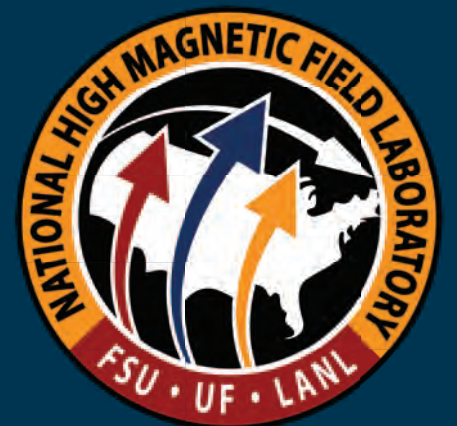
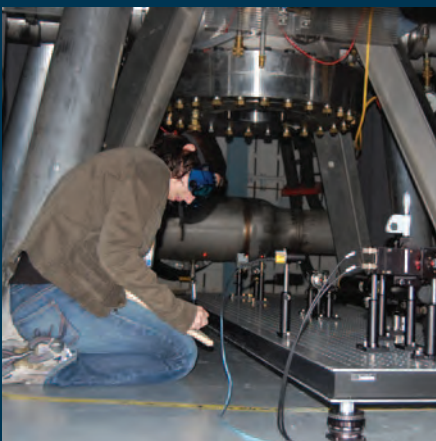
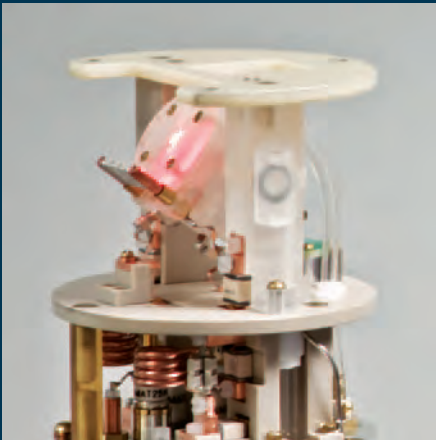
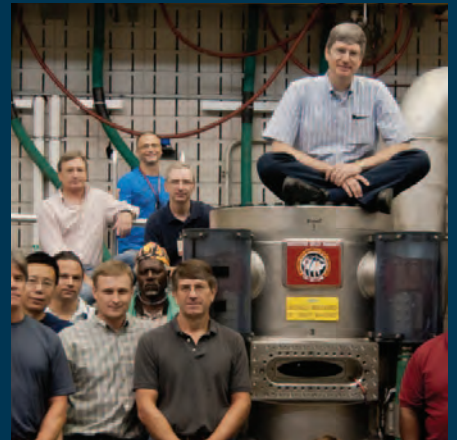
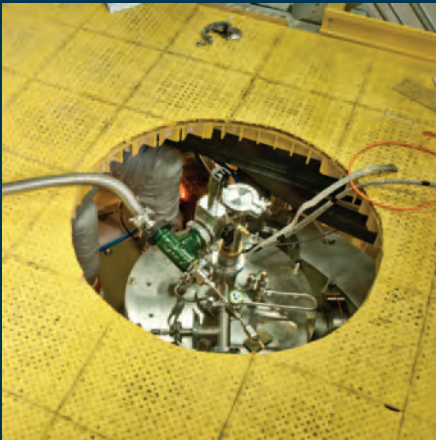


The National High Magnetic Field Laboratory 2011 Annual Report





The Magnet Lab

2011 Annual Report

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The National High Magnetic Field Laboratory

1800 East Paul Dirac Drive
Tallahassee, FL 32310-3706

PHONE NUMBER

(850) 644-0311

FAX NUMBER

(850) 644-8350

NHMFL DIRECTOR

Greg Boebinger

EDITOR

Kathy Hedick

ASSOCIATE DIRECTOR

Brian Fairhurst

GRAPHIC DESIGNER

Liz Vernon

This document is available in alternate formats upon request. Contact Kathy Hedick for assistance. If you would like to be added to our mailing list, please e-mail hedick@magnet.fsu.edu.

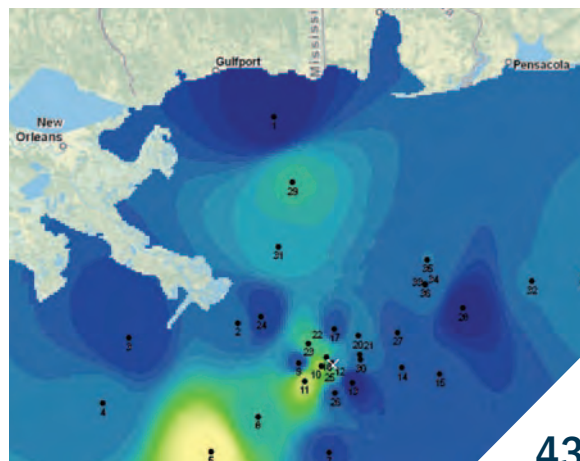
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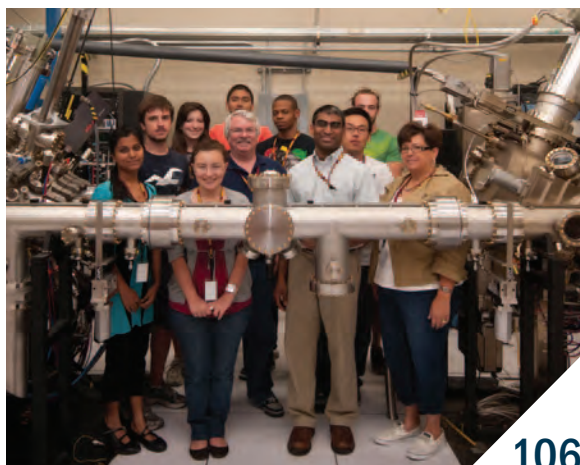


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CHAPTER 1

Year in Review

by Gregory Boebinger

2011 a banner year for lab users, infrastructure

2011 was a heck of a year for the MagLab.

This annual report presents 39 highlights selected from 444 research reports — an all-time high. This record number of reports reflects the continued growth of our user community and research productivity, as well as the important role played by high magnetic fields in rapidly expanding areas of research:

- Graphene, model magnetic systems (low-dimensional, frustrated, Bose-Einstein condensed, quantum entangled... the list gets too long for this column), and the ever-since-1987-but-still-a-mystery-yet-now-also-becoming-technologically-important high-temperature superconductors.
- Energy, from petroleum analysis to pollution analysis (Deepwater Horizon and the North Pacific), to a molecular level probing of energy storage technologies.
- Applications of novel resonance techniques that utilize MagLab magnets and probe technologies for not only biochemistry and biomedicine (protein structures, the structure and function of HIV, and the pioneering of sodium MRI and f-MRI), but increasingly in materials (NASA foams and battery materials).

In June, we celebrated the commissioning of the 25 T Split Magnet. The launch of the Split represented a huge triumph for both the team who built



ABOVE: From administrators to students to facilities personnel, all hands were on deck for the installation of long sections of underground pipe as part of the lab's ongoing effort to improve helium recovery & economy. The project has already resulted in dramatically reduced helium usage. (Photo by Dave Barfield)

it and the staff and users who, almost immediately, began utilizing its suite of capabilities.

With four large ports open at the mid-plane of the magnet where stress and temperatures are highest, the Split required a complete rethinking of resistive magnet technology's limits. The Split is notable for both what it doesn't have — namely, 50% of its mid-plane — and for what it does have: direct 180-degree opti-

cal access at 25 tesla, and user access to a type of experiment that simply didn't exist before. With 18,726 individual parts and a half-decade of planning, the Split is the most challenging, complicated resistive magnet project ever developed.

Two months after the commissioning of the Split, and just a month after a major wildfire temporarily shut down Los Alamos, the Pulsed Field Facility reclaimed the world record for a non-destructive



LEFT: The 25 T Split Magnet began producing user data in June 2011, the very week it was commissioned. See data from one of its first users, Madalina Furis, on page 20. (Photo by Madalina Furis) **RIGHT:** The lab's flagship probe – the 900 MHz triple-resonance MAS (magic angle spinning) probe, in service since April 2011. (Photo by Dave Barfield)

pulse with a 97.4 T shot, opening up user research to 95 T and paving the way for 2012's 100 T milestone. The record was great, but the expanded capability for our users was the goal; in fact, even the record-setting shot contained user experiments. Work conducted in the newly boosted field resulted in user work that has already been published in *Proceedings of the National Academy of Sciences*, *Physical Review Letters* and *Physical Review B*. For a full account of each facility's user-focused improvements, see Chapter 3 of this report.

Research Reports reflect sustained user community growth

In 2011, 444 research reports were received in 18 categories, representing the life sciences, chemistry, magnet science and technology, and condensed matter physics.

- 20% of the research activities (87 reports) were already published in 2011, many in prominent journals.
- 22 reports were accepted for publication; 42 were submitted for publication; and 173 have manuscripts in preparation.

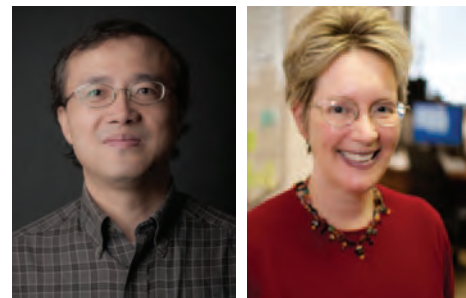
- In 2011, 81 first-time principal investigators requested magnet time.
- The majority of research projects were funded by the U.S. National Science Foundation, the U.S. Department of Energy, and the U.S. National Institutes of Health. Other funding organizations included: NASA, U.S. Department of Defense, U.S. Air Force Office of Scientific Research, U.S. Army, U.S. Navy, and numerous universities. Research was also supported by science federations, ministries, and universities in countries around the world including: Brazil, Canada, China, Denmark, Germany, Japan, Russia, Slovenia, South Korea, and the United Kingdom.
- The Magnet Lab User Collaboration Grants Program encourages collaborations between internal and external investigators, promotes bold but risky efforts and provides initial seed money for new faculty and enhancements of experimental techniques. This program supported 32 of the 444 research activities and was the primary support for seven projects.

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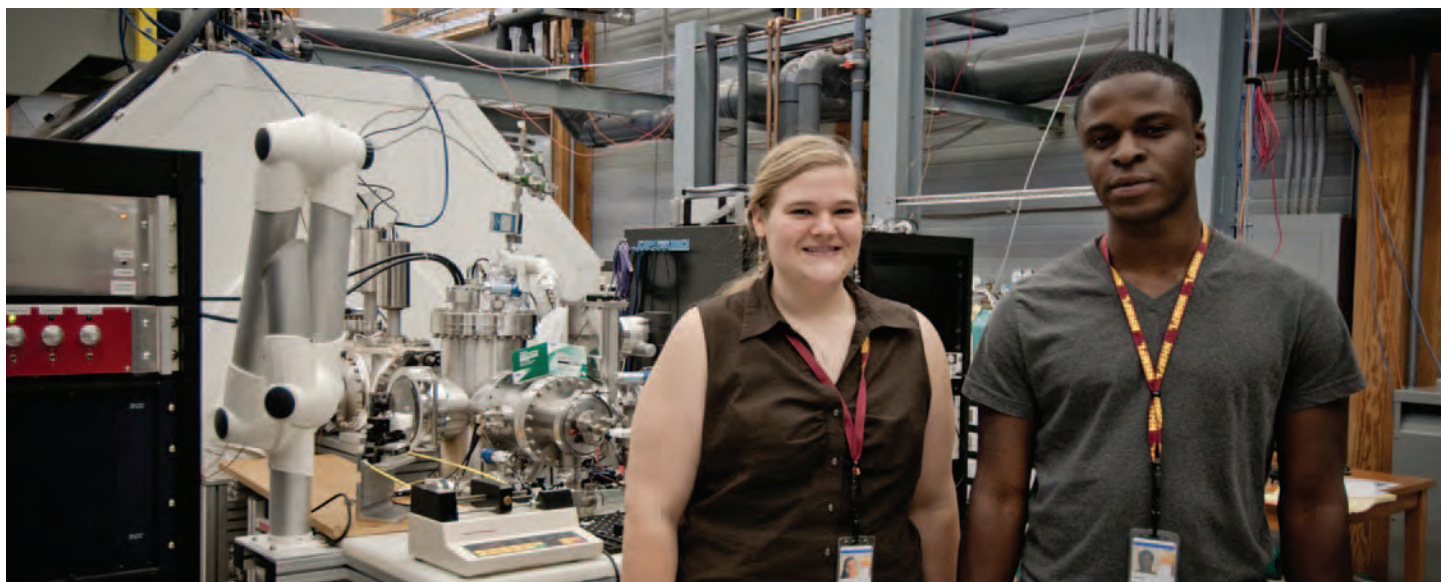
In July, the Magnet Lab hosted the 19th International Conference on Electronic Properties of Two-Dimensional Electron Systems and the 15th Conference on Modulated Semiconductor Structures. With two dozen invited speakers and 385 registered attendees, the event offered the chance for attendees from all over the world to share their work and get acquainted with the MagLab.

Honors, awards and promotions

User Committee Chair **Jan Musfeldt** of UT Knoxville conducted the lab's first-ever career impact survey in 2011. Jan has been an active and extremely



ABOVE: Kun Yang and Jan Musfeldt.



ABOVE Pictured in the Ion Cyclotron Resonance bay are Alecia Shorts of Gerdner-Webb University and Terrie Kweifio of Virginia Tech, both Research Experiences for Undergraduates (REU) students during summer 2011. Shorts studied outcomes of the Deepwater Horizon oil spill, while Kweifio worked in technique development. (Photos by Dave Barfield)

effective chair, advocating for users and involving users directly in the MagLab's strategic planning and renewal proposal development.

Kun Yang, a Florida State University professor and member of the Condensed Matter/ Theory group, was elected a Fellow of the American Physical Society for "significant theoretical contributions to our understanding of novel phenomena in Quantum Hall Systems".

Chris Hendrickson of ICR was named a Florida State University Distinguished University scholar, one of only ten named by the university. The award recognizes outstanding

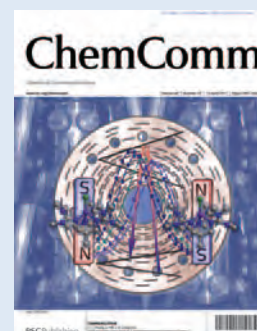
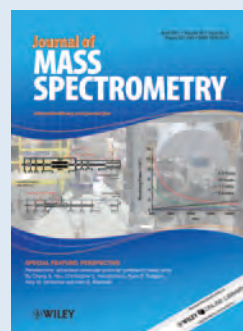
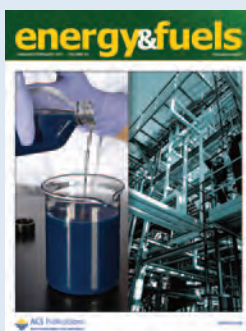
performance by non-tenured or non-tenure-seeking Florida State employees who have longstanding track records of research and/or creative activity at the university and occupy more senior levels in their respective positions.

Lab outreach reaches students, community, educators

With 20 different programs, the Center for Integrating Research and Learning (CIRL) continued its broad, highly successful outreach efforts. CIRL hosted 15 Research Experiences for Undergraduates and 19 Research Experiences for Teachers participants this

year, providing the hands-on research opportunities essential for students interested in STEM fields, and for the teachers charged with engaging a new generation of kids in science. Events like SciGirls, MagLab Summer Camps, Science Café, Doing Science Together, and the MagLab annual Open House offered opportunities for community members of all ages to connect with the lab. The MagLab substantially grew its Twitter and Facebook communities and enjoyed a surge in the popularity of its YouTube channel.

Diversity effort makes inroads



ABOVE Some of the publication covers highlighting research done by Magnet Lab users and staff in 2011.

While continuing its already varied diversity initiatives, the MagLab sought to advance its diversity initiatives in new ways during 2011. In collaboration with “The Alliance for the Advancement of Florida’s Academic Women in Chemistry and Engineering” (AAFAWCE), an NSF ADVANCE-PAID grant, it organized a workshop on “Faculty Recruitment for Excellence and Diversity” (FRED) to present methods for recruiting to promote excellence and diversity in the workplace. From 2012 onward, FRED will be required for any scientist to serving on a scientific search committee. Dragana Popović, Director of the Magnet Lab’s Diversity Program, became the co-PI on the FSU portion of the AAFAWCE grant, a collaboration of five Florida universities to increase the role of women in STEM fields. She is also co-PI on a recently submitted ADVANCE-IT proposal “Collaborative Research: Advance-IT, Florida!” a collaboration of the same five Florida institutions (FSU, UF, FAMU, USF, FIU) that seeks to institutionalize the initial successes of the original ADVANCE-PAID program. For full information on the lab’s diversity initiatives see Chapter 9 of this report.



ABOVE The MagLab reaches over 10,000 students face-to-face each year with classroom outreach and special events. Here, kids get intense about some pretty sweet (candy-related) research.

CHAPTER 2

Research Highlights

	Reports Received	Highlights Selected
Condensed Matter Science	221	20
Magnets & Magnet Materials	45	5
Chemistry	98	8
Life Sciences	80	6
TOTAL	444	39

This year's 39 highlights were selected by combing through the annual report's 444 user and faculty submitted research reports from 18 categories representing the life sciences, chemistry, magnet science and technology and condensed matter science.

The highlight-selection criteria emphasize research that is published, features

a new technique for future users, and showcases outstanding research. Together, the highlights span all three Magnet Lab sites and seven user programs. After we receive the reports, the lab's Science Council, composed of scientists representing all three Magnet Lab sites, reviews each report and narrows the field to a few dozen standouts. That field is then nar-

rowed into a final list by lab Director Greg Boebinger.

The Science Council is made up of Chair Albert Migliori, and members Art Edison, Gail Fanucci, Zhegong Gan, Lev Gor'kov, Stephen Hill, Jurek Krzystek, David Larbalestier, Dragana Popović, Ryan Rodgers, Theo Siegrist, Glenn Walter and Huub Weijers.

The 2011 Science and Engineering Highlights are published as Special Edition of the laboratory's magazine *Mag Lab Reports*, and are presented in this report as representative of the lab's broad research portfolio. For more information on the scientific productivity of the Magnet Lab, including presentations and theses, see Chapter 10 of this report.

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Graphene

The fabrication of monolayer graphene on boron-nitride substrates has resulted in an increase of the charge carrier mobility, allowing the authors to observe quantum Hall effects at all integer filling factors. The picture that emerges is one of exchange driven quantum Hall ferromagnetism within the combined spin-valley isospin space. By tuning the Zeeman energy over a wide range, the dependence of the isospin ferromagnetic order on Landau level index N is demonstrated for fixed relative filling. In particular, for $N \neq 0$ at half filling, the experiment finds evidence for Skyrmionic excitations.

• Accepted for publication in *Nature Phys.* (<http://www.nature.com/nphys/journal/vaop/ncurrent/pdf/nphys2307.pdf>)

Evidence for Skyrmionic Excitations in Graphene

A.F. Young, H. Ren, P. Cadden-Zimansky, P. Kim (Columbia University, Physics); C.R. Dean (Columbia Univ., Electrical Engineering); L. Wang (Columbia Univ., Mechanical Engineering); K. Watanabe, T. Taniguchi (National Institute for Materials Science, Japan)

Introduction

The fabrication of graphene on boron-nitride (BN) has produced an increase in the upper-bound of the carrier mobility possible in unsuspended graphene. This increased mobility enables the SU(4) symmetric Landau levels (LLs) to have their degeneracy lifted at lower fields, and subsequently the spin-activation of these emergent LLs to be characterized using high-field measurements at tilted angles.

Experimental

Our samples are prepared by first mechanically exfoliating graphene and BN onto separate substrates. The exfoliated flakes are separately characterized by optical and AFM measurements and the graphene flakes are then transferred onto BN and re-characterized. Multiple gold probes are subsequently deposited on the graphene using conventional electron beam lithography techniques. Samples that show the most well developed quantum Hall states are measured at the Magnet Lab, where transport measurements at low temperatures and fields as high as 35T are performed.

Results and Discussion

We have observed quantum Hall effects at all integer filling factors in graphene (Figure 1), consistent with exchange-driven quantum Hall ferromagnetism within the combined spin-valley isospin space. Tilted field measurements of the activation gaps

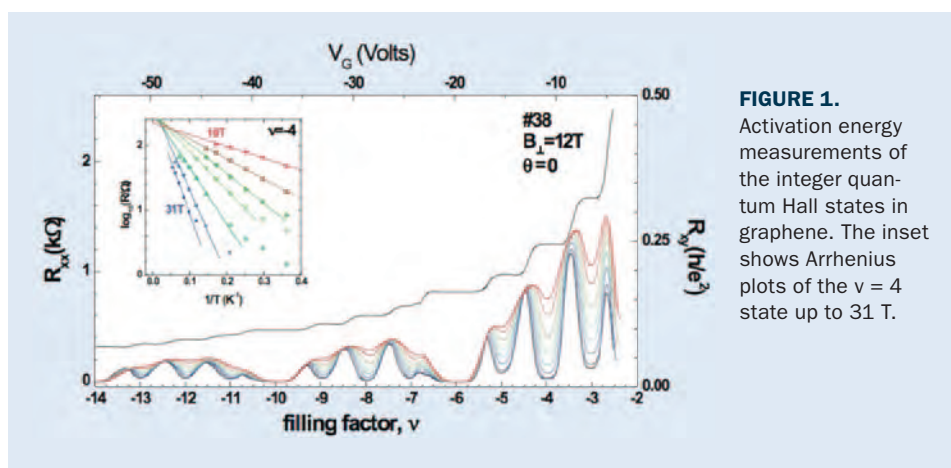


FIGURE 1. Activation energy measurements of the integer quantum Hall states in graphene. The inset shows Arrhenius plots of the $\nu = 4$ state up to 31 T.

associated with the broken symmetry quantum Hall states has allowed us to extract quantitative information about the spin textures of the ground state and its elementary excitations. For the half-filled Landau levels, such as the $\nu = 4$ state, the effective g -factor of the charge carriers can exceed its bare value of 2 (Figure 2). Measurements of multiple samples show a correlation between effective g -factor, measured energy gaps, and sample quality. This correlation suggests that the multiple-spin Skyrmionic excitations that serve as charge carriers in these states are disorder limited, with larger Skyrmions forming as sample quality improves.

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1. A.F. Young, et al., submitted to *Nature Physics* (2011).

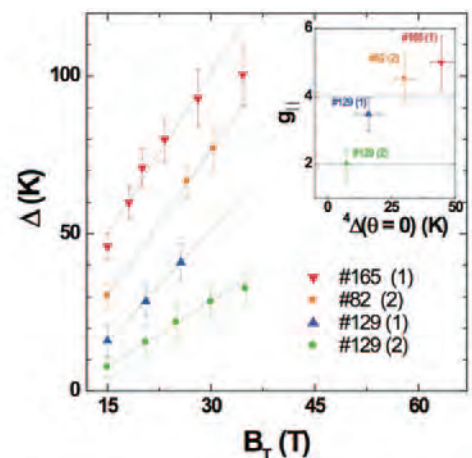


FIGURE 2. Measured activation energy of the $\nu = 4$ state for 4 samples as a function of in-plane field. The cleaner samples show higher activation energy and higher effective g -factor (inset).

