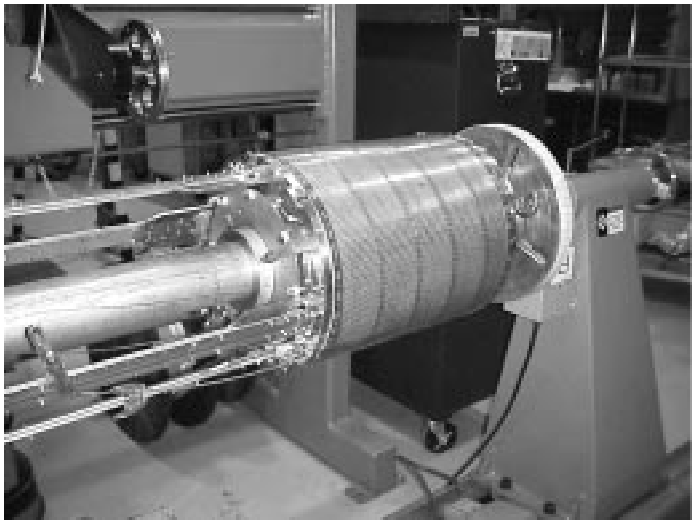


Figure 1. The model coil 3 is completely wound. The model coil 3 has the same inner and outer diameters of the production coil 3 and a reduced height and is used to practice manufacturing procedures one last time before winding with the expensive superconducting wire.

Figure 2. Production coil 6 has been wound at IGC.

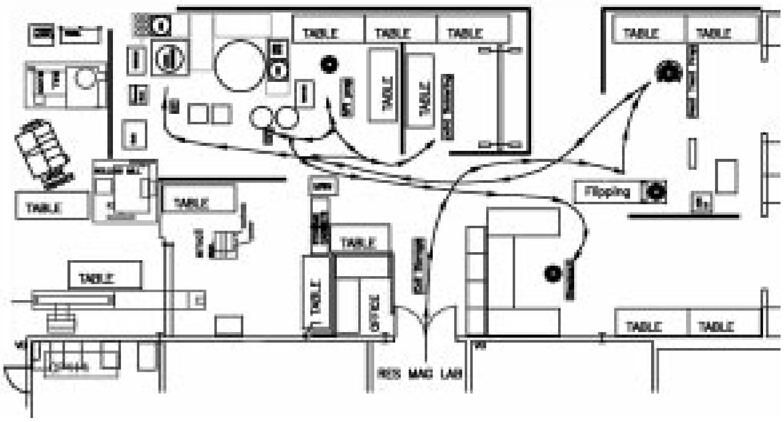


Figure 3. Walls are being constructed in the OPMD area to define and secure the key processing areas required to complete the production of the 900 MHz magnet system. (Drawing by Steve Kenney).

900 MHz PROJECT continued from page 1

Based on the recommendations of the external review committee, the project schedules and tasks have been adjusted accordingly. A series of proof of principle tests are being conducted to confirm key design decisions. Emphasis has been put on the full scale testing of the persistent joints. The bucket test program has been expanded to a full scale test and demonstration with operation as close to 1.8 K as possible using a pumped Lambda Plate cryogenic system. We expect to reach 21.1 T (900 MHz) in the bucket test. Meanwhile the production effort is going full steam ahead.

Some of the key milestones achieved over the past year are as follows.

- All the superconducting wire and copper-stainless steel reinforcement wire required to complete the project has been fabricated, insulated, and received.
- All the coil forms for coils 1-7 have been designed, ordered, and received, and coil form material for coils 8-10 has been received.
- Model coil 3 (Figure 1), model coil 6, and production coils 2 and 6 (Figure 2) are completely wound. IGC is responsible for the winding of the NbTi coils (coils 6-10), and the NHMFL is responsible for the winding of the Nb_3Sn coils (coils 1-5).
- Production coils 4 and 7 are presently being wound.
- The heat treatment and impregnation facilities have been set up in the Operations and Magnet Development area of the NHMFL and a coil processing area is being constructed that provides separate areas for heat treatment, joint soldering, epoxy impregnation, and coil breakout from excess epoxy (Figure 3).
- A dummy load has been fabricated that simulates the thermal mass of the production coils so that the heat treatment process and facilities can be debugged in preparation for the Nb_3Sn production coils.
- An internal review of the compensation coil assembly design (coils 8-10) was held at the NHMFL on June 10, 1999. The review was attended by 900 MHz team members from IGC and the NHMFL.

For further information about the 900 MHz magnet project, contact Tom Painter, 850-644-5752, painter@magnet.fsu.edu, who contributed this article.