Graphene

The most common structure of the natural graphite crystal is the Bernal (staggered) stacking. This report describes high-field magnetotransport evidence for Bernal stacking in a graphene bilayer grown on SiC. These findings render this system particularly attractive for electronic and optoelectronic device applications.

• Published in *Nano Letters* **11**, 3624-3628 (2011).

Magnetotransport Properties of Quasi-Free-Standing Epitaxial Graphene Bilayer on SiC

K. Lee, S. Kim, M.S. Points, E. Tutuc (Univ. Texas Austin, Electrical and Computer Eng.); T. E. Beechem, T. Ohta (Sandia National Labs)

Introduction

Graphene bilayers in Bernal stacking exhibit a transverse electric field tunable band gap, a property that renders this material attractive for device applications. Here, we investigate magnetotransport properties of quasi-free-standing epitaxial graphene bilayer on SiC.

Experimental

We prepared quasi-free-standing epitaxial graphene bilayer on SiC by atmospheric pressure graphitization in Ar, followed by H₂ intercalation. To probe the transport properties of these graphene bilayers, we fabricate top-gated Hall bars. The Hall bar location on the substrate is first chosen using optical and atomic force microscopy (AFM) in order to identify an appropriately wide terrace. Electron beam (e-beam) lithography and O₂ plasma etching are used to pattern the Hall bar active area; the graphene is etched outside the Hall bar. Metal contacts are realized using a second e-beam lithography step, followed by a 40 nm Ni deposition and lift-off. For the gate dielectric, 15nm thick Al₂O₃ film was deposited using atomic layer deposition (ALD). E-beam lithography and then Ni deposition are used to define the top gate. Magnetotransport properties were measured using the DC field facility at the National High Magnetic Field Laboratory.

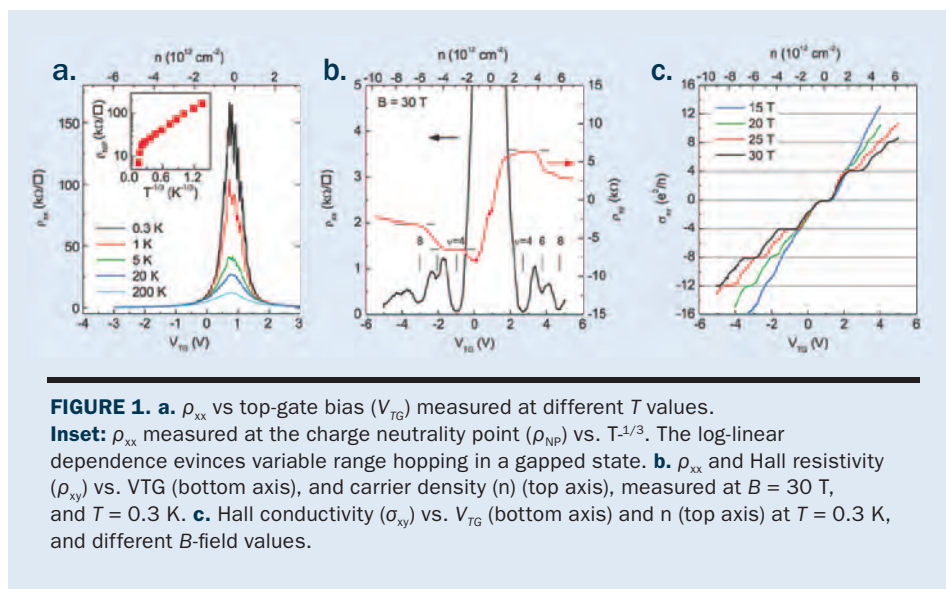


FIGURE 1. **a.** ρ_{xx} vs top-gate bias (V_{TG}) measured at different T values. **Inset:** ρ_{xx} measured at the charge neutrality point (ρ_{NP}) vs. $T^{-1/3}$. The log-linear dependence evinces variable range hopping in a gapped state. **b.** ρ_{xx} and Hall resistivity (ρ_{xy}) vs. VTG (bottom axis), and carrier density (n) (top axis), measured at $B = 30$ T, and $T = 0.3$ K. **c.** Hall conductivity (σ_{xy}) vs. V_{TG} (bottom axis) and n (top axis) at $T = 0.3$ K, and different B -field values.

Results and Discussion

At the charge neutrality point, the longitudinal resistance (ρ_{xx}) shows an insulating behavior (Figure 1a), which follows a temperature (T) dependence consistent with variable range hopping transport in a gapped state. In a perpendicular magnetic field (B), we observe quantum Hall states (QHSs) both at filling factors (ν) multiples of four ($\nu = 4, 8, 12$), as well as broken valley symmetry QHSs at $\nu = 0$ and $\nu = 6$ (Fig. 1, (b) and (c)). These results unambiguously show that the quasi-free-standing graphene bilayer grown on the Si-face of SiC exhibits

Bernal stacking, rendering this material interesting for electron physics and potential platform for device applications.

Conclusions

We investigated the magnetotransport in quasi-free-standing graphene bilayers on SiC. We observed QHSs at fillings $\nu = 0, 4, 6, 8, 12$, consistent with a Bernal stacked graphene bilayer in the presence of a transverse field.

Acknowledgements

We thank NSF (DMR-0819860) and NRI for support.

Kondo/ Heavy Fermion Systems

The β -pyrochlore osmates AOs_2O_6 ($A=\text{Cs, Rb, K}$) are remarkable for their crystalline structure where small size ions, A , are placed inside large cages formed by the OsO_6 octahedra. The elastic potential for the A -ions moving in the cage is then highly anharmonic. Indeed, normally, the phonon frequencies of lighter ions should be higher; it is different in AOs_2O_6 where, for instance, for $A=\text{K}$ the dispersionless Einstein mode is as low as $\sim 20\text{K}$. Importantly, these low energy modes dubbed the “rattling modes” seem to be responsible for the s-wave phonon driven superconductivity (SC). The highest $T_c=9.6\text{K}$ is observed for KOs_2O_6 , with the lightest $A=\text{K}$. Thermodynamic and transport data have provided numerous evidences in favor of the strong electron-lattice interactions in these materials. In particular, superconducting characteristics definitely differ from the ones for the weak coupling BCS SC.

The major fact obtained in this report is that the electron-phonon coupling is uncommonly strong in KOs_2O_6 . In the de Haas-van Alphen experiments numerous fundamental frequencies were observed, as it seems, in the reasonable agreement with the shapes of the Fermi surfaces found from the band structure calculations. Comparison of the “band” mass and the observed mass extracted by way of the Lifshitz-Kosevich analysis provides the direct measure of the e-ph coupling, λ . For most orbits it was found $\lambda \sim 6$, the value never seen anywhere. (For one orbit, for the frequency ρ the observed mass was 26 times heavier than the free electron mass!)

These results indicate the new type of SC in the β -pyrochlore osmates, AOs_2O_6 . Theoretically, there is no clue to how to approach such strong coupling phonon SC. In the famous case of SC in lead, Pb one has $\lambda \sim 1$.

• Accepted for publication as a Rapid Communication in *Phys. Rev. B* (<http://arxiv.org/abs/1201.5425>)

de Haas-van Alphen Measurements on the Rattling-Induced Superconductor KOs_2O_6 Using PDF in 35 T

T. Terashima, N. Kurita, S. Uji (Natl. Inst. Mat. Sci., Japan); **A. Kiswandhi, E.-S. Choi, J.S. Brooks** (NHMFL); **K. Sato, J. Yamaura, Z. Hiroi** (Inst. Solid State Phys., Univ. Tokyo); **H. Harima** (Kobe Univ., Physics)

Introduction

The alkali-metal osmium oxides AOs_2O_6 ($A = \text{K, Rb, and Cs}$) crystallize in the cubic β -pyrochlore structure. The A ion is enclosed in an oversized cage formed by OsO_6 octahedra and vibrates in an anharmonic potential with a flat bottom, giving rise to nearly-localized low-energy anharmonic phonon modes, i.e. rattling modes. With reducing the ionic size from Cs to K, the anharmonicity grows and the rattling intensifies. AOs_2O_6 exhibit superconductivity below the transition temperatures of $T_c = 9.6, 6.3,$ and 3.3 K for $A = \text{K, Rb, and Cs}$, respectively. Hiroi and coworkers^{1,2} have found from a detailed comparative study of the three compounds strong evidence that the superconductivity is mediated by the rattling mode. To shed light on the nature of the electron-rattling interaction, we have studied the many-body mass enhancement

in KOs_2O_6 via de Haas-van Alphen (dHvA) torque measurements³.

Experimental

KOs_2O_6 single crystals were grown at the ISSP. We used a 35 T resistive magnet (cell 8) and the portable dilution refrigerator (PDF) at the NHMFL-Tallahassee. The PDF was essential because of heavy effective masses of electrons. dHvA torque oscillations were detected using piezoresistive microcantilevers.

Results, Discussion, and Conclusions

Figure 1(a) shows an example of magnetic torque in KOs_2O_6 . The measurement temperature is 0.05 K. The field-up and field-down sweeps separate at a field between 31 and 32 T, which we identify with B_{c2} . dHvA oscillations are clearly observed and the Fourier transforms indicate sev-

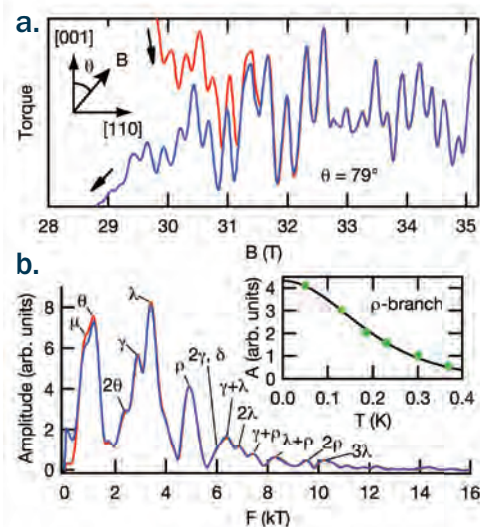


FIGURE 1. a. Magnetic torque in KOs_2O_6 . **b.** Corresponding Fourier transforms (in $1/B$). **Inset:** T dependence of the oscillation amplitude of the frequency ρ .

eral fundamental frequencies with their harmonics and combinations (Figure 1b). The inset shows the temperature dependence of the amplitude of the frequency ρ . With increasing temperature, the amplitude rapidly decreases. A Lifshitz-Kosevich fit (solid curve) indicates an associated effective mass of $26 m_e$, m_e being the free electron mass.

We determined effective masses for a total of 17 frequencies at three different field orientations and compared them with band masses. Mass enhancement parameters $\lambda (=m^*/m_{\text{band}}-1)$ are in a range between 5 and 8, consistent with the

specific-heat mass enhancement parameter of 6.3¹. These values are unusually large for electron-lattice coupling. We examined dependence of the estimated λ 's on band (or Fermi surface sheet), orbit, and orientation, in comparison with MgB₂ and LuNi₂B₂C, and concluded that the many-body mass enhancement in KOs₂O₆ is relatively homogeneous, most likely reflecting the local nature of the electron-rattling interaction.

Acknowledgements

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Innovative Areas "Heavy Electrons" (No. 23102725) of The Ministry of Education, Culture, Sports, Science, and Technology, Japan.

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Kondo/ Heavy Fermion Systems

In this work, published in *Physical Review Letters*, a method has been developed that enables continuous tuning of the density of high-mobility two-dimensional (2D) electrons formed just underneath the surface of SrTiO₃, an insulator well known for its ferroelectricity. The 2D layer of electrons produced by this clean, powerful method exhibits evidence for the Kondo effect involving Ti³⁺ spins.

• Published in *Phys. Rev. Lett.* **107**, 256601 (2011).

Electrolyte Gate-Controlled Kondo Effect in SrTiO₃ Using 30T

D. Goldhaber-Gordon, M. Y. Lee, J. R. Williams (Stanford Univ., Physics);

Sipei Zhang, C. Dan Frisbie (Univ. of Minnesota, Chemical Engineering and Material Science)

Introduction

A classic correlated material, in which much of the electronic properties are understood, is SrTiO₃ (STO) and its related compounds like interfaces between LaAlO₃ (LAO) and STO. Recently investigation into transport in high-quality STO and LAO/STO interfaces have shown departures from conventional metallic behavior, including superconductivity and ferromagnetism. Understanding how these phases evolve as a function of density is key to the origin of correlated phenomena in these systems.

Experimental

To investigate the evolution of phases at low density, where STO is an insulator, to high density where the phase is poorly understood, we fabricated Hall bars on STO to investigate the longitudinal and Hall resistance as a function of density (between 0 and 2×10^{14} cm⁻²), achieved using ionic gating. The experiments were performed in a flow cryostat, with a variable temperature range between 1.4K and 300K in Cell 9, which provides a DC magnetic field up to 31T.

Results, Discussion, and Conclusions

Using the NHMFL, we were able to expand on the body of evidence for Ti³⁺ magnetism in STO that conducts in two dimensions. We demonstrate a gate-controlled Kondo effect in the 2D electron system in undoped STO formed beneath the bare surface by the electric field from an ionic gel electrolyte, and interpret this system as an admixture of magnetic Ti³⁺ ions (unpaired and localized electrons) and delocalized electrons partially filling the Ti 3d conduction band, as predicted theoretically. The Kondo effect is an archetype for the emergent magnetic interactions amongst localized and delocalized electrons in conducting alloys, and the ability to produce and tune the effect by purely electrostatic means in any conducting system is of interest in its own right. The observed appearance of the Kondo effect in STO as a function of applied electric field points to the emergence of magnetic interactions between electrons in STO due to electron-electron correlations rather than the presence of dopants. This work has been published in *Physical Review Letters*¹ and was selected as a Physics Viewpoint² and as an Editor's Choice.

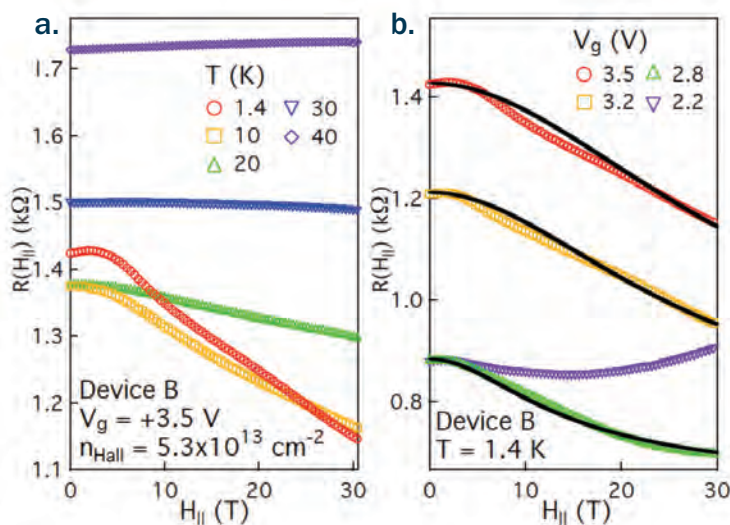


FIGURE 1. Resistances as a function of applied magnetic field as a function of temperature (a) and gate voltage (b). The results are consistent with the expected response in magnetic field of a system in the Kondo regime.

Acknowledgements

The development of ionic gating technique was supported as part of the Center on Nanostructuring for Efficient Energy Conversion, an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science Office of Basic Energy Sciences under Award Number DE-SC0001060. The measurement and study of STO were supported by the MURI program of the Army Research Office Grant No. W911-NF-09-1-0398. The Minnesota contribution was supported by the National Science Foundation through the MRSEC program at the University of Minnesota, Award DMR-0819885.

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Magnetism and Magnetic Materials

Investigating the spin dimer system $\text{SrCu}_2(\text{BO}_3)_2$ in high magnetic fields brings up a unique opportunity to study the interactions between low energy magnetic excitations $S_z=1$ (triplons) in the presence of strong magnetic frustration in a 2D lattice. The external magnetic field is used to close the spin gap at a field-induced quantum critical point, as well as to control the triplon population density once the gap is closed. Triplon repulsion and frustration-induced localization lead to the emergence of magnetic stripes forming texture that manifests as steps in the magnetization at integer ratios of the saturation magnetization. A significant spin lattice coupling was observed with the first magnetostriction measurements in pulsed fields to 97.4 T. In addition to confirming the known low-field textures, by their effect in the lattice parameter, two new features at magnetic fields of 74 T and 82 T were observed, demonstrating unambiguously that the interplay of magnetic and lattice degrees of freedom can be probed over a large magnetic field range.

Microstrain-Sensitivity Magnetostriction of $\text{SrCu}_2(\text{BO}_3)_2$ to 97 T

R. Daou (HLD, Dresden); S. Crooker, A. Uchida, M. Jaime (LANL, NHMFL); F. Weickert (LANL, CMMS); H.A. Dabkowska, B.D. Gaulin (McMaster, Physics)

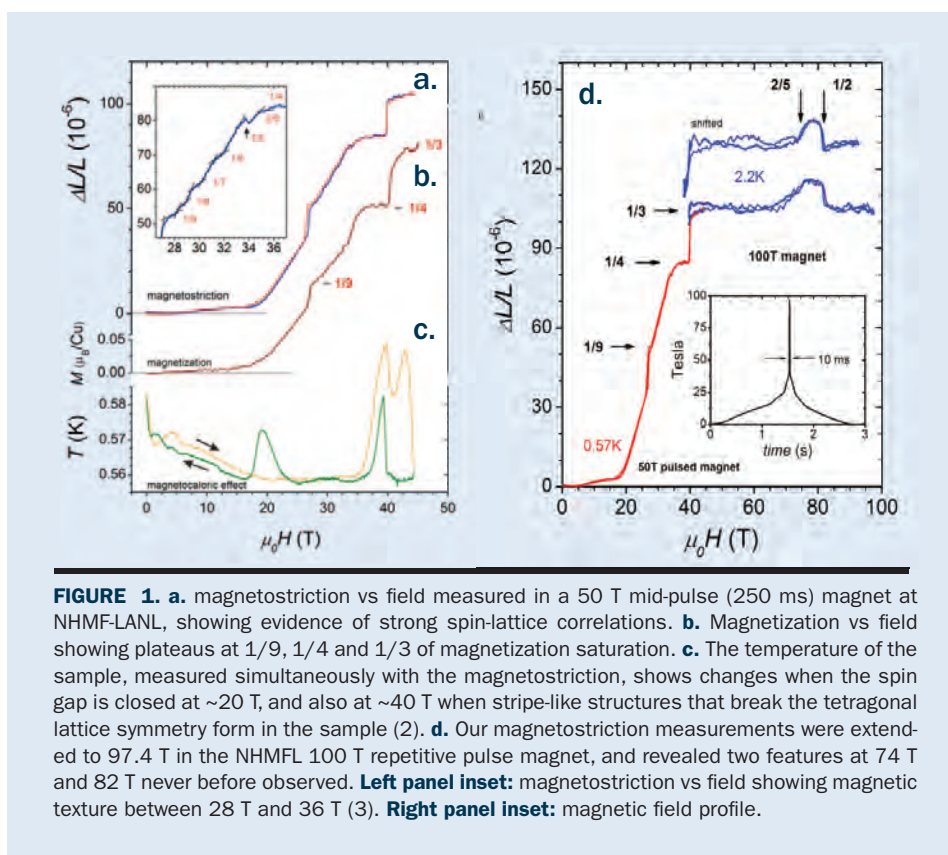


FIGURE 1. **a.** magnetostriction vs field measured in a 50 T mid-pulse (250 ms) magnet at NHMF-LANL, showing evidence of strong spin-lattice correlations. **b.** Magnetization vs field showing plateaus at $1/9$, $1/4$ and $1/3$ of magnetization saturation. **c.** The temperature of the sample, measured simultaneously with the magnetostriction, shows changes when the spin gap is closed at ~ 20 T, and also at ~ 40 T when stripe-like structures that break the tetragonal lattice symmetry form in the sample (2). **d.** Our magnetostriction measurements were extended to 97.4 T in the NHMFL 100 T repetitive pulse magnet, and revealed two features at 74 T and 82 T never before observed. **Left panel inset:** magnetostriction vs field showing magnetic texture between 28 T and 36 T (3). **Right panel inset:** magnetic field profile.

Introduction

The orthogonal-dimer geometry of the Shastry-Sutherland lattice¹ and the ratio of next-nearest to nearest neighbor exchange interactions between the spin $1/2$ Cu^{2+} ions, $J_1/J_0 \sim 0.62$ ($J_0 \approx 74\text{K}$), make $\text{SrCu}_2(\text{BO}_3)_2$ a paradigm of frustrated quantum magnetism², where an external magnetic field can be used to induce mag-

netic texture³. The strength of required magnetic fields has until now prevented, however, the unambiguous observation of magnetization fractions beyond $1/3$ of saturation.

Here we report microstrain-sensitivity magnetostriction (MS) data obtained for a single crystal sample of $\text{SrCu}_2(\text{BO}_3)_2$ in pulsed magnetic fields to 97.4 T using a

recently developed fiber Bragg gratings FBG technique⁴. The magnetostriction was measured with the magnetic field $H//c$ -crystallographic axis (Figure 1) and with $H \perp c$ -axis (not shown) at different temperatures down to $T = 0.5\text{K}$ ⁵. We found a remarkable correspondence between magnetostriction and magnetization vs field data, that confirms previously discussed magnetic texture following the series $1/n$ with $n = 3, 4, \dots, 9$ in $\text{SrCu}_2(\text{BO}_3)_2$ ^[3]. We also found two new features at $\mu_0 H = 74$ T and 82 T that we attribute to superstructure corresponding to $2/5$ and $1/2$ ($n=2$) of magnetization saturation respectively.

Acknowledgements

AF acknowledges NSF funding under grant DMRG-0955707. Experiments at the High Magnetic Field Laboratory Dresden (HLD) (not shown) were sponsored by Euro-MagNET II under the EU contract 228043. Work at the NHMFL was supported by the National Science Foundation, the U.S. Department of Energy, and the State of Florida.

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Magnetism and Magnetic Materials

LaCoO₃ is a material with a spin state cross-over occurring at laboratory accessible fields. Additionally, a new form of cooperative orbital-magnetic order, combining the S=0 and S=1 states, was discovered. This field induced spin-state crystallization is a novel phenomenon, and may also occur in ferric perovskite making up part of the Earth's crust, affecting the dynamics of seismic waves.

Spin-State Crystallization in LaCoO₃ in Magnetic Fields Using 97T

M.J.R. Hoch (NHMFL, Florida State Univ.); **M.M. Altarawneh**, **N. Harrison**, **A. Uchida**, **M. Jaime**, **C.H. Mielke**, **S.A. Crooker**, **J.B. Betts**, **D.G. Rickel** (NHMFL, LANL); **G.-W. Chern**, **C.D. Batista** (LANL); **J.F. Mitchell** (Argonne National Lab)

During recent tests of the 95 tesla plus multishot magnet in Los Alamos, a new world record for non-destructive magnetic fields of 97.4 T was achieved. During the testing, several experiments were run in parallel involving recent users at the pulsed field facility. One of these concerned magnetization measurements of LaCoO₃ — performed in-situ utilizing the same susceptometer as used to calibrate the magnetic field using the de Haas-van Alphen effect in copper wire.

LaCoO₃ is of interest because it is a rare example of a crystalline material subject to a spin state crossover tuned by laboratory accessible magnetic fields¹. Whereas one simple spin-state crossover had been expected involving solely single ion effects, pulsed magnetic fields to ~65 T (inset to Figure 1a) revealed a curvature of the phase boundary at higher temperatures that had been missed in a recent study by competing group in Japan². A field-induced phase appeared to be developing. Sure enough, a field-induced phase was subsequently revealed in magnetic fields approaching 100 T by the observation of a second transition.

The discovery of the field-induced phase is significant because it constitutes an entirely new form of cooperative orbital-magnetic order involving multiple spin states (of S = 0 and 1) — each spin state having very different orbitals. It is, in effect, field-induced spin-state crystallization. Evidence for a reconstructive phase

transition is provided by the extensive hysteresis between rising and falling magnetic fields and by the presence of a giant magnetostrictive anomaly at each of the transitions (shown in Figure 1b; measured during a subsequent experimental study in the same magnet). An entire hierarchy of different spin states orders, each with its own magnetization plateau, are now anticipated in a recently-developed theory by the Los Alamos theoretical division, although the third and fourth transitions are likely to occur in excess of 140 T. Experiments performed in the single turn magnet system at Los Alamos (shown in the inset to Figure 1b) revealed no further transitions up to this field.

The discovery of spin-state crystallization could be relevant deep within the Earth's crust where a spin-state crossover is expected to occur in ferric perovskites of the same crystalline structure³. Spin-state crystalline, if it occurs, could potentially alter the dynamics of seismic waves.

Acknowledgements

Supported by NSF DMR-0654118 and BES program "Science at 100 tesla." John Singleton, Chuck Swenson, Ross McDonald, Yates Coulter and Mike Gordon are acknowledged for technical help during the experiment.

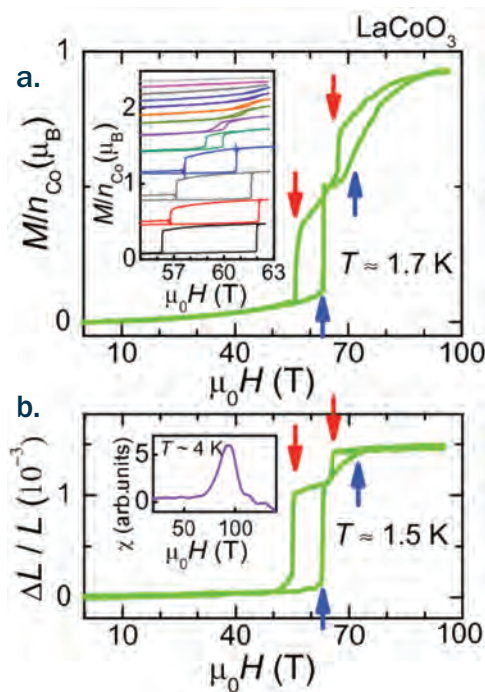


FIGURE 1. Magnetization M (a) and length expansion $\Delta L/L$ vs $\mu_0 H$ (b) measured in strong magnetic fields at Los Alamos. The insets show the first transition measured over a broader range of temperature (a) and single turn magnet susceptibility results (b). The rapid rate-of-change of field in the latter causes the two observed transitions to collapse into a single transition.

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Magnetism and Magnetic Materials

Magnetization measurements were performed on a new family of Cu coordination polymers in fields of up to 92 T at the pulsed-field facility in Los Alamos. Magnetic fields in excess of 60 T were essential for determining the magnetic exchange energies and dimensionalities of these model antiferromagnetic compounds.

• Published in *Inorganic Chemistry* **51**, 2121-2129 (2012).

High-Field Magnetization of the 1D $\text{CuBr}_2(\text{pyzO})(\text{H}_2\text{O})_2$ and 2D $\text{CuBr}_2(\text{pyz})$ Using 92T

J. A. Schlueter (Argonne National Lab); J. L. Manson (Eastern Washington Univ.); J. Singleton, R. McDonald (NHMFL-PFF)

Introduction

The magnetic properties of the newly crystallized $\text{CuBr}_2(\text{pyzO})(\text{H}_2\text{O})_2$ (pyzO = pyrazine- N,N' -dioxide) coordination polymer have been studied at fields up to 85 T and compared with those obtained for the related $\text{CuBr}_2(\text{pyz})$ (pyz = pyrazine) complex¹. The crystal structure of $\text{CuBr}_2(\text{pyzO})(\text{H}_2\text{O})_2$ is characterized by one-dimensional chains of Cu^{2+} ions linked through bidentate pyzO ligands. These chains are joined together through $\text{OH}\cdots\text{O}$ hydrogen bonds between the water ligands and pyzO oxygen atoms and through $\text{Cu}-\text{Br}\cdots\text{Br}-\text{Cu}$ contacts. Bulk magnetic susceptibility measurements at ambient pressure show a broad maximum at 28 K that is indicative of short-range magnetic correlations. The dominant spin exchange is through the $\text{Cu}-\text{Br}\cdots\text{Br}-\text{Cu}$ pathway. The magnetic data were fitted to a Heisenberg 1D uniform antiferromagnetic chain model with $J_{1D}/k_B = -45.9(1)$ K. Muon-spin relaxation measurements were unable to definitively establish the presence of long range magnetic order in $\text{CuBr}_2(\text{pyzO})(\text{H}_2\text{O})_2$ down to 0.26 K. The results for the $\text{CuBr}_2(\text{pyzO})(\text{H}_2\text{O})_2$ complex has been compared to the related $\text{CuBr}_2(\text{pyz})$ material, the structure of which is characterized by bridged $\text{Cu}-\text{Br}_2-\text{Cu}$ chains linked through bridging pyrazine molecules resulting in a 2D rectangular lattice.

Experimental

Measurements made use of a 1.5mm bore, 1.5mm long, 1500-turn compensated-coil susceptometer, constructed from

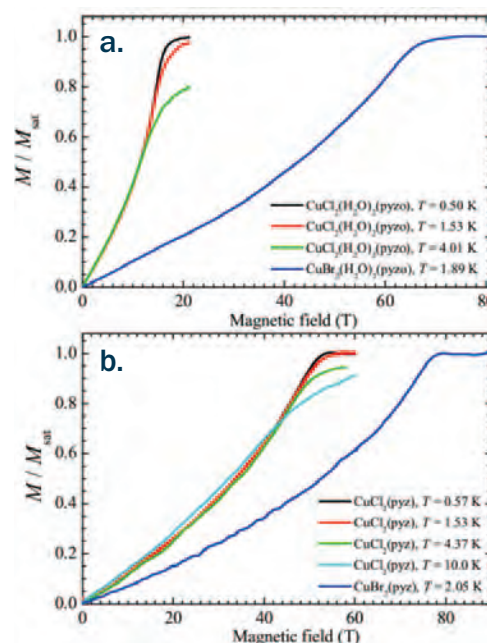
50 gauge high-purity copper wire and specially adapted for the 100 T multi-shot magnet. When a sample is within the coil, the signal is $V \propto (dM/dt)$, where t is the time. The sample is mounted within a 1.3 mm diameter ampoule that can be moved in and out of the coil. Accurate values of M are obtained by subtracting empty coil data from that measured under identical conditions with the sample present. Fields were provided by the 60 T short-pulse and 100 T multi-shot magnets at NHMFL-Los Alamos. The susceptometer was placed within a ^3He cryostat for which temperatures as low as 0.4 K could be achieved.

Results and Discussion

Isothermal magnetization was measured as a function of pulsed magnetic field (figure). In the case of $\text{CuBr}_2(\text{pyzO})(\text{H}_2\text{O})_2$, the magnetization saturates at a field of 66.7(5) T, with strong upward curvature at lower fields indicative of one-dimensional magnetism. In a Heisenberg chain, the magnetization is expected to saturate at a field $B_{\text{sat}} = -2k_B J_{1D}/g\mu_B$, where the dominant exchange energy J_{1D} is expressed in Kelvin². Using the measured value of B_{sat} , $J_{1D} = -46.4(5)$ K was obtained. For $\text{CuBr}_2(\text{pyzO})(\text{H}_2\text{O})_2$, B_{sat} was found to be 78.2(5) T, yielding a $J_{1D} + J$ of $-51.8(5)$ K.

Conclusions

Pulsed-field magnetization data to fields greater than 60 T were essential for validation of this method for obtaining exchange energies and confirmation of the magnetic dimensionality. Close agreement



was found between the exchange energies obtained from fits of magnetic susceptibility data and those obtained from pulsed field magnetization.

Acknowledgements

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Magnetism and Magnetic Materials

Madalina Furis (U. Vermont) has demonstrated the first successful high-field Magnetic Circular Dichroism (MCD) experiment at 27.5 T in the Florida HELIX split-pair magnet. The measurements were performed on crystalline thin films of a prototypical organic semiconductor, copper phthalocyanine, revealing the onset of carrier-mediated exchange at low temperature.

Magnetic Circular Dichroism (MCD) of Copper Phthalocyanine Crystalline Thin Films Using the 25T Split Magnet

Z. Pan, N. Rawat, C. Lamarche, M. Furis (UVM, Physics); T. Tokumoto, D. Semenov, S. McGill (NHMFL)

Introduction

Research on metal-phthalocyanines (MPC) as archetype for organic semiconductors and optoelectronics applications has been extensive over the last decade. However, the magnetic studies on MPC, especially in the solid state phase, are sparse. In a crystalline phase MPC, π electrons are highly delocalized through the quasi-1D molecular chain, and interactions between localized unpaired d-shell electron spin of central ions could be mediated by the delocalized π electrons of the PC ring¹. Understanding the exchange mechanism will be extremely critical for magnetic applications. In our study, we are particularly interested in copper phthalocyanine (CuPC) crystalline thin film fabricated by solution processed pen-writing techniques², since in this spin $\frac{1}{2}$ system, direct exchange is negligible³ and we could study pure indirect exchange between through itinerant carriers. In order to identify the electronic states responsible for the magnetism in the CuPC crystalline thin film, we performed magnetic circular dichroism (MCD) spectroscopy measurement in high magnetic fields.

Experimental

MCD measurements was carried out in the split-coil HELIX magnet in cell 5 of NHMFL with B fields up to 27.5 Tesla at 100 and 300 K. Light from an Oriol 300 watt Xenon lamp dispersed by a Cornerstone 260 monochromator with bandwidth of 2 nm was modulated into left and right circularly polarization in 50 kHz and focused using free space optics onto samples in Faraday geometry ($\vec{k} \parallel \vec{B}$). Signal was collected by a multimode fiber and focused

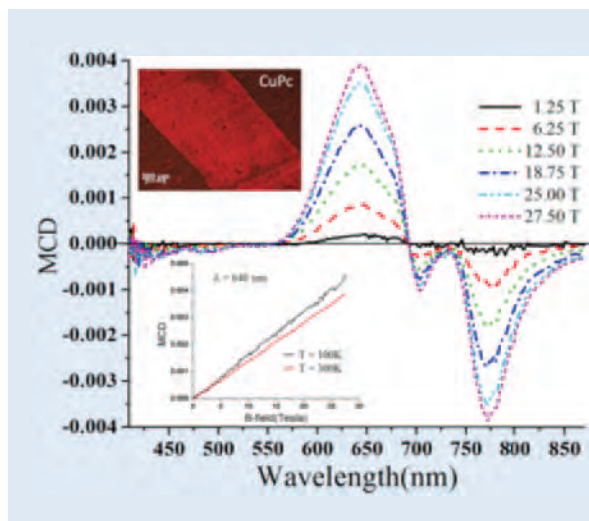


FIGURE 1. MCD spectra recorded at various magnetic fields up to 27.5T from a CuPC crystalline thin film.

Lower Inset: Room temperature MCD at 640nm increases linearly with applied magnetic field reflecting the expected diamagnetic behavior. Upper Inset: Polarized microscope image of the CuPC thin film under study. The contrast is the result of different orientations of the crystalline grains.

onto a silicon diode detector.

Results and Experiment

Figure 1 displays 300K MCD spectra from the CuPC film recorded at different magnetic fields. Each of the Gaussian features is associated with a distinct transition between states located at the bandgap of CuPC. All features are significantly broadened and redshifted in comparison to the ones observed in monomers. Since the MCD magnitude is proportional to the time-average of the total change in orbital momentum associated with a particular electronic transition and the electronic g-factor, it is expected that MCD increases linearly with applied magnetic field in the absence of any magnetic interactions. This is precisely what we observe at room temperature where MCD evolving with B field (inset) can be very well fitted with a straight line. This dependence remains linear at 100K with a slight increase in slope which corresponds

to an increase in the g-factor. The results are not surprising since carrier-mediated exchange is only expected to manifest itself at temperatures lower than 10K.

Conclusions

We demonstrated the first successful high field MCD experiment at 27.5T. MCD evolved linearly as B field increase at both 100 and 300 K with different slope (g-factor). Lower sample temperatures are needed to reveal the magnetic exchange mechanism in this system.

Acknowledgements

The Furis group was supported through NSF CAREER award DMR #105658.

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Magnetism and Magnetic Materials

Understanding why wave functions localize in the presence of disorder is a fundamental but difficult problem that is important for a wide variety of systems. Experimental and theoretical understanding of Bose glasses and Anderson localization has long been sought in diverse systems including superconductors, cold atoms, metals with impurities and helium. Bose glasses in quantum magnets are one of the most accessible and simplest to describe theoretically. This work makes one of the first contacts between theory and experiment in this field, and thus is a critical step forward.

Magnetic Susceptibility Measurements of the Bose-Glass Phase in $\text{NiCl}_{1.85}\text{Br}_{0.15}\text{-4SC(NH}_2)_2$ Down to 1 mK

L. Yin, J.S. Xia, N.S. Sullivan (Univ. Florida, Physics); C. Huan (Georgia Tech & Univ. Florida, Physics); V.S. Zapf (LANL); A. Paduan-Filho (Univ. de Sao Paulo); T. Roscilde (Ecole Normale Sup'erieure de Lyon); R. Yu (Rice Univ.)

Introduction

The phenomenon of a magnetic field induced Bose-Einstein Condensation (BEC) of quasiparticles in quantum magnets has been the subject of several investigations over the last decade, and it has been studied in a wide variety of materials, including $\text{NiCl}_2\text{-4SC(NH}_2)_2$ (DTN) which consists of coupled quasi-1D $S=1$ chains with strong single-ion anisotropy^{1,2}. By adding disorder to a spin-gapped antiferromagnet by doping with non-magnetic impurities, the BEC is hindered with respect to the pure system by Anderson localization of the quasiparticles. At the critical field of the pure system quasiparticles do not condense in a zero-momentum state, but they fragment over an extensive number of localized states, and therefore the ground state of the system lacks global phase coherence.

Experimental

We have measured the AC susceptibility of a bound-diluted quantum magnet $\text{NiCl}_{1.85}\text{Br}_{0.15}\text{-4SC(NH}_2)_2$ down to 1mK and with a magnetic field ranging from 0 to 15 T. The experimental setup has been described elsewhere^{2,3}.

Results and Discussion

Below a crossover temperature $T_{cr} = 100\sim 200$ mK, we find that the critical fields H_c for Bose-Einstein condensation obey the scaling relation $|H_c(T) - H_c(0)| \sim T^\alpha$, with a novel and universal scaling exponent $\alpha \sim 0.9$, which is in agreement with numerical results from a theoretical model^{4,5}.

Conclusions

Our findings provide strong evidence of the existence of a Bose glass phase in $\text{NiCl}_{1.85}\text{Br}_{0.15}\text{-4SC(NH}_2)_2$, and they display a quantitative signature of the transition between a Bose glass and a Bose Einstein condensate.

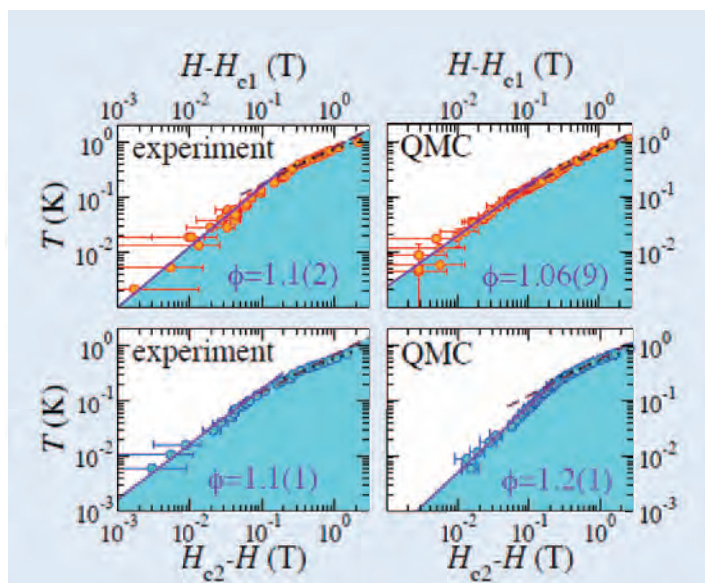


FIGURE 1. Scaling of the critical temperatures with the distance from $T = 0$ critical fields, exhibiting a crossover between various exponents.

Acknowledgements

This research was carried out at the NHMFL High B/T facility which is supported by NSF Grant DMR 0654118 and by the State of Florida.

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Magnetism and Magnetic Materials

Multi-frequency EPR measurements were performed in fields up to 35 T on a Co(II) complex that was recently found to display slow magnetization relaxation behavior at low temperatures. High-fields were essential for unambiguously determining the spin-Hamiltonian parameters for this compound. The results suggest a new mechanism underpinning this slow relaxation behavior, thus motivating the development of new theoretical models describing the spin-lattice relaxation.

• Published in *Chemical Communications* **48** (33), 3927-3929 (2012).

High-Field EPR Studies of a Mononuclear Co^{II} Molecular Magnet

J.M. Zadrozny (UC Berkeley, Chemistry); J. Liu (UF, Physics); S. Hill (NHMFL & FSU, Physics); N.A. Piro, C.J. Chang, J.R. Long (UC Berkeley, Chemistry)

Introduction

We report high field EPR studies on a mononuclear cobalt complex [(3G)CoCl](CF₃SO₃) (1). Ac susceptibility measurements on 1 demonstrate slow relaxation of magnetization with a relaxation barrier of 24 cm⁻¹. High-field EPR measurements were performed on 1 to obtain a definitive determination of the sign and magnitude of the magnetic anisotropy of the compound¹.

Experimental

Single-crystal high-field EPR measurements were carried out on 1 in a 35 T resistive magnet. A Millimeter Vector Network Analyzer and several different multipliers were used as a microwave source and detector. Powder EPR data for 1 were collected in a 15/17T superconducting magnet. A phase-locked Virginia Diodes solid-state source was employed, followed by a chain of multipliers.

Results and Experiment

The EPR data are interpreted with the following Hamiltonian:

$$\hat{H} = D\hat{S}_z^2 + E(\hat{S}_x^2 - \hat{S}_y^2) + \mu_B \mathbf{B} \cdot \mathbf{g} \hat{\mathbf{S}}$$

The main panel of Figure 1 shows the positions of the EPR peaks observed via high-field studies of a single crystal oriented *in situ* such that the field was close to the parallel (z) direction. The most notable feature is that three resonances are observed in the frequency range between 315 and 355 GHz. This can only be explained if 1 possesses easy-plane type anisotropy

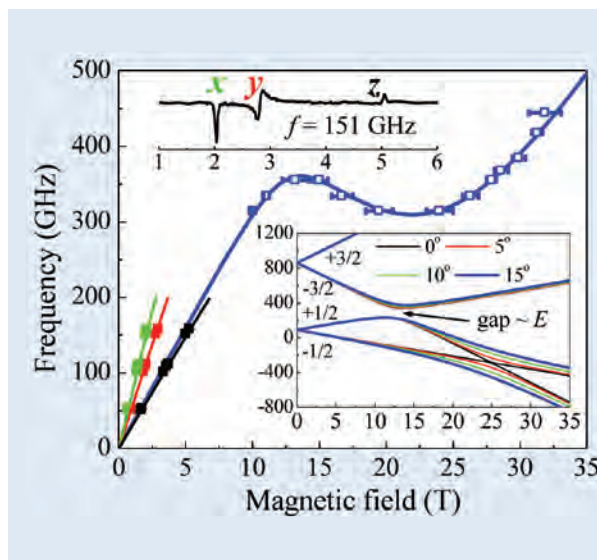


FIGURE 1. Frequency dependence of EPR peak positions collected on a powder sample at 5 K ($f < 200$ GHz) and a single crystal at 4.2 K ($f > 300$ GHz) aligned 15° away from the parallel (z) direction. The solid lines are simulations of the frequency dependence of the peak positions employing the parameters given in the main text.

Upper inset: Powder EPR spectrum recorded at 5 K and a frequency 151 GHz showing the x, y, and z transitions.

Lower inset: Zeeman diagrams for various field misalignments.

($D > 0$) and the field is applied close to the z-axis; otherwise, only one ground state transition would be observed. The solid blue curve corresponds to the best simulation of the data employing the following parameters: $D = +12.7$ cm⁻¹, $E = 1.2$ cm⁻¹, $g_z = 2.17$ and a field misalignment of 15°. The same parameterization (with $g_x = g_y = 2.30$) accounts perfectly for the powder data (lower left portion of Figure 1).

Conclusions

High-field EPR data unambiguously demonstrate that 1 possesses easy-plane type anisotropy. To the best of our knowledge, this is the first example of a mononuclear transition metal complex with easy-plane type anisotropy that also exhibits slow magnetic relaxation. We

propose that this behavior is due to spin-phonon selection rules that force relaxation to occur through excited states. A theoretical model is under development to explain the slow relaxation behavior.

Acknowledgements

This research was supported by DoE/LBNL grant 403801 (synthesis) and NSF grants CHE-1111900 (magnetism) and DMR-0804408 (EPR). The National High Magnetic Field Laboratory is supported by the NSF (DMR-0654118) and the State of Florida.

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Molecular Conductors

The high magnetic field behavior of resonance peaks and coherence peaks of angular magnetoresistance oscillations (AMRO) in quasi-two-dimensional electron systems was studied. The two-dimensional AMRO, or Kartsovnik-Kajita-Yamaji (KKY) oscillations, are widely observed in many layered materials with weak electron transport along the interlayer direction. Direct observation of spin-splitting of Shubnikov-de Haas oscillations and the observation of the modulation of the KKY oscillations are among the outstanding outputs of which the latter cannot be explained from the current theory of the KKY oscillations.