Summary Mentorship Experiences

Students, Teachers, and NHMFL Faculty Learning Together

Learning at the Lab during the summer months is distinctly different from academic-year educational activities at the NHMFL. From May through July undergraduates, secondary students and teachers, and NHMFL faculty all integrate into novel highly-focused mentorship experiences under the direction of the laboratory's Center for Integrating Research and Learning.

"The mentorship program is particularly exciting because it allows us to merge our goals in education and research," said Dr. Justin Schwartz, an FSU associate professor of mechanical engineering, researcher, and mentor at the NHMFL. "It shows the undergraduate students that although degree programs have disciplinary boundaries, research often does not."

As much as the opportunity helps teachers and undergraduates, Dr. Schwartz says it also helps the mentors. "For mentors, the program provides an opportunity to work with students with widely varying educational backgrounds."

The Center promotes and facilitates mentorship throughout the year, but its efforts culminate in the summer with two very significant programs—Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET). The Center also incorporates high school and middle school students into summer programs, encouraging them to explore science in ways generally not possible in secondary schools.

This is the seventh year that the REU program at the NHMFL in Tallahassee has been pairing undergraduates with senior researchers. This year eighteen undergraduates (from seven states and Brazil) are teamed with twelve NHMFL researchers at Florida State University, University of Florida, and Los Alamos National Laboratory. In addition, three NHMFL faculty members at the University of Florida—Steve Blackband, John Eyler, and Kevin Ingersent—are directing other REU programs in biology, chemistry, and physics.

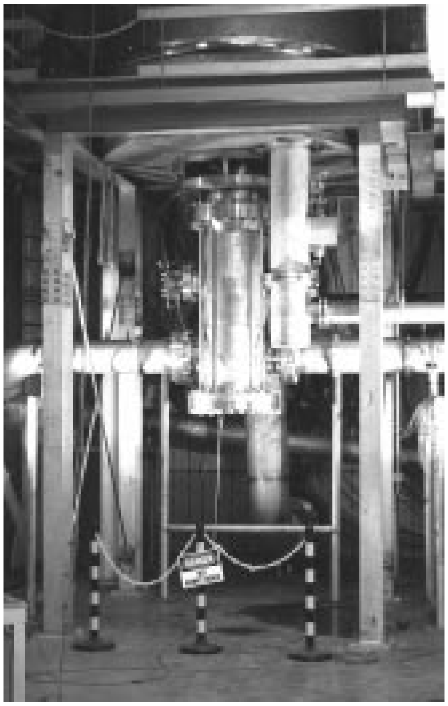
The RET program kicked off its inaugural year at the NHMFL with ten educators from Tallahassee and Jacksonville, Florida. The RET program gives teachers the opportunity to learn and develop new curriculum ideas by working closely with NHMFL faculty. The resources and new understandings the teachers develop at the laboratory will be used in their classrooms to help enhance their students' learning.

Since the research topics vary so widely, students and teachers held weekly colloquiums detailing each stage of their projects. Both groups created their presentations using PowerPoint—affording students the opportunity to teach the teachers! On July 13, the Florida State contingent traveled to UF and met with

MENTORSHIP continued on page 18

Hybrid News

The 45 T Hybrid and the 900 MHz magnet systems were part of the initial charges to the laboratory in 1990, and these extremely challenging research, design, and development projects are both becoming realities. A report on the 900 MHz, 110 mm bore, NMR magnet is found on page 1, but progress on the 45 T Hybrid changes from day-to-day, so an in-depth feature at this juncture would be outdated before publication.



We are pleased to report, however, that the 45 T Hybrid, 32 mm bore, magnet has been completed and installed, and testing is underway. The resistive insert coil successfully reached 32.4 T on May 17, and the 14-ton superconducting outsert coil was cooled down to 4.2 K at an intentionally slow rate in May and June. A small leak developed in the 20 K shield loop and it was decided to warm the system and repair this leak before continuing the cooldown. In addition, small modifications were made to the helium reservoir system to provide additional liquid helium for the transition from 4.2 K operation to 1.8 K operation. Testing of this unique magnet will proceed throughout the summer in order to prepare it for users. Upcoming issues of *NHMFL Reports* should include updates.

While magnet testing continues, Bruce Brandt, director of the DC Field Facility in Tallahassee, and NHMFL safety officers have been addressing safety and security issues. New barriers have been installed; tours are being rerouted; a plan for assigning personnel during operations is being implemented; and training is being provided for all NHMFL employees and visitors. The laboratory has maintained an extremely high level of safety and safety awareness for nearly a decade, and these new actions are just part of a sustained program that ensures the safe operation of the facility.

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MENTORSHIP continued from page 17

REU students and faculty there; on July 16, the UF students came to Tallahassee for a colloquium and tour.