High Field Behavior of Kartsovnik-Kajita-Yamaji Resonance Peaks and the Coherence Peak of Quasi-two-dimensional Electrons

W. Kang (Ewha Womans Univ., Physics); **Y. J. Jo** (Kyungpook Univ., Physics)

Introduction

We studied high magnetic field behavior of resonance peaks and coherence peaks of angular magnetoresistance oscillations (AMRO) in quasi-two-dimensional electron systems. The two-dimensional AMRO, or Kartsovnik-Kajita-Yamaji (KKY) oscillations, are widely observed in many layered materials with weak electron transport along the interlayer direction. The positions of peaks follow the expression proposed by K. Yamaji. However, the height of peaks, especially that of the coherence peaks, varies drastically from one compound to another, which obscures their origin. There is a debate on the occurrence mechanism for the coherence peak. Recently, we observed giant and almost delta-function like KKY resonances and coherence peaks in a pressurized sample of β -(BEDT-TTF)₂I₃. In view of their quality, this sample is the most suitable to study quantitatively temperature and magnetic field dependence of resonant electronic transport behavior.

Experimental

The samples are mounted to a specially designed sample supports which is also fit into the probes in the NHMFL. Most of samples studied at home were

conserved and brought to NHMFL. Precise determination was necessary in view of strong azimuthal angle dependence. Fine tune of the azimuthal angle was made in SCM2 (18T, mainly in the persistent mode) and further experiments were performed in one of resistive magnet to resolve the newly emerging structures on the AMRO near 90 degree.

Results and Discussion

We obtained two new outstanding results concerning the direct observation of spin-splitting of Shubnikov-de Haas oscillations (Figure 1) and the modulation of the KKY oscillations (Figure 2). The latter cannot be explained from the current theory of the KKY oscillations and is subject to further studies.

Acknowledgements

This work is supported by the government of Korea through a NRF Grants (2011-0000982, 0018744, 0019893).

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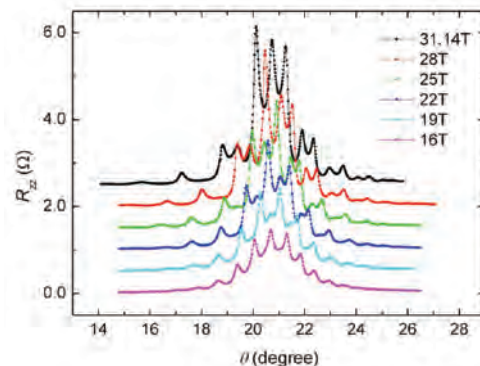


FIGURE 1. Magnetic field dependence of the first KKY resonance peak of β_{H} -(BEDT-TTF)₂I₃. Direct observation of the spin-splitting becomes apparent above 20 T.

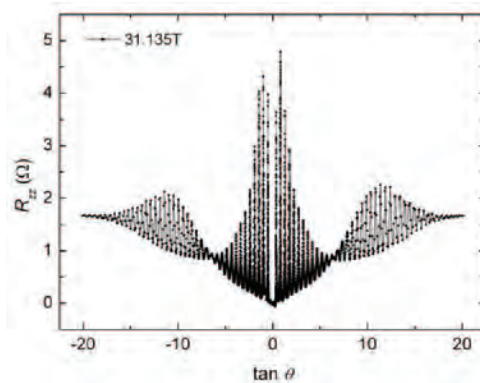


FIGURE 2. Modulation behavior of KKY resonances in β_{H} -(BEDT-TTF)₂I₃. Being an essentially geometrical effect, the KKY resonances are not expected to show any modulation behavior.

Other Condensed Matter

This is a remarkable piece of theoretical artwork from the Master. The paper, in very physical and elegant fashion, sheds a new light on the nature of Charge Density Waves, an issue debated for decades. The author points out the important role of strong interactions between charge carriers and crystal lattice vibrations leading to polaronic effects. The conclusion agrees with recent experimental observations.

• Published in *J. Supercon. Nov. Magn.* **25**, 573 (2012).

Strong Electron-Phonon Interactions and Polaronic Effects in Compounds with Transition-Metals-Atoms

L. P. Gor'kov (FSU, NHMFL)

Introduction

Mechanisms of Charge Density Waves (CDW) in Transition-Metals Di-Chalcogenides (TMDC) continue to be the topic of debates since the CDW discovery in 1974. For a long time the interpretation of the phenomenon was in terms of the popular “nesting” mechanism. Numerical calculations have not confirmed presence of such features for the Fermi-surfaces in these materials. Analysis of the early experimental data for CDW in $2H$ -TaSe₂ have found the short coherence length in the system below transition and large fluctuations, all in strong disagreement with predictions of the nesting scenario¹. Recent progress in the ARPES experiments revived the topic. In the report it is shown that both the normal and superconducting properties of TMDC reflect the important role of strong electron-phonon interactions displaying the polaronic effects.

Results and Discussion

We consider interaction of conduction electrons with the displacements of transitional atoms. Strong enough coupling transforms the harmonic potential of an ion into the potential well with two-or-more deep minima. The system becomes the system of the Ising spins. The inter-site interactions are responsible for the CDW transformation. Since the structural vector,

Q at such mechanism has nothing in common with the Fermi surfaces' parameters, the system remains metallic below the CDW transition. Among the most typical manifestations of such strong *e-ph* coupling in the system are large characteristic energy scales significantly exceeding the temperatures for the onset of the CDW phase. Large value of the pseudogap seen in the tunneling experiments is related to the deep minimum of the two-well potential. It is shown that onset of CDW affects the density of state for the electronic band away from the Fermi surface, thus explaining the result of ARPES experiments². Properties of conduction electrons above and below the transition agree with the results of ARPES experiments. If *e-ph* coupling is strong enough for one or more bands, polaronic effects practically decouple these bands from the rest. This suggests the interpretation for a rather unexpected observation of the dHvA oscillations on the small pocket in $2H$ -NbSe₂ in the vortex state well below H_{c2} .

Conclusions

The available experimental data, including the recent ARPES results, support the interpretation of properties of the transition-atoms-dichalcogenides in terms of the local polaronic effects.

Acknowledgements

The work was supported by the NHMFL through NSF Grant No. DMR- 0654118 and the State of Florida.

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Other Condensed Matter

The two-dimensional conduction layer forming at the interface of LaAlO_3 (LAO) and SrTiO_3 (STO) oxides is a subject of intense experimental and theoretical studies. This report focuses on unusual coexistence of magnetism and superconductivity observed between these nonmagnetic insulators. The nature of this intriguing phenomenon is not clear but for sure stems from an exotic superconducting ground state. On the application side, this novel two-dimensional magnetic material may be used in spintronics where both orbital and spin properties are used to process information.

• Published in *Nature Physics* **7**, 762-766 (2011).

Coexistence of Magnetism and Two-Dimensional Superconductivity at Oxide Interface Using SCM and Torque Magnetometry

Lu Li (Univ. Michigan), **C. Richter** (Univ. Augsburg), **J. Mannhart** (Max Planck), **R. C. Ashoori** (MIT)

Introduction

Transition metal oxide has been a rich field for many intriguing physical phenomena, including high temperature superconductivity and colossal magnetoresistance. Interface devices of semiconductors are the driving force of current modern technology, such as transistors in computer chips, solid state lasers, and solar panels. We cannot help but wonder what novel effects will appear by combining interface fabrication and transition metal oxides. In this work atomic flat interface made between two nonmagnetic band insulators LaAlO_3 and SrTiO_3 (see the structure sketch in Figure 1a) turns out to be magnetic as well as superconducting¹, an coexistence never observed in two dimensional systems.

Experimental

Nb ohmic contacts were fabricated to measure the conductivity of the LAO/STO wafer. The torque magnetometry studies were performed in SCM1 and SCM2 using metal cantilevers. Background magnetic signals are measured of an empty cantilever, a bare SrTiO_3 , and a 0 u.c. sample that was grown and annealed in the same condition. We also tried to carry out the torque magnetometry and electrical transport property *in situ* in the same setup.

Results and Discussion

We resolved the magnetic moment by measuring the torque on the interface sample under an external magnetic field. Figure 1b compares the magnetic field dependence of the resistance and magnetization of the sample. The magnetization curve resembles that of soft ferromagnet¹. On the other hand, the zero resistance demonstrates that the interface is indeed superconducting.

Conclusions

The unusual coexistence of superconductivity and magnetism would probably lead to an exotic superconducting ground state. On the practical side, our discovery leads to a new way to realize two dimensional magnetic materials, a crucial step for “spintronics”, which uses the “spin” property of the electron to make ultrahigh density hard drive and faster computer chips.

Acknowledgements

We thank the support from the Pappalardo Fellowship, MIT (L. L); ARO-54173PH (R.C.A), and DFG-TRR 80, EC-OxIDes (J.M.)

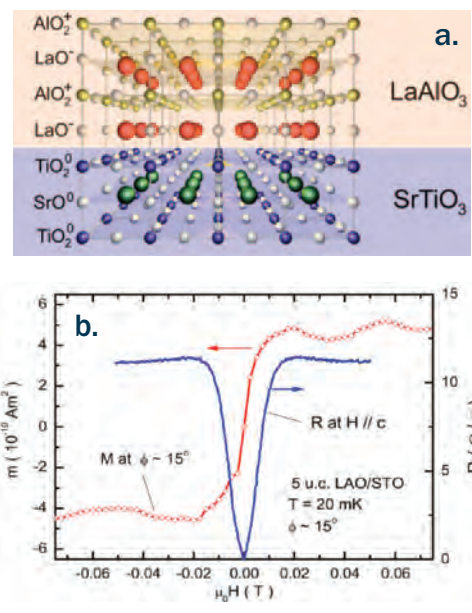


FIGURE 1. **a.** LaAlO_3 thin film on a Ti-O_2 terminated atomic flat SrTiO_3 substrate. Taken from Reference 2. **b.** Low field dependence of magnetization (red) and resistivity (blue) at 20 mK at interface $\text{LaAlO}_3/\text{SrTiO}_3$.

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Qubits and Quantum Entanglement

Silicon based quantum dots and qubits are promising building blocks for quantum computer applications due to their long spin coherence times and potential scalability. Single electrons bound to donor atoms in Si:P have low temperature spin-lattice relaxation times of the order of seconds. Triple-Gate finFETs were fabricated and conductance measurements were carried out at 20 mK and magnetic fields of up to 18 T. The observed resonant transport features are consistent with tunneling through single donors, and the convergence is likely due to onset of two-electron tunneling. At high gate voltages, the carrier transport is in the Coulomb blockaded regime of multi-electron quantum dots. Producing entangled states should be possible in such systems.

Engineering CMOS-Compatible Quantum Dot Qubits for Local and Non-Local On-Chip Quantum Communication

C. C. Lo, J. Bokor (Lawrence Berkeley National Lab and Univ. of California, Berkeley); T. Last (UC Berkeley); T. Schenkel (LBNL)

Introduction

Semiconductor-based quantum dot and donor qubits are particularly promising as fundamental building blocks for quantum information processing (QIP) owing to their long coherence times and scalability^{1,2}. For instance, single electron spins bound to shallow donor atoms in silicon (e.g. P, As, and Sb) have spin-lattice relaxation times at low temperatures of the order of seconds. Towards the development of CMOS-compatible silicon-based nanostructures for QIP, we carried out low temperature magnetotransport measurements to characterize few-dopant triple-gate finFETs (TG-finFETs).

Experimental

We developed silicon TG-finFETs owing to their compatibility with single-ion implantation for large-scale donor qubit integration for QIP. These custom-built few donor doped devices were fabricated on 50nm thick silicon-on-insulator wafers. After defining the silicon fins by dry etching, the side-gates were deposited and patterned with a narrow gap in between. The exposed fins then received a low-dose ion implantation, and the smallest fins received five donor atoms on average. The SEM micrograph of a typical device prior to center fin-gate deposition is shown in Figure 1.

Magnetotransport measurements were carried out for two TG-finFETs using the SCM1 dilution refrigerator at the NHMFL with a base temperature of 20mK.

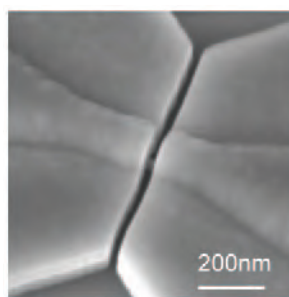


FIGURE 1. SEM micrograph of a TG-finFET prior to fin-gate deposition.

Results and Discussion

Figure 2 shows the conductance plot of a TF-finFET with lithographic length of 100nm and width of 50nm, measured with 0V dc drain bias and ac excitation of 20 μ V. The measurement was carried out with fixed side-gate voltages while the fin-gate voltage (V_g) is varied. For $V_g < 100$ mV, a few of the transport resonance features shift with magnetic field: while some features split, others converge with increasing magnetic field. The splitting of the resonance lines can be understood as a manifestation of the Zeeman shifts for resonance features associated with paramagnetic states³. The

convergence of the resonance features, on the other hand, is related to the increased probabilities for two-electron co-tunneling events that occur⁴. While these transport signatures are compatible with tunneling through single donors, further investigation is required for the definitive identification of the origin of these features. The oscillations at higher gate voltages ($V_g > 150$ mV) are periodic and reproducible, indicating carrier transport in the Coulomb blockaded regime in a multi-electron quantum dot.

Acknowledgements

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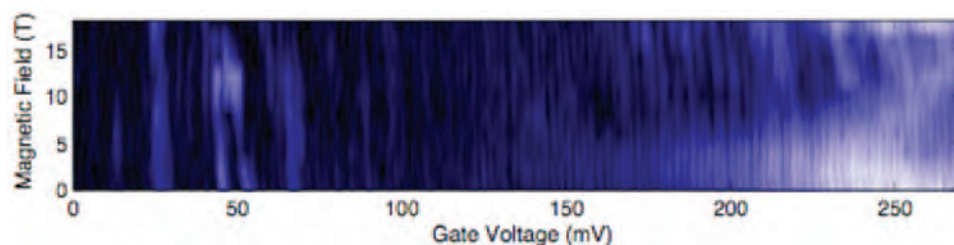


FIGURE 2. Conductance measurements carried out at $T = 20$ mK. The side gates are biased at 0.8 V. Scale is from 0-3.7 μ S.

Semiconductors

Superfluorescence is a phenomenon where macroscopic coherence spontaneously appears from initially incoherent electron-hole pairs and abruptly decays producing giant pulses of light. It has been observed in atomic gases and rarefied impurities in glasses and crystals. This report describes the first evidence for superfluorescence in a semiconductor. The solid-state realization of superfluorescence using high magnetic fields and low temperatures provides an unprecedented degree of controllability, opening up new opportunities for both fundamental many-body studies and device applications.

• Published in *Nature Physics* **8**, 219-224 (2012).

Time-Resolved Evidence for Superfluorescent Radiation from Quantum Wells in 17.5T

J. H. Kim, G. T. Noe, J. Kono (Rice U., ECE/Physics); A. A. Belyanin (TAMU, Physics); S. A. McGill (NHMFL)

Introduction

Superfluorescence (SF) is the process of cooperative emission of coherent radiation from an initially incoherent ensemble of excited dipoles. It represents one of the unusual examples of self-organization processes where macroscopic coherence spontaneously develops through many-body interactions among the individual dipoles. SF has been observed in atomic and molecular gases, but not in condensed matter systems where ultrafast scattering phenomena typically destroys such coherence.

Here, we present evidence for SF through time-resolved differential transmission (TRDT) and time-resolved photoluminescence (TRPL) measurements on an undoped $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}$ multiple quantum well sample in magnetic fields up to 17.5 T. A magnetic field quenches the kinetic energy of electrons and holes and restricts the phase space available for phonon scattering, thereby increasing the coherence time. Furthermore, the concentration of density of states via Landau quantization increases the oscillator strengths of interband magneto-optical transitions. Combining the TRDT and TRPL measurements reveals the nature of the relaxation and the subsequent emission from the magneto-excitonic states.

Experimental

We performed the experiments in the Fast Optics Facility of the National High Magnetic Field Laboratory in Tallahassee, FL, using the 17.5 T superconducting magnet in Cell 3 (SCM3). The sample was placed in the magnet in the Faraday geometry. We used a high-intensity chirped pulse amplifier (CPA) to optically pump the sample, creating a high density of electron-hole pairs in the magneto-excitonic states. For TRDT measurements we used a tunable optical parametric amplifier (OPA) to probe the population of the states as a function of time delay using an optical delay line. For TRPL measurements, we collected the emission using two 0.6-mm core diameter multimode fibers: one placed directly behind the excitation spot and the other at the edge of the sample after redirecting the in-plane emission with a right-angle microprism. We then used a streak camera with a time resolution of 2 ps with a spectrometer to measure the spectrally resolved, time-resolved PL after the optical fiber.

Results and Discussion

Our data exhibit superfluorescent bursts under the conditions of high magnetic field, high excitation power, and low temperature (Figure 1). The data shown here is representative. We varied the magnetic field, excitation power, and temperature to show how the population and emission change under the various conditions.

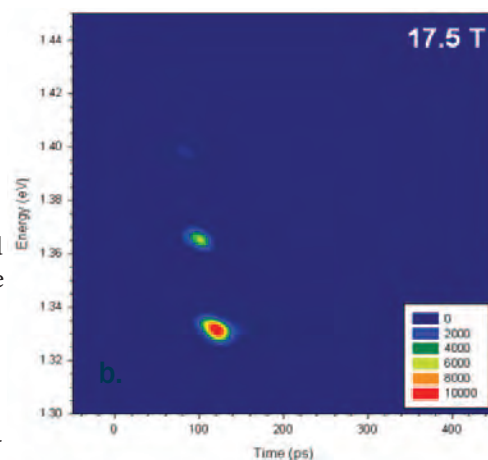


FIGURE 1. TRPL map as a function of delay time and photon energy at 17.5 Tesla, 2 mW excitation, and 5 K.

Conclusions

Our time-resolved measurements mark the first time SF has been convincingly observed in a condensed matter system.

Acknowledgements

This research was sponsored by the NSF through grant DMR-1006663.

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Semiconductors

There is great interest currently in the origin and properties of the fractional quantum Hall (FQH) state at the even-denominator Landau level filling factor $\nu=5/2$. This interest partly stems from the expectation that the quasi-particle excitations of this state might obey non-Abelian statistics and be useful for topological quantum computing. The stability and robustness of the $5/2$ state are thus of great importance. This report describes the study of the stability of the FQH effect at $\nu=5/2$ when two electric subbands are occupied. The $5/2$ state is found to be surprisingly stable near the crossing of the Landau levels belonging to the different electric subbands.

• Published in *Phys. Rev. Lett.* **107**, 176805 (2011).

Anomalous Robustness of the $\nu = 5/2$ Fractional Quantum Hall Effect Near a Sharp Phase Boundary

Y. Liu, J. Shabani, D. Kamburov, M. Shayegan, L. N. Pfeiffer, K.W. West and K.W. Baldwin (Princeton U., Dept. of Electrical Engineering)

Introduction

Fractional quantum Hall effect (FQHE) in a 2D electron system where two subbands are occupied reveals intriguing phenomena¹⁻³. Here we report our studies on electrons confined to a wide GaAs quantum well (QW), when both the symmetric (S) and antisymmetric (A) subbands are occupied. We studied the stability of the even denominator FQHE at $\nu = 5/2$ and $7/2$, when the Landau levels (LLs) belonging to different subbands cross.

Experimental

Each of our samples consists of a GaAs QW bounded on its sides by undoped $\text{Al}_{0.24}\text{Ga}_{0.76}\text{As}$ spacer layers. The density (n) and subband separation are controlled by applying front- and back-gates, and measured through the Fourier analysis of the Shubnikov-de Haas oscillations. The FQHE measurements were carried out in SCMI and resistive magnets.

Results and Discussion

Our surprising discovery², illustrated in Figure 1, is the anomalous robustness of the $\nu = 5/2$ FQHE near the crossing of the spin-up $N = 1$ LL of the symmetric subband (S1 \uparrow) and the spin-up $N = 0$ LL of the antisymmetric subband (A0 \uparrow). This is clearly evident in the plot of the excitation gap ($^{5/2}\Delta$) of the $\nu = 5/2$ FQHE vs magnetic field (B) or n in Figure 1d: the $\nu = 5/2$ FQHE becomes stronger with increasing n

before it collapses. Another noteworthy observation in Figure 1d is that, at a common density of $n = 3.2 \times 10^{11} \text{ cm}^{-2}$, $^{5/2}\Delta$ for the 31-nm-wide QW is nearly twice larger than for the 30-nm-wide QW. We conclude that the dramatic rise of $^{5/2}\Delta$ is related to the crossing of the S1 \uparrow and A0 \uparrow levels. When the density is further increased and the Fermi energy (E_F) moves to the A0 \uparrow level, $^{5/2}\Delta$ suddenly collapses. The sharpness of the collapse suggests a first-order transition of the FQHE to a metallic state.

Conclusions

Our results¹⁻³ show that: (i) The even-denominator FQHE states are stable when E_F is in an $N = 1$ LL. (ii) The odd-denominator states are most stable when E_F is in an $N = 0$ LL. (iii) The $5/2$ FQHE is anomalously stable near the crossing of the S1 \uparrow and A0 \uparrow levels.

Acknowledgements

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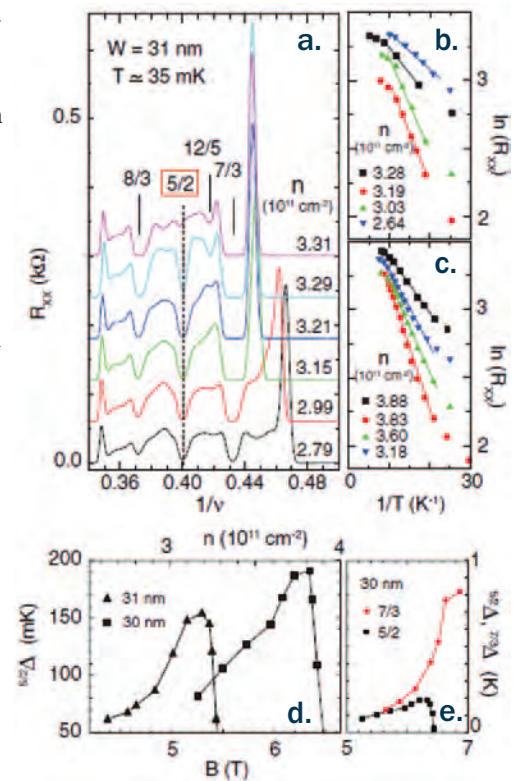


FIGURE 1. **a.** Waterfall plot of R_{xx} vs $1/\nu$ for the 31-nm-wide GaAs QW as n is changed from 2.79 to $3.31 \times 10^{11} \text{ cm}^{-2}$. **b.** & **c.** Arrhenius plots of R_{xx} at $\nu = 5/2$ vs inverse temperature for the 31- and 30-nm-wide QWs at the indicated densities. **d.** Measured energy gap for the $\nu = 5/2$ FQHE in both samples as a function of magnetic field or density. **e.** Measured energy gaps for the $\nu = 5/2$ and $7/3$ FQHEs in the 30-nm-wide QW.

Superconductivity – Basic

A long-lasting question concerning possible coexistence of superconductivity and antiferromagnetism competing locally in the real space seems to be now resolved positively by the NMR experiments of Mounce *et al.* The problem was first posed in the late 90'- early 2000s, after the observations (B. Lake *et al.*) of a static incommensurate antiferromagnetism in the vortex state of LSCO with a sizable average magnetic moment on the Cu^{2+} sites; the moment kept increasing with increase of the magnetic field. Scanning tunneling microscopy (STM) could see such a superstructure only as a checkerboard pattern in DOS on the surfaces of cleaved BSCCO. Unlike neutrons which are a bulk probe or the surface-sensitive STM, NMR is a bulk probe that can explore the local environment. In this report the authors provide results confirming coexistence of the diamagnetic currents at a vortex with SDW close to the normal vortex core and show evolution of the local SDW with increasing field.

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Spin Density Wave Near the Vortex Cores of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$

A.M. Mounce, S. Oh, W.P. Halperin (Northwestern Univ.); A.P. Reyes, P.L. Kuntz (NHMFL), K. Fujita, M. Ishikado, S. Uchida (Univ. of Tokyo)

Introduction

The coexistence of superconductivity and magnetism in the high temperature superconducting (HTS) cuprates is a dichotomy still not fully understood. To investigate this relationship, experiments of spatially resolved nuclear magnetic resonance (NMR) are performed on the HTS $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ (BSCCO) at high magnetic fields and low temperatures. A model for the experimental results indicates a spin density wave originates from the vortex cores and is enhanced with increasing external magnetic field.

Experimental

Samples were prepared by ^{17}O isotopically exchanging single crystals of BSCCO and annealed to the overdoped regime with $T_c = 82$ K. Spectra and spin-lattice relaxation data were taken with the crystal c-axis parallel to the external magnetic field and at low temperatures down to $T = 4$ K. Experiments were performed at the NHMFL and Northwestern University.

Results and Discussion

Previous spatially resolved NMR experiments on $\text{YBa}_2\text{Cu}_3\text{O}_{7+\delta}$ (YBCO) have shown a local magnet field dependent relaxation due to the Doppler shift of quasiparticles¹. Results from BSCCO show a non-monotonic relationship between local magnetic field and spin-lattice relaxation, while the average $1/T_1$ is consistent with the

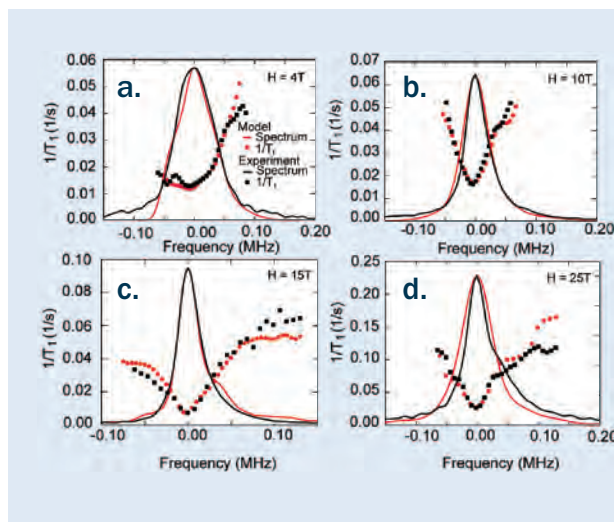


FIGURE 1. Spatially resolved NMR spin lattice relaxation at $T = 4$ K and various magnetic fields, up to $H = 25$ T. At low magnetic field, $H = 4$ T, the frequency dependence of $1/T_1$ is nearly monotonic, similar to that of YBCO¹. As the magnetic field increases, the SDW component of local magnetic field increases, redistributing the local field to $1/T_1$ correspondence producing a non-monotonic relaxation profile.

Volovik effect² indicating a vortex mechanism through Doppler shift. We use a model of a spin density wave (SDW) decaying away from the vortex core in addition to the local magnetic fields due to supercurrents. This results in a non-monotonic relationship between local magnetic field and Doppler-shifted relaxation. With increasing magnetic field, the SDW increases in magnitude changing the relaxation profile, Figure 1.

Conclusions

The spatially resolved NMR relaxation for BSCCO is explained by an additional SDW contribution to the local magnetic field. The field dependence of the SDW fitting parameters indicate an increasing

amplitude with increasing magnetic field. This work has recently been published in *Physical Review Letters*³.

Acknowledgements

This work is supported by DOE/BES: DE-FG02-05ER46248 and the NHMFL by NSF and the State of Florida.

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Superconductivity – Basic

Currently, there is great interest in the origin and properties of the fractional quantum Hall (FQH) state at the even-denominator Landau level filling factor $\nu=5/2$. This interest partly stems from the expectation that the quasi-particle excitations of this state might obey non-Abelian statistics and be useful for topological quantum computing. The stability and robustness of the $5/2$ state are thus of great importance. This report describes the study of the stability of the FQH effect at $\nu=5/2$ when two electric subbands are occupied. The $5/2$ state is found to be surprisingly stable near the crossing of the Landau levels belonging to the different electric subbands.

• Published in *Phys. Rev. Lett.* **107**, 176805 (2011).

Quantum Oscillations in the Thermoelectric Properties of $\text{YBa}_2\text{Cu}_3\text{O}_{6.54}$ to 45 T in the Hybrid Magnet

N. Doiron-Leyraud, S. René de Cotret, J. Chang, F. Laliberté (Sherbrooke); L. Taillefer (Sherbrooke and CIFAR); B. Ramshaw (UBC); R. Liang, D. Bonn, W. Hardy (UBC and CIFAR)

Introduction

Quantum oscillations and Hall effect measurements have revealed the existence of a small closed electron Fermi surface in underdoped YBCO^{1,2}, in sharp contrast with the large hole Fermi surface seen in overdoped Tl2201³. This naturally suggests that a Fermi surface reconstruction occurs as a function of doping, possibly at a quantum phase transition where a form of density-wave order sets in. While a number of scenarios have been proposed, “the cause of the reconstruction, and its implication for the origin of high-temperature superconductivity, is a subject of active debate”⁴. In order to identify the cause of the reconstruction, we need to gain a better understanding of the Fermi surface of underdoped cuprates, a question we have recently examined through a series of thermoelectric experiments in high magnetic field.

Experimental

We performed a series of thermoelectric experiments up to 45 T using the hybrid magnet in cell 15 at the National High Magnetic Field Laboratory in Tallahassee. Our work focused in highly ordered ortho-II specimens of $\text{YBa}_2\text{Cu}_3\text{O}_{6.54}$ ($p = 0.11$) grown by the group of Liang, Bonn, and Hardy at the University of British Columbia. In Figure 1 we show the Seebeck coefficient S of $\text{YBa}_2\text{Cu}_3\text{O}_{6.54}$ as a function of applied magnetic field at a temperature of 2 K. At sufficiently high field, above the

vortex lattice melting line, the normal-state thermopower is strongly negative and exhibits large quantum oscillations (QOs)⁵. The curve shown in Figure 1 are raw, unsmoothed, data. QOs were also observed in the Nernst effect.

Results and Discussion

The existence of a small electron pocket was initially inferred from the simultaneous observation of QOs and a negative Hall effect^{1,2}. It has been argued, however, that a negative Hall effect may come from vortices or a Fermi surface with changing curvature. The thermopower, however, is free from these effects and the observation of QOs on a strongly negative Seebeck coefficient is unambiguous evidence that the Fermi surface supporting the orbits is indeed electron-like⁵. We recently examined the range in doping and temperature of this negative Seebeck coefficient in YBCO and Eu-LSCO, a cuprate in which a form of spin and charge order known as “stripe order” has been observed. Our study revealed a detailed and striking similarity between the two materials, showing that the electron pocket and the Fermi surface reconstruction must share a common origin, namely stripe order⁶. NMR experiments in high magnetic field recently revealed stripe order in YBCO⁷.

Conclusions

We have observed large QOs in the

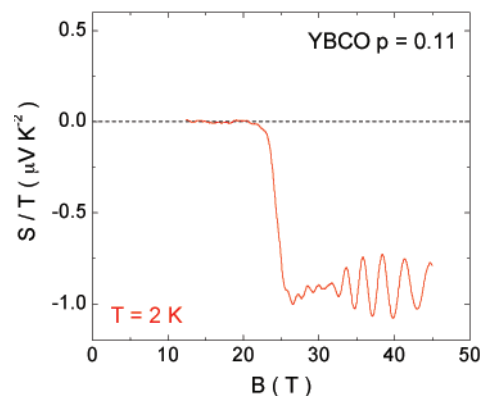


FIGURE 1. Seebeck coefficient S over temperature T of $\text{YBa}_2\text{Cu}_3\text{O}_{6.54}$ as a function of magnetic field B . From⁵.

Nernst and Seebeck effects on $\text{YBa}_2\text{Cu}_3\text{O}_{6.54}$, which confirms the existence of an electron pocket and provides a novel window for the study of the Fermi surface of YBCO.

Acknowledgements

We acknowledge support from CIFAR, NSERC, FQRNT, CFI, and a Canada Research Chair.

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Superconductivity – Basic

A key challenge in understanding quantum oscillations in high T_c superconductors has been an identification of the underlying electronic structure, and a reconciliation with complementary experiments such as photoemission. Using data that extends over an unprecedented field range up to 101 T, Sebastian *et al.* suggest an elegant way of reconciling quantum oscillation experiments that reveal multiple frequency components, with photoemission results that reveal a nodal density of states with a small bilayer coupling. A comprehensive explanation is suggested in which quantum oscillations arise from bilayer-split nodal Fermi surface pockets accompanied by magnetic breakdown tunnelling.

• Published *Phys. Rev. Lett.* **108**, 196402 (2012).

Multiple Quantum Oscillation Frequencies from Nodal Pocket in Underdoped Cuprates to 95 T

S.E. Sebastian, G.G. Lonzarich (U. of Cambridge, Physics); C. Mielke, N. Harrison (Los Alamos National Laboratory); R. Liang, W.N. Hardy, D. A. Bonn (U. of British Columbia, Physics)

Introduction

Discerning the electronic structure of the underdoped cuprates poses a pressing conundrum. Among key questions to be addressed are the issue of whether the electronic structure comprises multiple pockets, and whether any of these are located at the antinodal region of the Brillouin zone where photoemission experiments reveal a significant gap in density of states at the Fermi Energy.

Experimental

We have performed quantum oscillation measurements on $\text{YBa}_2\text{Cu}_3\text{O}_{6.56}$ (hole doping of $\approx 10\%$) using the resonant oscillator technique, up to unprecedentedly high magnetic fields of 101 T at NHMFL Los Alamos. The wide field range thus accessed (24 – 100 T) enables a frequency resolution of $\approx 30\text{T}$, enabling superior resolution of multiple quantum oscillation frequencies¹.

Results and Discussion

A distinct pattern of quantum oscillation frequencies observed, with a spectrally dominant frequency at 532(2)T, flanked on either side by frequencies 440(10)T and 620(10)T spaced equidistantly from the central frequency (Figure 1). At first sight, these three frequencies appear challenging to reconcile with a single Fermi surface pocket indicated from chemical potential oscillations.

We propose that this pattern of frequencies can be explained by the effect of bilayer splitting accompanied by magnetic breakdown on a nodal pocket. $\text{YBa}_2\text{Cu}_3\text{O}_{6.56}$ comprises bilayers (i.e. pairs of planes) of CuO_2 , the effect of bilayer coupling is to split each Fermi surface pocket into two surface (as shown in Figure 2). This still leaves us with the problem of how to explain three frequencies from a Fermi surface pocket.

In the case of a nodal pocket, however, we invoke the additional effect of magnetic breakdown due to the small size of bilayer splitting at the nodes compared to the antinodes.

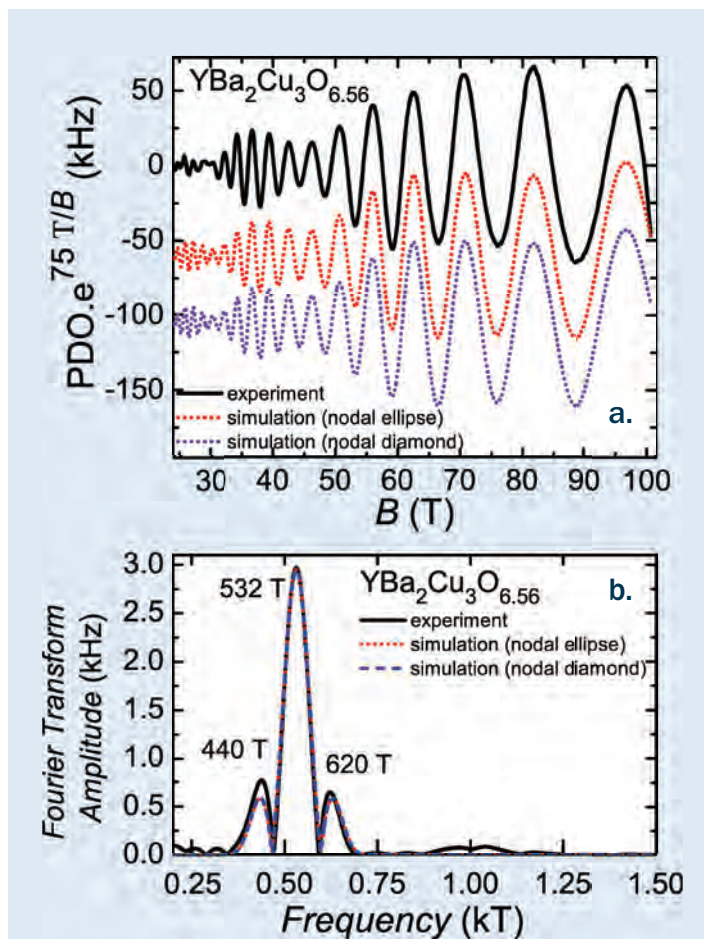


FIGURE 1. Quantum oscillations measured in contactless resistivity using a proximity detection oscillator (PDO) from 24 - 101 T in (a), the Fourier transform in (b) shown by black lines. Red and blue dotted lines are simulations for an elliptical and diamond nodal pocket.

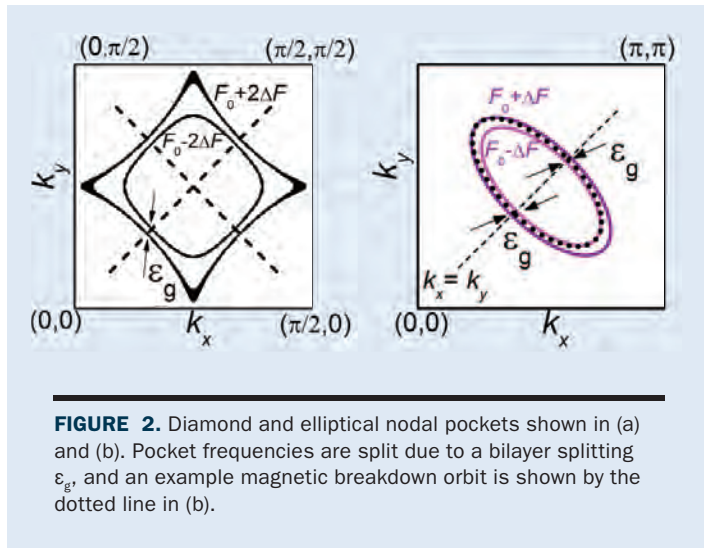


FIGURE 2. Diamond and elliptical nodal pockets shown in (a) and (b). Pocket frequencies are split due to a bilayer splitting ϵ_g , and an example magnetic breakdown orbit is shown by the dotted line in (b).

Quasiparticles can therefore tunnel between the two split pockets at the nodes. An example is shown in Figure 2b, where the pink and purple ellipses are the split elliptical nodal pockets. The dotted purple line shows an elliptical orbit arising due to magnetic breakdown between the two split pockets, with frequency equal to the average of the two split frequencies. Another example is shown in figure a, where the nodal pocket has a diamond shape. The resulting frequency spectrum therefore would have the form $F+\Delta F$, $F-\Delta F$, and their average F — which is in fact precisely the same as that experimentally observed.

The dotted lines in Figures 1a and 1b show a simulation of the oscillation spectrum anticipated for a nodal pocket of an ellipsoidal shape, and a diamond shape respectively with a single adjustable variable: the size of magnetic breakdown field, good agreement is seen with the experimentally observed quantum oscillation spectrum.

Conclusions

Quantum oscillations measured up to 101 T in the underdoped cuprate $\text{YBa}_2\text{Cu}_3\text{O}_{6.56}$ reveal well separated multiple frequencies with a characteristic $F+\Delta F$, $F-\Delta F$, F pattern. We propose that these can be explained by effects of bilayer splitting accompanied by magnetic breakdown on a nodal pocket.

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Superconductivity – Basic

A team of scientists from Oxford University and Bristol University reports dHvA oscillations in LiFeAs and LiFeP. ARPES data disagree with the Fermi surfaces in LiFeAs obtained in the band structure calculations. That prompted the bulk study of electronic spectrum of these materials in the dHvA experiments. The outcome is that the observed Fermi surfaces are in good agreement with those from the band calculations. For LiFeAs the comparison of the calculated “band masses” with the observable orbital masses has shown considerable enhancement due to both electron-electron and electron-phonon interactions. As LiFeAs and LiFeP are predicted to have similar electron-phonon coupling it is very likely that the observed effect is related to enhanced electronic correlations linked to higher T_c in iron-based superconductors.

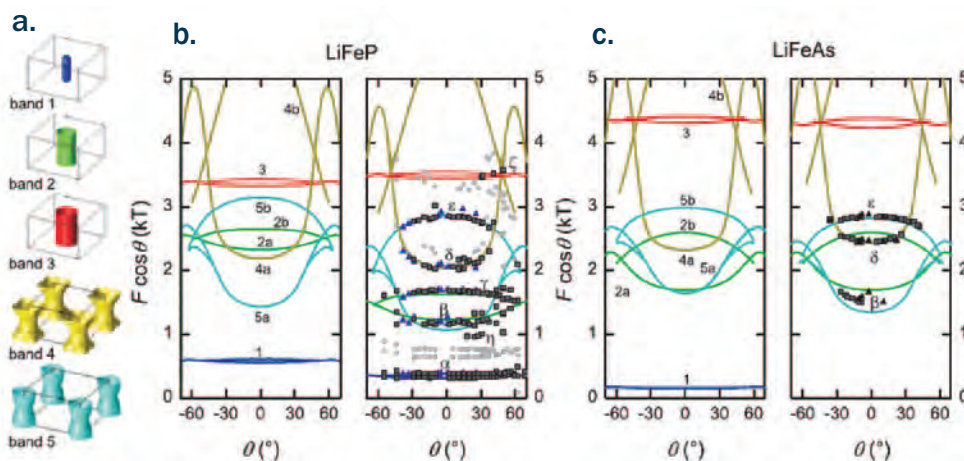
• Published in *Phys. Rev. Lett.* **108**, 047003 (2012).

Quantum Oscillations in the 111 Iron Pnictide Superconductors: LiFeAs and LiFeP Using 45T Hybrid Magnet

A.I. Coldea, M.D. Watson (Oxford University, UK); C. Putzke, I. Guillamon, A. Carrington (Bristol University, UK.); S. Kasahara, T. Shibauchi, Y. Matsuda (Kyoto University, Japan)

The aim of our experiment was to study the Fermi surface topology of the ‘111’ structure superconductors in the superconducting LiFeAs with $T_c=18.5$ K¹ and LiFeP with $T_c=5$ K which are two of only a few iron-based superconductors which superconduct at ambient pressure in their undoped stoichiometric form. ARPES studies have suggested that LiFeAs has a Fermi surface that disagree with band structure calculations and bulk studies of the Fermi surface are required to clarify whether spin fluctuations are relevant in iron pnictides². Furthermore, these materials can be grown in high crystal-line form and have been found to show different gap symmetry, having a fully gapped superconducting order parameter in LiFeAs and there are suggestions that LiFeP has nodes³. An additional challenge concerning experimental investigation of these materials, which are supposed to be some of the cleanest iron pnictides, is their significant sensitivity to air.

During our last experiment in the 45T hybrid magnet we have been able to observe dHvA oscillations in these two compounds in order to map out the Fermi surface of these two isoelectronic systems. We have determined almost completely the Fermi surface of LiFeP in broad agreement with band structure calculations and found out that the mass enhancement varies significantly between bands, being



quite small for one of the bands. These findings could suggest that the inner hole band could be the place for nodes formation⁴. Our study on LiFeAs has found that the observed orbits belong to the electron bands and are well described by the band structure calculations without any energy shifts; the mass enhancement for the observed electron bands in LiFeAs is significant, a factor up to 5, being linked to the higher T_c of this optimally doped system⁴. However, more work is required to clarify how well nested the Fermi surface of LiFeAs is.

Acknowledgements

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tract no.228043, KAKENHI from JSPS. A part of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-0654118, the State of Florida, and the U.S. Department of Energy.

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Engineering Materials

The desire to create next generation materials with better mechanical properties can be achieved using metal matrix composites by incorporating a fine dispersion of strengthening particles. A crucial requirement to achieve the enhanced performance is that the fine particles be homogeneously dispersed throughout the matrix. In addition, preferential directional (textured) performance of the final material can be achieved by leveraging the magnetocrystalline anisotropy of the material. This research indicates that both uniformly dispersed nanoparticles and a textured matrix can be obtained in a single alloy by a combination of thermomagnetic processing and electromagnetic acoustic transducer technologies.

Enhanced Performance Materials Through Thermomagnetic Processing Solubility Enhancement and Nanoparticles Dispersion Strengthening Using 20T (up to 19T) Wide-Bore Magnet

G.M. Ludtka; G. Mackiewicz-Ludtka, O. Rios; J.B. Wilgen; R.A. Kisner, G.Muralidharan (Oak Ridge National Lab); M. Manuel (Univ. of Florida)

Introduction

This research demonstrates that significantly enhanced materials microstructures and improved performance can be achieved by coupling two previously independent materials research concepts, namely, the thermo-magnetic processing (T-MP)¹ and the electromagnetic acoustic transducer (EMAT)² technologies. In prior, separate NHMFL research endeavors, ORNL researchers have demonstrated that: 1.) thermo-magnetic processing (T-MP) can significantly enhance Ni solubility in Fe by up to 30%; and 2.) using the electromagnetic acoustic transducer (EMAT) technology can significantly improve cast product homogeneity. Based on these earlier successful results, we proposed simultaneously coupling these two R&D approaches/effects (i.e., T-MP with EMAT), in order to simultaneously achieve: 1.) *enhanced elemental solid-solubility* in Mg and in at least one Fe-based alloy; and 2.) *uniform dispersion* of intentional additions of inert nanoparticles in Mg. Developing homogeneous dispersions of inert nanoparticles is and has been pursued as one of the “holy grails” for achieving unprecedented materials performance and highly desired mechanical properties, e.g., in creep and oxidation resistant alloys. Successfully coupling these two technologies would provide the ability to create uniquely controlled nano-scale microstructures that currently are unachievable by any other materials processing technologies.