The summer mentorship programs benefit everyone involved—students, teachers, and researchers. Dr. Leroy Odom, a geology professor and NHMFL researcher who mentored five REU interns, summed up the experience: "I believe that the interns benefited by the opportunity to get a taste of research in a state-of-the-art laboratory. An important aspect of it is the close, daily association they have with those "strange people" who choose to spend their lives asking questions and seeking answers. Perhaps they might even consider making such a choice. I can think of several benefits I derived from the intern program, but I have to say that foremost was the pure joy of working with these very bright young scholars."

For more information about the NHMFL Center for Integrating Research and Learning, contact Dr. Sam Spiegel, 850-644-5818, spiegel@magnet.fsu.edu.

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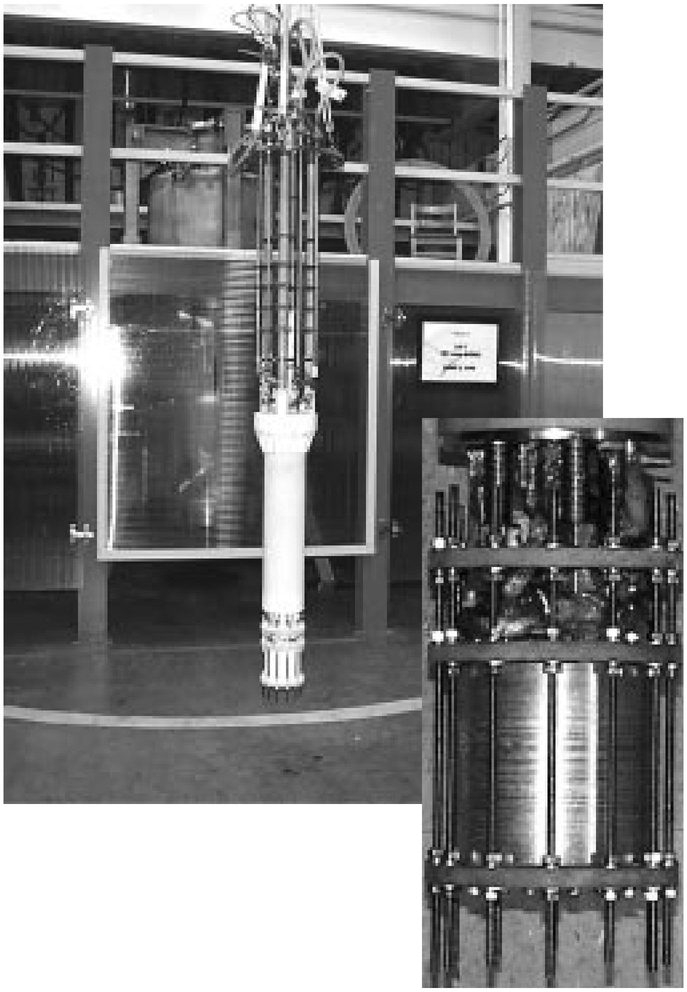
3-T Class HTS Insert Coil Successfully Tested

A collaboration between Oxford Superconducting Technologies (OST) and the NHMFL has led to the construction and successful testing of a high temperature superconductor based insert coil for the generation of high magnetic fields. On June 28, the HTS coil generated 2.95 T in a 19 T background field, and 4.6 T without the background. The ultimate goal of the NHMFL program is the construction of a 5 T insert as part of development efforts for a 1.1 GHz (25 T) NMR magnet system. The 3 T coil is an important step.

The coil is based upon wind-and-react $Bi_2Sr_2CaCu_2O_8$ (Bi2212) conductor. The unreacted conductor was manufactured by OST and shipped to the NHMFL. The NHMFL insulated the conductor and wound it into double pancakes. The insulation used was the (patent-pending) sol-gel insulation developed at the NHMFL. Heat treatment optimization studies and final coil heat treatments were done by both the NHMFL and OST. The coil contains over 1 km of conductor.

The coil comprises three stacks of double pancakes. The innermost stack ("A-stack") conductor sheathing is pure Ag. The middle ("B-stack") and outermost ("C-stack") conductor sheathing is AgMg alloy, thus providing improved mechanical support.

The critical currents and total field generation for the coil are shown in the following table.



Participating in this research and development effort from the NHMFL: J. Schwartz, Y. Hascicek, H. Weijers, Y. Viouchkov, Q. Hu, E. Celik, M. Guenoun, and I. Cubukcu; and from Oxford Superconducting Technologies: K. Marken, J. Parrell, and W. Dai.

Background Field	**I_c(A stack)**	**I_c (B stack)**	**I_c (C stack)**	**Field Generated**
0 T	111 A	79 A	76.6 A	**4.6 T**
19 T	66 A	49 A	43.6 A	**2.95 T**

For further information about the 3-T Class HTS Insert Coil, contact Dr. Justin Schwartz (schwartz@magnet.fsu.edu, 850-644-0874), who contributed this article.

Florida State University•University of Florida•Los Alamos National Laboratory

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