Experimental

A series of 14 different Mg samples were prepared that either had a pure Mg or Mg-Li alloy matrix and nanoparticles dispersions of either diamond, Er₂O₃, or Dy₂O₃. In addition, several Fe-Co-Ni alloys were cast for enhanced texturing and increased solute solubility. The Mg alloy samples were processed with the T-MP and EMAT processes superimposed (stopped EMAT 20 °C above liquidus) to homogeneously distribute the nanoparticles whereas the Fe-based alloys had the EMAT effect turned off to promote magneto anisotropy-induced texturing to occur during solidification.

Results and Discussion

Subsequent radiography and microscopy analyses of the Mg and Mg-alloy castings showed uniform dispersions of nanoparticles could be achieved but results were directly dependent on the quality/uniformity of the starting materials. The Fe-based experiments, shown in Figure 1, showed that very highly textured, bulk castings could be achieved over a broad range of cooling rates (30 to 300 °C/min) by applying a high magnetic field (19 T) during solidification.

Conclusions

Combined T-MP and EMAT processing facilitates uniform, non-agglomerated dispersions of nano-particles in Mg. In addition, T-MP processing of Fe-based

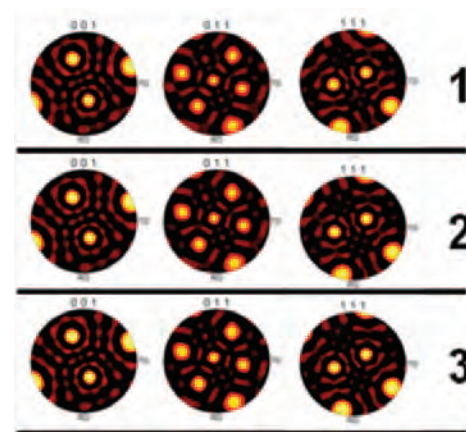


FIGURE 1. Identical pole figures at three separate locations in the Fe-based bulk castings show significant texturing was achieved.

alloys during solidification can achieve highly textured, bulk castings.

Acknowledgements

Research supported by the ORNL's Laboratory Directed Research and Development Program.

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Magnet Technology

REBCO coated high temperature superconductor has excellent tensile properties in rolling direction due to the use of high strength alloy as a substrate. In transverse direction, however, the conductor fails early, mechanically as well as electrically due to delamination and destruction of the superconducting layer. The authors achieved a technological breakthrough in magnet technology by devising a method that mechanically uncouples transverse loads from the conductor by using a thin-walled polyester heat shrink tube around the conductor.

• Published in *Appl. Phys. Lett.* **99**, 202506 (2011).

Mechanical Decoupling of ReBCO Coated Conductors in High Field Coils Using Thin-Walled Heat-Shrink Tubing Insulation to Prevent Stress-Induced Damage

D.K. Hilton, H.W. Weijers (NHMFL-MST); M. Dalban-Canassy, U.P. Trociewitz, D.C. Larbalestier (NHMFL-ASC)



FIGURE 1. A coil wound with copper-plated conductor (4 mm wide) insulated with thin-walled heat-shrink tubing. This coil consistently generated 4.2 T in a 31.2 T background field, for a total of 35.4 T, a world record for superconducting coils.

Introduction

REBCO coated conductors, such as those based on $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ and other rare-earth variants of this structure are now being developed and commercialized. Particularly, they show great potential for the construction of high field magnets, since they retain their superconducting state in magnetic fields well above 100 T at low temperatures, whereas the materials presently used to construct superconducting magnets, Nb-Ti and Nb_3Sn , cannot operate in fields that exceed 25 T or so. Construction of superconducting magnets requires not just a suitable conductor, but also a suitable insulation to resist over-voltages during quenches, and suitable winding encapsulants to prevent tape movement, delamination, and resulting damage during encapsulant curing, thermal cycling, and electrical energization of the magnet.

Experimental

We incorporate an unusual conductor insulation, a medical-grade, low-temperature compatible, extremely thin-walled heat-shrink tubing, manufactured by and proprietary to Vention Medical, Inc. This tubing consists of an extruded and expanded polyethylene terephthalate, a polyester, with a melting point of about 508 K, an operating temperature range of 77 K – 408 K, and a $3.8 \mu\text{m}$ minimum thickness.

Recently confirmed in an epoxy-impregnated world-record superconducting coil (Figure 1), this insulation uniformly insulates tape conductors, including the edges of the conductors, and does not crack at low temperatures, especially while sustaining bending or tensile strain. Because shrinkage and not adhesion is the functional basis of this tubing, thermal and electromagnetic tensile and shear stresses are minimized at the boundary between conductor and encapsulant.

Discussion

The heat-shrink tubing allows the use of a strong encapsulant such as epoxy, which otherwise bonds strongly to the conductor or insulator surface. However, magnet cooling or energization produces perpendicular tensile stresses that can delaminate the metal-oxide interfaces in the conductor, greatly degrading performance. Having almost no strength, the interface between the conductor and the insulation

thus allows an encapsulant such as epoxy, anchoring the windings without applying perpendicular tensile stresses to the conductor. Numerous examples of conductor delamination in various labs due to stresses developed during cooling or energization of epoxy-impregnated superconducting coils make this development of great value.

Conclusions

Because all present designs of coated conductors tend to have relatively weak bonding between their metal and oxide components, and because high field magnets necessarily develop significant stresses, this invention addresses an important problem of this technology. A U.S. provisional patent application (61/420,429) has been filed that is being converted into a U.S. utility patent.

Acknowledgements

This work is funded by the NSF (Award No. DMR-0654118).

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Magnet Technology

In a household extension cord, the copper wire is coated with plastic, which electrically insulates the wire. At the Magnet Lab, magnets are made from electrically conducting wires that also need to be insulated from one another. One magnet that is being developed, the 32 T all-superconducting magnet, is made with bare flat wires that carry the current. When the coil is wound, these flat tapes are electrically isolated from one another with a flat stainless steel tape that is coated with a layer of insulating material. In this study, two different insulating materials that coat the stainless steel tape, each with its own method for being applied, were developed.

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Insulation of Coated Conductors for High Field Magnet Applications

J. Lu, H. Kandel, K. Han, W.R. Sheppard, D.M. McRae, A. Voran, K.W. Pickard, R.E. Goddard, Y.L. Viuchkov, H.W. Weijers and W.D. Markiewicz (NHMFL, Florida State Univ.)

Introduction

Insulation in a high field superconducting magnet plays a critical role. High field magnets require very thin (e.g. $< 12.5 \mu\text{m}$) insulation with sufficient mechanical and dielectric strength under high stresses at cryogenic temperatures^{1,2}. Within the framework of the construction of the 32 T all-superconducting magnet, two types of reel-to-reel systems, which insulate either the coated conductor or steel co-winding tapes, have been developed.

Experimental

A UV cured epoxy coating system has been built as shown in Figure 1. A suitable UV cured epoxy EPO-TEK® UVO-114 has been identified and used in the process. For insulation of steel co-winding tape, we also chose a ceramic sol gel coating process. The sol gel is made by mixing (in weight) one part of silica sol gel (Silbond H-5), two parts of ethanol and 0.3 part of $0.3 \mu\text{m}$ sized alpha alumina powder. The reel-to-reel dip coating system in Figure 1 is modified by addition of a tube furnace, so the sol gel coated steel tape is dried at 300 C and calcinated at 700 C.

Results and Discussion

The UV epoxy insulation is nominally $10 \mu\text{m}$ thick with a typical breakdown voltage of about 400 V. It has about $5 \mu\text{m}$ thickness variation along the tape width. The corners are not fully covered, although in case of the 32 T pancake coils, the corner coverage is not critical. These problems are related to the rheology of the coating process. Sol gel coating on steel tapes has

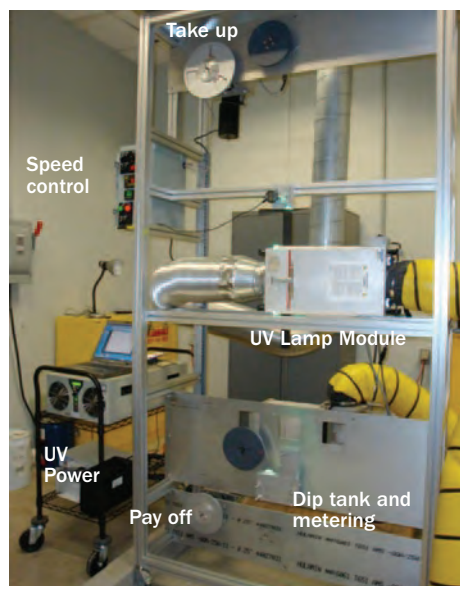


FIGURE 1. The UV epoxy coating system.

superior thermal properties. The coating thickness is approximately $2 \mu\text{m}$ with a typical breakdown voltage of about 200 V. Similar to the epoxy coating, the sol gel coating has issues of corner coverage and the thickness build-up near the edges. An air-flow assisted sol gel drying process is being developed as a promising technique to mitigate these problems. Both methods were used to insulate hundreds of meters of steel co-winding tapes which have been successfully used in the 32 T test coils.

Conclusions

Both the UV-cured epoxy-coating and sol gel coating has been developed for insulating YBCO coated conductors and steel co-winding tapes. Long length steel

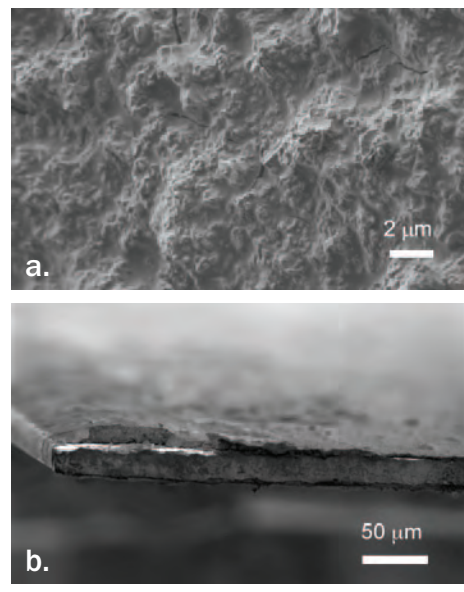


FIGURE 2. SEM images of silica sol gel coated steel tape. (a) Surface and (b) cross-section.

tapes have been insulated for 32 T test coils using both techniques. The issues of corner coverage and the thickness build-up at the edges are being addressed.

Acknowledgements

This work was supported by the National Science Foundation under Grant No. DMR-0654118.

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Superconductivity – Applied

The full potential of Bi2212 high temperature superconducting round wire is masked by void space that forms inside the conductor during the thermal processing that is required to form a well aligned current carrying crystal structure. The authors achieved a technological breakthrough by devising a processing scheme that significantly reduces the void space in the conductor and at least doubled the critical current density in a series of short wire samples consistently.

• Published in *Superconductor Science and Technology* **24**, 082001 (2011).

Doubled Critical Current Density in Bi-2212 Wires by Reduction of Gas Bubble Density

J. Jiang, W.L. Starch, M. Hannion, F. Kametani, U.P. Trociewitz, E. E. Hellstrom and **D.C. Larbalestier** (NHMFL, Florida State Univ.)

Introduction

The filament density of Bi-2212 wire in the as-drawn state is much less than 100%, typically about 70% of the theoretical density of Bi-2212. In order to better understand the effects of this less than full density on the critical current density (J_c), we quenched samples of Bi-2212 wires just after they entered the melt phase and observed many large gas bubbles, most as big as the filament diameter. Although the overall effect of melt processing on J_c is highly positive, J_c is certainly lowered by formation of these bubbles which of course do not support a supercurrent.

Experimental

In order to fill the filaments with O_2 gas, which can diffuse through the Ag sheath, Bi-2212 wire samples were heated at 400 °C for 48 h under a vacuum of 20 mtorr. After cooling, the samples were filled with 1 bar oxygen and held for 16 h. When the wires were removed from the furnace, their ends were immediately sealed by dipping in molten Ag or Sn and the filaments were densified under a cold isostatic pressure (CIP) of 2 GPa before the following melt processing step.

Results

The longitudinal cross sections of the quenched samples are shown in Figure 1. Gas bubbles in the as-received wire are big, being 2 to 3 times as long as their diameter, while the bubbles in the CIPped wire are much shorter, round and are smaller than the filament diameter. Table 1 compares the values of I_c (4.2 K, 5 T) and the resistive transition index n for fully-processed as-received and CIPped wires. The I_c (4.2

K, 5 T) values for the CIPped samples were more than doubled, and their n values are also much higher than for the as-received wires, consistent with an increase in the longitudinal uniformity of the I_c . J_c (4.2 K, 5 T) was increased from 1667 to 3600 A/mm² for the CIPped wire.

Conclusions

We found a significant improvement of J_c in recent Bi-2212 round wires by replacing residual air in the filament by pure oxygen and cold isostatic pressing them before melt-processing. The fewer and smaller bubbles formed in the melt allowed the critical current I_c (4.2 K, 5 T) to be doubled. Controlling the formation of bubbles through approaches like CIPping was shown to be a very effective pathway to achieve very high J_c in Bi-2212 wires.

Acknowledgements

The work at the NHMFL was supported by an ARRA grant of the US Department of Energy Office of High Energy Physics and by the NHMFL which is supported by the National Science Foundation under NSF/DMR-0654118 and by the State of Florida.

T_{max} °C	AR or CIP	I_c (A)	J_E (A/mm ²)	J_c (A/mm ²)	n value
884	AR	155.0	325	1174	9
884	CIP	385.4	807	3602	21
885	AR	175.8	350	1332	13
885	CIP	386.4	809	3611	20
888*	AR	220.0	438	1667	11

*888 °C gave the maximum I_c for AR wire.

TABLE 1. I_c (4.2 K, 5 T), J_E (4.2 K, 5 T) J_c (4.2 K, 5 T) and n value for fully processed as-received (AR) and CIPped samples of 37x18 wire.

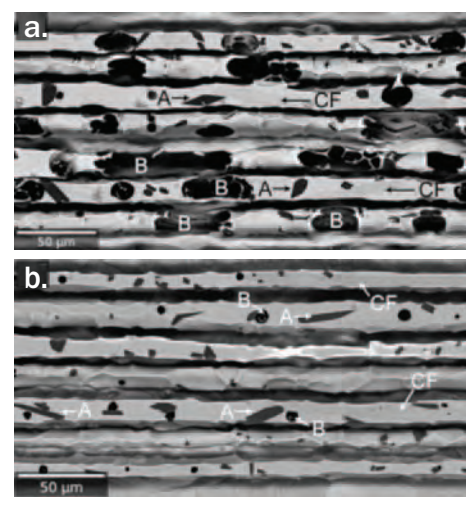


FIGURE 1. SEM images of longitudinal cross sections of filaments from an inner bundle of quenched wires. (a) As-received and (b) CIPped wire. All filaments show a continuous amorphous solid structure containing bubbles (B), alkaline earth cuprates (A) and copper free (CF) phases.

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Superconductivity – Applied

To integrate high-temperature superconductors (HTS) in sizeable high field magnets, like a 60 T DC Hybrid magnet, HTS cables are required. Of the three concepts that seem viable at this time, this is the first to be tested in realistic conditions. The results under hoop stress at low temperature and high magnetic field are very encouraging.

• Published in *Supercond. Sci. Technol.* **25**, 014003 (2012).

Critical Current Measurement at 4.2 K Up to 20 T of REBa₂Cu₃O_{7-δ} Coated Conductor Cables Designed for High-Field Magnet Applications

D.C. van der Laan (NIST and Univ. of Colorado Boulder) ; **H. Weijers, P. Noyes, G. Miller** (NHMFL, Florida State Univ.)

Introduction

The next generation of high-field magnets requires operating fields exceeding 20 T and that cannot be reached with low-temperature superconductors, such as NbTi or Nb₃Sn, and high-temperature superconductors (HTS), such as REBa₂Cu₃O_{7-δ} (REBCO) coated conductors, are the only option. We have introduced a new cabling method that enables the construction of round, HTS cables that meet the requirements for high-field magnets^{1,2} and performed the first cable tests at 4.2 K at magnetic fields up to 20 T at the user facility of the NHMFL.

Experimental

Several REBCO coated conductors cables were constructed using the method as outlined in Reference 1. The cables were mounted into the support structure (see Figure 1a) to support them against the high Lorentz force that occurs at 20 T. The critical current (I_c) of each cable will be measured at 4.2 K, at magnetic fields of up to 20 T.

Results and Discussion

The critical current as a function of magnetic field at 4.2 K up to 20 T of one of the cables is shown in Figure 1b. The critical current could not be measured at fields below 2 T because of the 3500 A current supply limit. The cable I_c that

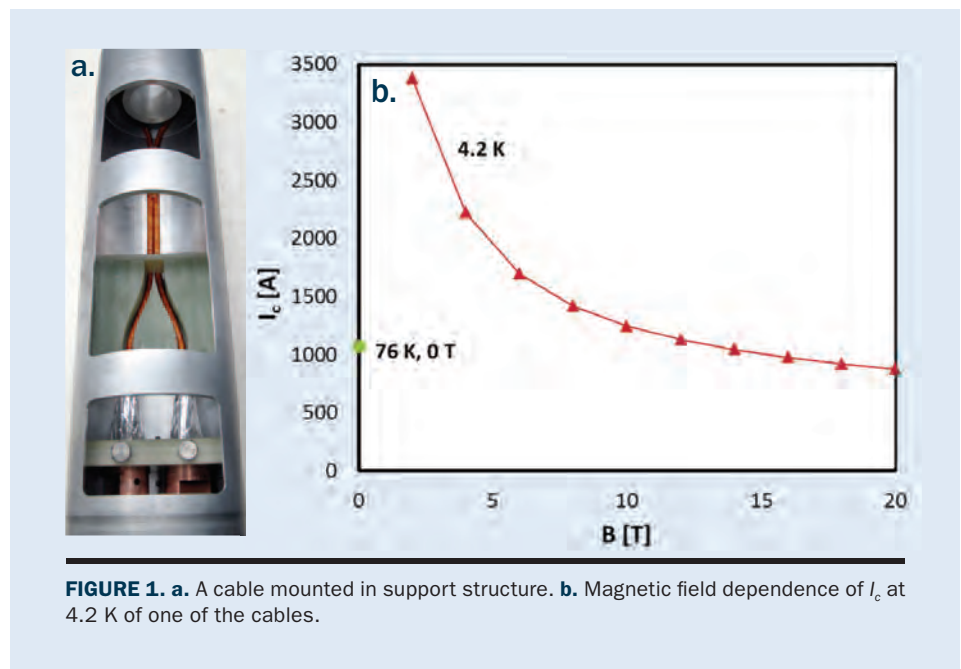


FIGURE 1. a. A cable mounted in support structure. b. Magnetic field dependence of I_c at 4.2 K of one of the cables.

was measured at 76 K in self-field is also included in the figure and, as expected, is comparable to that at 4.2 K and 20 T. No degradation in cable performance due to the high Lorentz force was measured.

Conclusions

We successfully performed the world's first measurement of an HTS cable at a field of 20 T. The results show the feasibility of HTS cables for high-field magnets.

Acknowledgements

This work was supported in part by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability under award number DE-AI05-98OR22652.

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Chemistry

Seven new cyclic depsipeptides were identified in a marine cyanobacteria, which is a validated source organism of potent and structurally diverse antiproliferative agents.

• Published in *Journal of Natural Products* **74**, 917-927 (2011).

Veraguamides A–G, Novel Cyclic Hexadepsipeptides with Antiproliferative Activity from the Marine Cyanobacterium *Symploca cf. hydroides* from Guam

L.A. Salvador, H. Luesch (Univ. of Florida, Medicinal Chemistry); J.S. Biggs (Univ. of Guam Marine Laboratory); V.J. Paul (Smithsonian Marine Station)

Introduction

Marine cyanobacteria of the genus *Symploca* are validated source organisms of potent and structurally diverse antiproliferative agents, yielding the HDAC inhibitor largazole and microtubule depolymerizers dolastatin 10 and symplostatin 1. We aim to find new classes of bioactive metabolites from *Symploca* sp. through a bioactivity-directed purification method.

Experimental

¹H and 2D NMR spectra were recorded on a Bruker Avance II 600 MHz spectrometer equipped with a 5 mm TXI cryogenic probe using residual solvent signals as internal standards.

Results and Discussion

Cytotoxicity-directed purification of a *S. cf. hydroides* collection afforded seven new cyclic depsipeptides, veraguamides A–G (1–7), characterized by an invariant proline residue, multiple *N*-methylated amino acids, an α -hydroxy acid, and a C₈-polyketide derived β -hydroxy acid moiety with a characteristic terminus as either an alkynyl bromide, alkyne, or vinyl group. These compounds and a semisynthetic analog (8) showed micromolar antiproliferative activity against HT29 colorectal adenocarcinoma and HeLa cervical carcinoma cell lines.

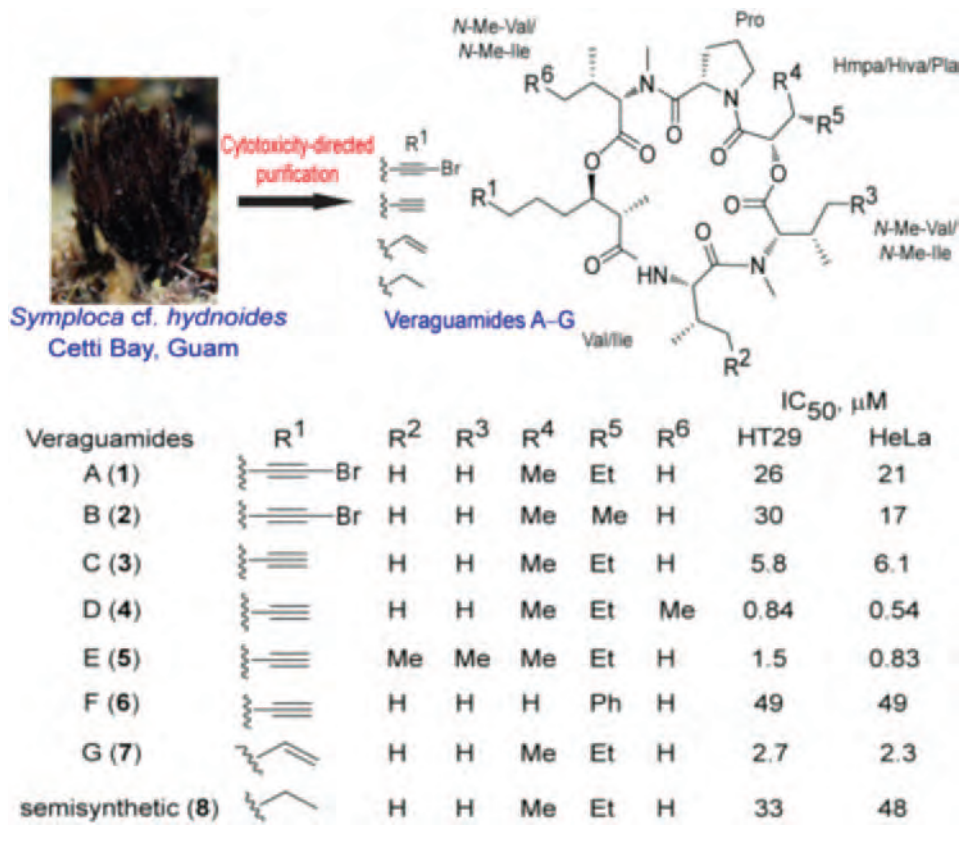


FIGURE 1. New antiproliferative agents from marine cyanobacterium *Symploca cf. hydroides* (1–7).

Conclusions

We identified new antiproliferative agents from the marine cyanobacterium *Symploca cf. hydroides*.

Acknowledgements

NIGMS grant P41GM086210, J. R. Rocca, and J. Quiñata.

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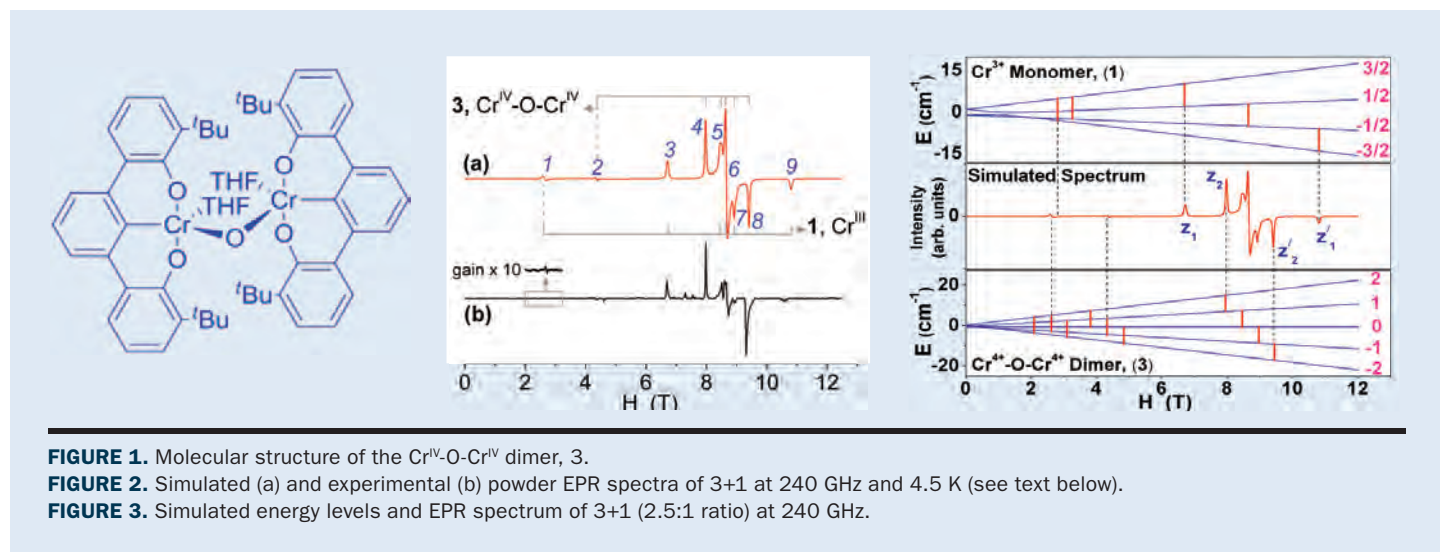
Chemistry

This work deals with magnetic interactions of Cr(IV) ions in a Cr-Cr dimer. It is important, as Cr(IV) is a largely unexplored oxidation state of chromium. Second, it probes the basic spin-spin interactions that are responsible for the phenomena of molecular magnets, and particularly molecular nanomagnets.

• Published in *Journal of the American Chemical Society* **133**, 13661-13673 (2011).

High Frequency EPR Study of a Cr(IV)-O-Cr(IV) Dimer Complex

M.E. O'Reilly, T.J. Del Castillo, J.M. Falkowski, M.C. Correia, K.A. Abboud, D.E. Richardson, A.S. Veige (Univ. of Florida, Chemistry); V. Ramachandran, M. Pati, N.S. Dalal (NHMFL, Florida State Univ., Chemistry)



Introduction

The 4+ oxidation state of Cr, with a 3d² configuration remains unexplored. This work details the assignment of the 4+ oxidation state of Cr in a Cr-O-Cr dimer, using high frequency EPR, as reported recently¹. The autocatalytic oxidation of the trianionic pincer Cr^{III} complex [tBuOCO]Cr^{III}(THF)₃, 1, by [tBuOCO]Cr^V(O)-(THF), 2, produces the intermediate Cr^{IV}-O-Cr^{IV} complex {[tBuOCO]Cr^{IV}(THF)}₂(μ-O), 3 (Figure 1); where tBuOCO = [2,6-(tBuC₆H₃O)₂C₆H₃]³⁻ and THF = tetrahydrofuran. 240 GHz EPR is used to determine of the electronic structure of 3.

Experimental

Variable temperature, high frequency (240 GHz), powder EPR measurements were made using the 240 GHz EPR spectrometer and 12.5 T SC magnet at the National High Magnetic Field Laboratory, Tallahassee, FL.

Results and Discussion

The experimental powder EPR spectrum of 3 (Figure 2b) indicates the presence of weak signals from Cr^{III} (1, S=3/2) along with those of 3 (S=2). Computer simulation of the spectrum using the standard spin Hamiltonian of a paramagnetic dimer with two spin fragments S₁ and S₂ did not reproduce all the observed lines. However, considering that 3 is in equilibrium with the monomeric complexes 1 and 2, we included 1 in the simulation. A combination of 3 and 1 (in the ratio 2.5:1) yielded a good fit to the observed resonances marked by the numbers 1 through 9 (Figure 2a). Signals from complex 2 (S=1/2) are difficult to be distinguished among the resonances 5, 6 and 7 (Figure 2a), and it is present in < 10%, thus we excluded 2 in the simulation. The spin Hamiltonian parameters for the Cr^{IV}-O-Cr^{IV} dimer (S=2) are g_{iso} = 1.976, D = 2400 G and E = 750 G, and those for the mono-

meric Cr^{III} complex 1 are g_{iso} = 1.976, D = 10500 G and E = 3000 G. Figure 3 shows the simulated energy levels of 1 and 3.

Conclusions

The good fit between the experimental and simulated spectra permits a conclusive assignment of the 4+ oxidation state for each Cr ion in complex 3. This is the first evidence of EPR in a Cr^{IV}-O-Cr^{IV} complex.

Acknowledgements

Supported by the NSF CAREER (CHE-0748408), the ACS-PRF(G) (#44063-G3), the Camille and Henry Dreyfus Foundation, the Alfred P. Sloan Foundation, and the NHMFL. We thank Z. Wang and Dr. J. van Tol for their assistance.

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Chemistry

Open shell organic molecules have low energy scales that make them susceptible to tuning with various external stimuli such as temperature, pressure, and magnetic field. In this work, J.L. Musfeldt *et al.* combine magneto-optical spectroscopy with first principles electronic structure calculations to understand the field-induced color change in 1,4-phenyldinitrene. They show that the magnetochromic response is a sensitive measure of the field-tunable singlet-triplet equilibrium and present an optical Curie-like analysis that can be used to reveal the spin gap.

• O. Gunaydin-Sen *et al.*, *J. Chem. Phys.* **135**, 241101 (2011).

Manipulating the Singlet-Triplet Equilibrium in Organic Biradical Materials

J.L. Musfeldt, O. Gunaydin-Sen, J. Fosso-Tande, P. Chen, J. L. White and R. J. Harrison (Univ. of Tennessee); T. L. Allen and P. M. Lahti (Univ. of Massachusetts); J. Cherian, T. Tokumoto and S. McGill (NHMFL)

Introduction

The photophysics of small organic molecules is of foundational importance to the field of physical organic chemistry. One very useful aspect of small molecule photochemistry is the ability to create and stabilize trapped spin states via low temperature photolysis¹. Open-shell molecules created in this way display unique electronic structure and magnetic exchange interactions that allow investigation of the interplay between charge, structure, and magnetism. A ground or thermally accessible paramagnetic state provides insight into behavior that is very promising for light harvesting, controllable reactivity, and spin valve applications. 1,4-Diazidobenzene attracted our attention in this regard. Like several other aromatic azides, it undergoes a photochemical reaction to yield 1,4-phenylenedinitrene. The latter is a persistent spin singlet biradical ($T < 90$ K) with a low-lying triplet state as shown schematically in Figure 1a². The singlet-triplet gap Δ_0 is small enough to allow population changes with temperature² and potentially support tuning by magnetic field.

Results and Discussion

Figure 1 summarizes our magneto-optical investigation of 1,4-phenylenedinitrene³. The rich magnetochromic response

occurs because applied field increases the concentration of the triplet state species, which has a unique optical signature by comparison with the singlet biradical and the precursor molecule. Ordinarily, one does not expect a low energy tuning parameter like magnetic field to impact high energy properties like electronic structure. Things are different here because a small spin gap allows an applied field to manipulate the population and (at high enough fields) drive the system into the fully polarized triplet state. A Curie-like analysis of the magneto-optical properties allows us to extract the spin gap, which is much smaller than previously supposed. These measurements establish the value of local-probe photophysical techniques for magnetic property determination in open-shell systems like biradicals where a traditional Curie law analysis has intrinsic limitations.

Acknowledgements

This work was supported by the National Science Foundation (DMR-1063880 and CHE 0834011).

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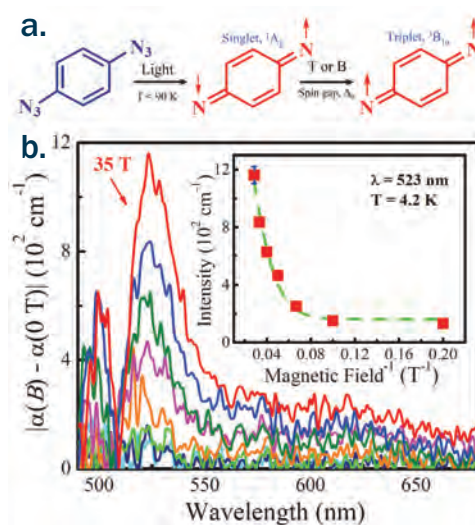


FIGURE 1. a. Chemical structure of the 1,4-diazidobenzene precursor (blue), and the biradical 1,4-phenylenedinitrene (red) after photochemical reaction. Temperature or applied magnetic field drives the singlet-triplet equilibrium.

b. Magneto-optical response of the biradical along with an optical Curie law fit that reveals the singlet-triplet gap. Using this high field method, we find Δ_0 is ~ 128 K, different than previously estimated².

2. M. Minato and P. Lahti, *J. Am. Chem. Soc.* **119**, 2187 (1997).
3. O. Gunaydin-Sen *et al.*, *J. Chem. Phys.* **135**, 241101 (2011).

Chemistry

First documented case of extreme biomarker enrichment in a production deposit and identification of perylene as the biomarker that is responsible for the blue color of the oil.

• Published in *Energy & Fuels* **25**, 172–182 (2011).

Analysis and Identification of Biomarkers and Origin of Color in a Bright Blue Crude Oil

P. Juyal, A.B. Andrews, A. Yen, S.J. Allenson, O.C. Mullins (NALCO); A.M. McKenna (NHMFL, Chemistry); R.P. Rodgers, A.G. Marshall (Florida State Univ., NHMFL, Chemistry); C.M. Reddy, R.K. Nelson, (Woods Hole Oceanographic Institute); E. Atolia (NHMFL)

Results and Discussion

We describe the detailed analysis and characterization of an unusual blue crude oil (Figure 1) and a deposit from the monoethylene glycol (MEG) regeneration unit (MRU) on an offshore crude oil production platform. To characterize the deposit and the components in the crude oil that give it such a distinct blue hue, we investigated the samples with comprehensive two-dimensional gas chromatography (GCxGC), Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS), and two-dimensional (2D) fluorescence spectroscopy. Perylene, a polycyclic aromatic hydrocarbon, known to fluoresce, was identified in the crude oil with all three of these techniques. On the basis of its photochemical properties and abundance (55 ppm), we infer perylene to be the most likely source of the blue color. In addition, we were able to conclusively identify by GCxGC a suite of pentacyclic triterpenoids, of which the most abundant species was 17R(H),21 β (H)-25-norhopane. The deposit is greatly enriched in these species. The presence of 25-norhopanes in a crude oil is considered as an indication for severe biodegradation.

Acknowledgements

The authors thank Anadarko Petroleum Corporation for providing the samples and permission to publish the results. Helpful discussions with Bob Buck (Anadarko) are sincerely appreci-



FIGURE 1. Unusual blue crude oil.

ated. FT-ICR MS was supported by the National Science Foundation (NSF) (DMR-06-54118) and the State of Florida. GCxGC analysis was supported by the Department of Energy (DOE) DE-FG02-06ER15775.

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P. Juyal, *et al.*, *Energy & Fuels* **25**, 172–182 (2011).

Geochemistry

The Gulf Oil Spill will undoubtedly be the most studied natural disaster in history. In an initial report by Chanton *et al.*, radiocarbon contents were tracked in the Gulf of Mexico and provide a radiocarbon map of the massive amount of oil that was introduced into the Gulf ecosystem. The oil provides a unique radiocarbon dead organic matter tracer that will be used in future studies to refine the resolution of the path of the oil spill and aid other analytical methods.

Radiocarbon Analysis of the Gulf Oil Spill

J. Chanton (Florida State Univ., Earth, Ocean and Atmospheric Sciences); **S. Bosman, A. Mickel** (FSU Coastal and Marine Laboratory); **S. Joye** (Univ. of Georgia, Marine Sciences); **C. Brunner** (Univ. of Southern Mississippi, Marine Sciences); **J. Cherrier and J. Sarkodee-Adoo** (Florida A&M Univ., Environmental Science); **D. Hollander**, (Univ. of South Florida Marine Sciences)

Introduction

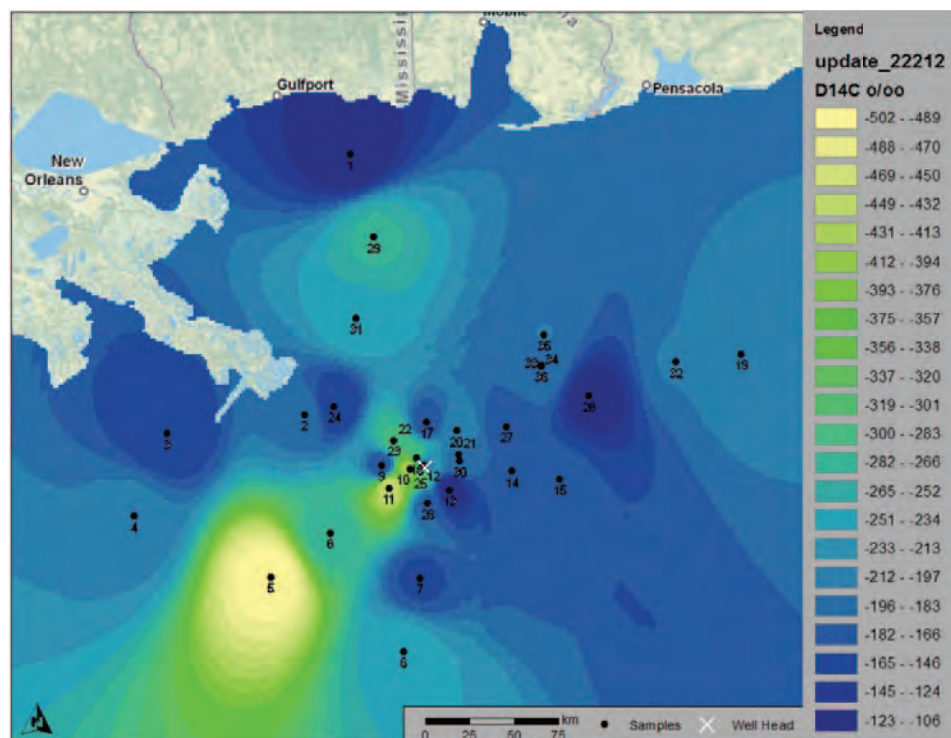
The Gulf Oil Spill injected a unique tracer into the Gulf of Mexico, radiocarbon-free fossil organic matter. Most Gulf organic matter is fixed at the surface with a modern radiocarbon (^{14}C) content. We have traced the input of petro-carbon into the Gulf by following input of radiocarbon dead organic matter into the sediments and fauna.

Experimental

Sediment and muscle tissue were ground to a fine powder using an electric mill. Approximately 500 micro-g of tissue for carbon and nitrogen analysis were wrapped in tin capsules for analysis at the National High Magnetic Field laboratory in Tallahassee, FL. Samples were analyzed by using a continuous flow Thermo Delta Plus Mass Spectrometer coupled to a CHNS analyzer. Subsamples were prepared for radiocarbon analysis on the vacuum line of Dr. Yang Wang at the Magnet Lab and measured at the NSF's National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS), at Woods Hole, MA.

Results and Discussion

This map shows the radiocarbon content of sedimentary organic matter on the seafloor of the Gulf of Mexico. The brighter colors and more negative values on the Delta- ^{14}C scale indicate less



radiocarbon (^{14}C) and thus more fossil (oil) carbon in the sediments. The SW trajectory of the plume is evident and the results show that the fossil carbon appears to have drifted as far as 150 km away from the oil blowout site which is marked with an x. Fossil carbon inputs are also observed in sediments to the north of the site towards Gulfport. Radiocarbon depleted tissue has been

observed in Gulf plankton samples and in oysters from Terrebonne Bay in South Louisiana.

Acknowledgements

We thank the Gulf of Mexico Research Initiative, the Northern Gulf Institute and the Florida Institute of Oceanography for funding this work.

Geochemistry

The dominant rocks of the upper part of the Earth's mantle (peridotites) are much different in isotopic signature than the basalts (extrusive volcanic rock from melting of the Earth's mantle) although data suggests that the peridotites heavily contributed to the basalts. The current data identifies the most extreme radiogenic isotopic compositions in all of the ocean mantle, confirming proposed ultra depleted and highly heterogeneous regions. The work will provide information on the degree of melting and age of these regions in the Earth's crust.

Ultra Depleted Mantle at the Gakkel Ridge Based on Hafnium and Neodymium Isotopes

V. Salters, A. Sachi-Kocher (NHMFL & Florida State Univ., EOAS); H. Dick (Woods Hole Oceanographic Institute)

Introduction

The Gakkel Ridge is one of the slowest spreading ridge segments in the global ridge system with some of the thinnest oceanic crust. In some locations there is little or no evidence for volcanic activity and the oceanic mantle is exposed directly to the ocean floor. This provides an excellent opportunity to investigate the heterogeneity of the oceanic mantle *in situ*.

Experimental

We have analyzed a number of peridotites from the western end of the Sparsely Magmatic Zone (3° to 28°E) for Hf and Nd isotopic compositions by multi-collector ICP-MS. In addition we analyzed diopsides for major and trace element analysis using the single collector magnetic sector ICP-MS. All analyses were conducted at the NHMFL.

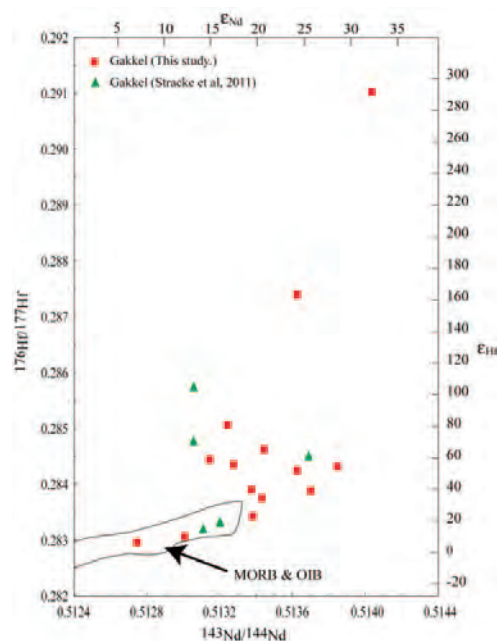
Results and Discussion

The samples (red symbols) we analyzed range to extremely radiogenic isotopic composition; *i.e.* the most radiogenic in Nd and Hf-isotopic composition of all ocean mantle. All but two samples are more radiogenic in either Nd or Hf than MORB. Four samples lie in the extension of the OIB MORB array with ϵ_{Nd} up to 23.7 and ϵ_{Hf} up to 54.6. The remainder of the data falls above the OIB-MORB array and its extension with ϵ_{Nd} values up to 27.4 and ϵ_{Hf} values up to 291! This data confirms the ultra depleted nature of the Gakkel Ridge mantle proposed by Stracke *et al.*¹ and its highly heterogeneous nature as proposed by Liu *et al.*² Since the Hf and Nd system is expected to have correlated fractionations during melting we can

add melt back into the peridotites until the Hf and Nd model age coincide. This will provide information on both the degree of melting and the age. Gakkel Ridge peridotites seem to have very little melt extracted from them (<1%) and have model ages that ranges from 2.4Ga to future ages with most between 600Ma and 1.2 Ga.

The Hf and Nd isotopes are best correlated with Sm/Yb whereby high Sm/Yb samples have unradiogenic Hf and Nd. The Cr# of the spinel is relatively low for all the samples (<30), although all samples have a LREE depleted character with Yb(N) between 8 and 3 and La(N) between 0.8 and 0.1

The Gakkel Ridge basalts form the radiogenic Hf-end of the MORB field (S. Goldstein pers.comm.), and although the peridotites are far out of isotopic equilibrium with the basalts, Hf-Nd systematics indicates that the peridotites have contributed to the basalts. The relatively depleted nature of the peridotites requires that a relatively large amount of peridotite has to contribute to the aggregated basaltic melt. Apart from documenting the heterogeneous nature of the MORB mantle, it also indicates that in addition to MORB-like mantle a far more depleted mantle exists. Based on abyssal peridotite trace element compositions and on melting calculations, these extreme peridotites could have an unusually complicated history, and this might not be the first time they are passing through a ridge melting regime. It is likely that they may represent ancient residual lithosphere. Because these peridotites are already depleted they will contribute little



in terms of major elements or incompatible trace elements to the melts. The Hf-Nd isotope variations in MORB, whereby MORB from individual ridge segments form parallel arrays, can also be explained by the existence of a highly depleted component like residual lithosphere: ReLish³.

Acknowledgements.

This research was supported by NSF OCE 0930429 to Salters.

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Magnetic Resonance Technique Development

Lithium-ion batteries have been the power sources of choice for portable electronics and are of growing use for large scale devices such as plug-in and hybrid electric vehicles. Solid state NMR spectroscopy has been used as a powerful tool for characterization and development of new electrode materials. The following report presents a new NMR technique developed jointly by scientists at the NHMFL and University of Cambridge for obtaining high-resolution magic-angle spinning spectra of many paramagnetic lithium-ion battery materials. The new technique can average anisotropic paramagnetic broadening up to 1MHz, far beyond any practically achievable sample spinning rate. The technique also solves a general problem solid state NMR at high magnetic fields, that of increasing anisotropic broadening.

• Hung, *et al.*, *J. Am. Chem. Soc.* **134**, 1898 (2011).

Obtaining Isotropic NMR Spectra of Paramagnetic Battery Materials with Large Anisotropic Broadening

I. Hung, Z. Gan (NHMFL); L. Zhou, F. Pourpoint, C.P. Grey (Cambridge)

Introduction

The use of Li-ion batteries as power sources for portable electronic devices such as laptops and cell phones, has grown dramatically. New positive and negative electrodes have been developed during the past 30 years to address issues of stored energy density, charge and discharge rates and service life^{1,2} and solid-state ^{6,7}Li NMR has played an important role in characterizing these materials and the changes of the Li local environment during charge and discharge processes³. Many Li-ion battery materials are paramagnetic and their solid-state NMR (ssNMR) spectra are often crowded with overlapping spinning sidebands (ssbs) due to the large anisotropic paramagnetic shift even under very fast magic-angle spinning (MAS). This report presents the use of a magic-angle turning phase-adjusted sideband separation (MATPASS)^{4,5} method under fast spinning frequencies to separate ssbs and yield ssNMR spectra as if MAS is infinitely fast⁶. This MAT experiment only employs $\pi/2$ -pulses, providing a broad excitation bandwidth, and is thus suitable for application to paramagnetic lithium battery materials with anisotropy of >1 MHz.

Experimental

Experiments were performed on a 19.6 T superconducting magnet equipped with a Bruker DRX console and a home-

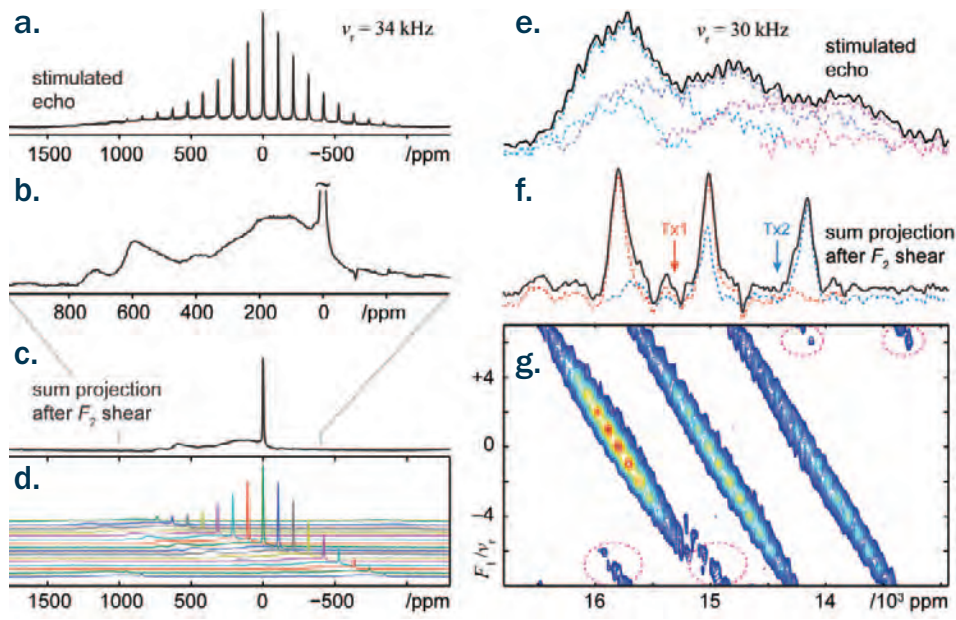


FIGURE 1. **a.** ⁷Li MAS spectrum of charged $\text{Li}_{2-x}\text{FeSiO}_4$ following four charge-discharge cycles. **b.** Expansion of the resonances from 0 to 720 ppm from the (c) isotropic spectrum of charged $\text{Li}_{2-x}\text{FeSiO}_4$ obtained from summation of the ssbs after F_2 shearing of the (d) 2D MATPASS spectrum. **e.** ³¹P NMR stimulated-echo spectrum of $\text{Li}_3\text{Fe}_2(\text{PO}_4)_3$ obtained by taking the skyline projection of several spectra acquired at carrier intervals of 300 kHz. **f.** Isotropic projection obtained after F_2 shearing of the (c) 2D MATPASS spectrum. The 2D MATPASS spectrum was acquired as two segments using the carrier positions Tx1 and Tx2. Dashed circles enclose aliased spinning sidebands due to insufficient number of t_1 increments.

built 1.8 mm single-resonance probe at 30-34 kHz MAS.

Results and Discussion

Figure 1a shows a fast MAS (34kHz) spectrum of a cathode material $\text{Li}_2\text{FeSiO}_4$ after four charge-discharge cycles. The

spinning is not fast enough to enhance the resolution of the broad signal centered at ~300 ppm (the sharp peaks are from impurities). The MATPASS^{4,5} experiment separates the ssbs according to their order (Figure 1d). A subsequent shearing and projection results in an isotropic MAS

spectrum without any sidebands, as if the spinning speed is infinitely fast. The expansion around ~300ppm (Figure 1b) reveals that the broad and featureless signal in Figure 1a is actually comprised of multiple isotropic resonances that spread over a range of about 800 ppm (>250 kHz). The result demonstrates that this new NMR technique can be applied for paramagnetic battery materials to resolve lines with width and anisotropy far larger than practically achievable MAS speeds. Fig 1e-g show an application to the ^{31}P nuclei in $\text{Li}_3\text{Fe}_2(\text{PO}_4)_3$ that have even shorter T_1 and T_2 relaxation times than ^7Li . Using the 2D MATPASS experiment at a single B_0 field and MAS frequency, three isotropic resonances can be identified in the broad spectrum of Figure 1e (>1.2 MHz), allowing for chemical shift measurement of individual peaks. Previously, multiple B_0 fields and varying MAS frequencies were necessary to resolve the interplay between the effects of sample heating and spinning sideband

positions upon change of spinning speed just to identify the peaks from the spinning sidebands⁶. The sideband-less feature of the MATPASS technique should greatly facilitate the use of ^{31}P NMR as an additional probe for the characterization of phosphorus-containing Li-ion battery materials.

Conclusions

It has been shown that isotropic spectra for ^7Li and ^{31}P nuclei with very short T_1 and T_2 relaxation times due to paramagnetic shift anisotropy can be obtained using the projection-MATPASS technique.

Acknowledgements

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Storage, an Energy Frontier Research Center funded by the U.S. DOE, BES under award No. DE-SC0001294. FP was supported by EPSRC and the Supergen consortium.

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Magnetic Resonance Technique Development

This report is interesting in its application of ultrashort TE (UTE) imaging to a novel problem. UTE imaging is generating a tremendous amount of excitement in the imaging community due to its ability to observe at protons with very short TEs typically representing bound water in bone, cartilage, or in this case in solid foams. UTE measurements require special imaging sequences and coils (which do not produce significant background at these short echo times). Whereas the application is of general interest due to the NASA connection, what is of real value is showing that the 900MHz can be used to perform UTE imaging opening up a host of different future user applications.

• Published in *International Journal of Heat and Mass Transfer* **55**, 69-72 (2012).

MRI of Absorbed Water in Solid Foams Using 21.1 T

M. Vanderlaan, M. Seshadhri, M. Barrios, S. Van Sciver (NHMFL/Florida State Univ., College of Engineering); J. Fesmire (NASA/KSC); W.W. Brey, V. Schepkin (NHMFL)

Introduction

In a number of practical situations there is a critical need to evaluate the distribution of small amounts of water absorbed throughout a solid foam sample. One of these pertains to Spray On Foam Insulation (SOFI) NCFI 24124, a thermal insulation material used on the liquid hydrogen and oxygen tanks of the Space Shuttle at Kennedy Space Center (KSC). However, several problems including infinitesimal amounts of water and inevitable water binding to the foam makes the MR signal weak especially for high resolution MRI. The 900 MHz Ultra wide bore (UWB) NMR spectrometer provides a unique opportunity to perform this evaluation due to its high MRI sensitivity at 21.1 T and its ability to examine large volume samples. The recent upgrade of the UWB 900 MHz MRI scanner (August, 2010), allows for ultra-short echo time (UTE) 3D MRI performance. The standard MR imaging technique in this case is not suitable, as it will yield a zero signal. Here we report the first 3D MR images of bound water and water content in solid foam NCFI 24124 samples conditioned to match launch pad conditions. Full Paper published in *International Journal of Heat and Mass Transfer*³.

Experimental

Foam samples were launch pad conditioned (LPC) for either 69 hours or 9.5 hours in a rig that subjects one side of the foam to 34 ± 2 °C (mean \pm standard deviation) air with a relative humidity greater than 75% with the other side in contact with a cold plate at 77 K. These conditions are similar to those experienced by the foam

on the NASA-KSC launch pad. The foam requires low thermal conductivity and durability. However, the cold surface is thought to draw water from the humid ambient air into the insulation, which KSC studies have shown can increase the weight of the insulation by as much as 30%-85%. This water adsorption translates to several thousand additional pounds on the shuttle¹. A new RF coil was constructed with materials lacking free protons, which dramatically reduced previously noticed background signals.

Results and Discussion

The average unprepared (as received) foam sample mass was 46.5 ± 2.2 mg. The 69-hour LPC samples gained an average 132 mg of water while a 9.5-hour conditioned sample resulted in an average gain of 23 mg. Sections void of water can be seen in 1a as two black bands, known as knit lines, dense areas between foam layers created in the application process. The dimensions of the majority of the cells range from 150-450 μ m, and are elongated in the rise direction. Many of the cells near the knit lines decrease in size to less than 50 μ m. The experiment has been successfully repeated with a larger RF coil bore of 20 mm.

Conclusions

The capability for ultra short echo time MRI with TE \sim 50 μ s is expanding the area of MR imaging analysis which can be performed at the NHMFL. The first experiments demonstrated accumulation of water in the insulation foam and represent an opportunity to perform an

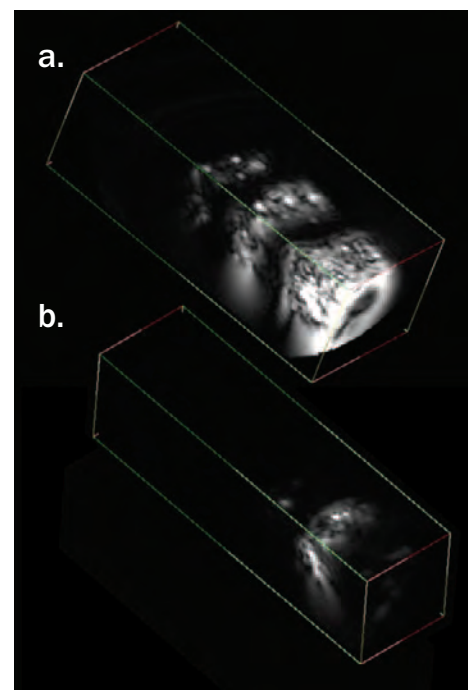


FIGURE 1. (MRI of water absorbed in Spray On Foam Insulation NCFI 24124 with ultra short echo time (TE = 45 μ s): **a.** sample conditioned for 69 hours. **b.** a sample conditioned for 9.5 hours. The warm side of the sample is oriented to the lower part of the image.

evaluation of the new insulation materials. Transitions in the knit lines layering are constrictions in the water flow path and if increased in number, might be used as tools in minimizing water absorption. An overall pore size reduction may also reduce water absorption but the advantages must be balanced with the disadvantages of increased weight in denser foam.

Acknowledgements

Thanks C. Ralph, G. Daspi (Southern Research Institute), P. Gor'kov and A. Blue. MRI studies were supported by NSF Cooperative Agreement No. DMR-0654118, the State of Florida, and the U.S. Department of Energy.

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Biochemistry

Knowing structure and dynamics is essential to understand the functioning of proteins and other bio-molecules. Polenova's group at U. Delaware uses solid-state NMR to gain atomic-level insight on the structure and dynamics of HIV-1 protein assemblies and their interactions with host proteins and small-molecule inhibitors. They have found that the tubular assemblies of capsid CA protein and capsid-spacer peptide 1 (CA-SP1) of Gag polyprotein from HIV-1 virus yield better spectral resolution than the conical and spherical shaped assemblies. They have obtained high-resolution multi-dimensional spectra of the tubular proteins using the 900MHz field and low-E triple resonance MAS probe, both are important for spectral assignment and dynamics measurement of the 231-residue protein stabilized in high-salt concentration.

• Supported by the MagLab User Collaboration Grants Program

Solid-State NMR Structural and Dynamics Studies of HIV-1 Protein Assemblies Using 21T and Low-E Probe

Y. Han, G. Hou, C. Suiter, **T. Polenova** (Univ. of Delaware, Dept. of Chemistry & Biochemistry); Z. Gan, W. Brey, I. Hung, P. Gor'kov (NHMFL)

Introduction

Gag polyprotein from HIV-1 virus is responsible for the assembly of virions from infected cells. Gag and its two products, capsid CA protein and capsid-spacer peptide 1 (CA-SP1) are the focus of this research. CA organizes and protects the viral genome by assembling into conical capsids. Following viral entry into the host, CA disassembles to allow release of the viral genetic material into the host cytoplasmic compartment (uncoating). CA and the Gag processing intermediate CA-SP1 have recently become attractive targets of HIV-1 uncoating and capsid maturation inhibitors. Despite the promise of targeting CA maturation and uncoating processes by novel inhibitors, the current research is hampered by lack of understanding of the molecular mechanisms of the maturation and uncoating and of their temporal regulation, and detailed atomic-resolution structural and dynamics information of the assembled Gag, CA, and CA-SP1 is still lacking. The objective of our ongoing work is to gain atomic-level insight on structure and dynamics of these HIV-1 protein assemblies and their interactions with host proteins and small-molecule inhibitors through state-of-the-art solid-state NMR spectroscopy.

Experimental

Solid-state NMR spectra were acquired at 21.1 T (900 MHz) on the ultra-wide bore 105 mm NMR magnet, outfitted with a 3.2 mm Low-E triple-resonance HXY probe developed and built at NHMFL. 2D MAS homo- and heteronuclear correlation spectra (DARR, NCA, and NCACX) were acquired on U-¹³C,¹⁵N-labeled CA and CA-SP1 assemblies of tubular morphology. All spectra were processed in NMRPipe and analyzed in Sparky.

Results and Discussion

In vivo, the 231-residue CA protein assembles into cone-like capsid structures containing about 1500 copies of the protein

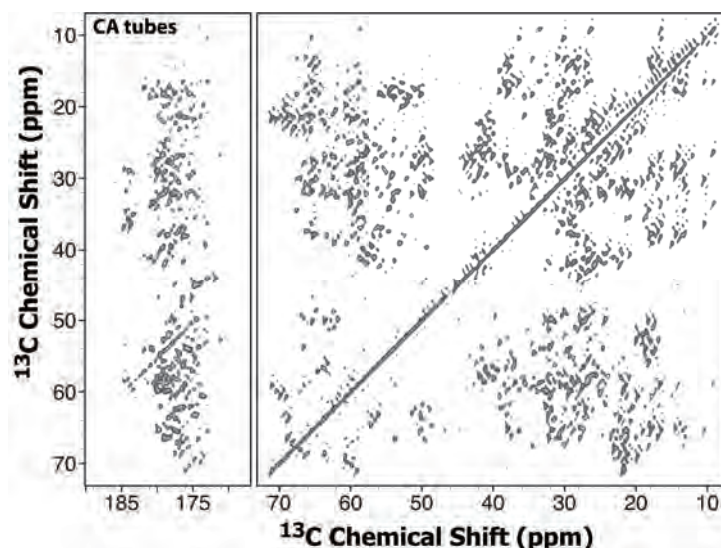


FIGURE 1. 21.1 T 2D DARR spectrum of U-¹³C,¹⁵N-enriched tubular CA assemblies acquired using enhanced-design Low-E triple-resonance MAS probe developed at NHMFL.

and enclosing the viral RNA genome. Significant heterogeneity in shape and in size of CA capsids has been observed in mature HIV-1 virions. *In vitro*, both CA and CA-SP1 proteins exhibit structural polymorphism, and assemblies of conical, tubular, and spherical shapes can be produced. We have established the conditions for the assembly of CA into the main three morphologies for solid-state NMR spectroscopy, have assigned two thirds of the residues and characterized the secondary structure of the conical CA assembly. Despite the generally high resolution of the 900 MHz spectra of conical capsids, lines are somewhat broader than in microcrystalline proteins, making it challeng-

ing to perform detailed structural characterization in U-¹³C, ¹⁵N isotopically enriched protein. We have turned our attention to tubular assemblies of the above proteins and discovered that those yield lines as narrow as those in microcrystalline proteins. Most recently, thanks to the enhanced-design Low-E triple-resonance MAS probe developed at NHMFL we have collected excellent-quality homo- and heteronuclear 2D correlation spectra of CA and CA-SP1 assemblies (Figure 1) at 21.1 T. With these data in hand, we expect to gain detailed structural and dynamics information of CA alone and interacting with host cell proteins and small-molecule inhibitors.

Conclusions

Excellent-quality 2D MAS NMR spectra were collected at 21.1 T for tubular CA and CA-SP1 assemblies that will permit detailed structural and dynamics characterization of HIV-1 protein assemblies.

Acknowledgements

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Biochemistry

The cell membrane is a unique environment made up of >1,000 different lipid species, many proteins, and microdomains. Structural information about proteins in this natural environment is scarce. In this report, the authors demonstrate the feasibility of characterizing the structure of the transmembrane domain of a human APP binding protein in native of *E. coli* membranes by using solid-state magic-angle spinning NMR.

• Published in *J. Am. Chem. Soc.* **133** (32), 12370-12373 (2011).

Structural Analysis of a Recombinant Protein in Native *Escherichia coli* Membranes Using Low-E Probe

R. Fu (NHMFL); X. S. Wang, R.L. Gill, F. Tian (Pennsylvania State Univ.); C. Li (Chinese Academy of Sciences); G.J. Pielak (Univ. of North Carolina)

Introduction

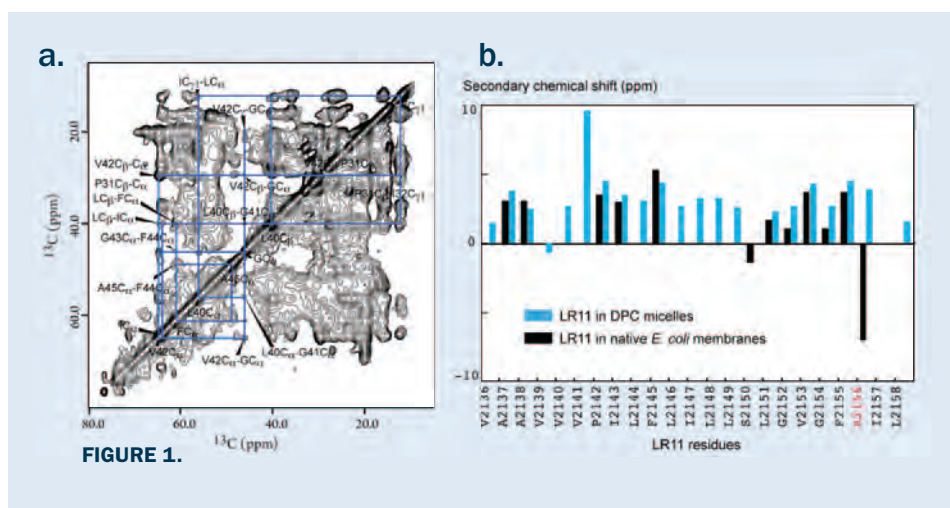
Cellular membranes are comprised of a diverse set of lipids (>1,000 different lipid species), and exhibit lateral heterogeneity (e.g. lipid rafts, lipid microdomains), trans-bilayer asymmetry, chemical and electrical gradients, dynamics, and various shapes¹. Furthermore, biological membranes are crowded and contain as much protein as they do lipid². Although the unique lipid environment is a major determinant of membrane protein conformation and function, information about protein structure in biological environment is scarce. Here, we demonstrate the feasibility of characterizing the structure of the transmembrane domain (TM) of a human APP binding protein, LR11, *in situ* in *E. coli* membranes by using solid-state magic-angle spinning (MAS) NMR³.

Experimental

The preparation of LR11 TM in *E. coli* membranes has been described⁴. NMR spectra were collected on a NHMFL 600 MHz spectrometer with a Bruker 4 mm or a homebuilt 3.2 mm low-E MAS probe.

Results and Discussion

Using ¹³C-¹³C PARIS data (Figure 1a) collected with different mixing times on a sample of LR11 TM in native *E. coli* membranes, we have readily assigned 12 out of 23 residues of the LR11 TM. All assigned residues show characteristic secondary



shifts of an α -helix and are in agreement with the secondary shifts of LR11 TM in DPC micelles (Figure 1b) except for residue Ala2156. This residue is near the C-terminus of the predicted TM domain and resides in the membrane-solution interface region, where there are substantial differences between bilayers and micelles and where structural discrepancy likely occurs.

Acknowledgements

We are grateful for financial supports from the National Institutes of Health (5R01GM081793-03 and 5DP10D783), the National Science Foundation (MCB1051819) and the Penn State University College of Medicine and the National Science Foundation of China (21075134).

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Biochemistry

The most common hereditary peripheral neuropathies are the axonal form of Charcot–Marie-Tooth (CMT) diseases caused by mutant proteins which gain new functions due to their altered protein structure. Despite this, previous crystal structures showed little conformational difference between dimeric wild-type and CMT-causing mutant proteins. In this report different mutant proteins were investigated in solution by hydrogen-deuterium exchange (monitored by mass spectrometry) and small-angle X-ray scattering to uncover structural changes that exposed the same conformational cleft that is mostly buried in the wild-type protein.

• Published in *P. Natl. Acad. Sci. U.S.A.* **108** (30), 12307-12312 (2011).

Dispersed Disease-Causing Neomorphic Mutations on a Single Protein Promote the Same Localized Conformational Opening

W. He, Y.E. Chong, M. Gin, X-L Yang (Scripps, Biochemistry); H-M Zhang (NHMFL, Biochemistry); A.G. Marshall (Florida State Univ., NHMFL, Chemistry)

Results and Discussion

The question of how dispersed mutations in one protein engender the same gain-of-function phenotype is of great interest. Here we focus on mutations in glycyl-tRNA synthetase (GlyRS) that cause an axonal form of Charcot–Marie-Tooth (CMT) diseases, the most common hereditary peripheral neuropathies. Because the disease phenotype is dominant, and not correlated with defects in the role of GlyRS in protein synthesis, the mutant proteins are considered to be neomorphs that gain new functions from altered protein structure. Given that previous crystal structures showed little conformational difference between dimeric wild-type and CMT-causing mutant GlyRSs, the mutant proteins were investigated in solution by hydrogen-deuterium exchange (monitored by mass spectrometry) and small-angle X-ray scattering to uncover structural changes that could be suppressed by crystal packing interactions. Significantly, each of five spatially dispersed mutations induced the same conformational opening of a consensus area that is mostly buried in the wild-type protein (see Figure 1) The identified neomorphic surface is thus a candidate for making CMT-associated pathological interactions, and a target for disease correction. Additional results showed that a helix-turn-helix WHEP domain that was appended to GlyRS in metazoans can regulate

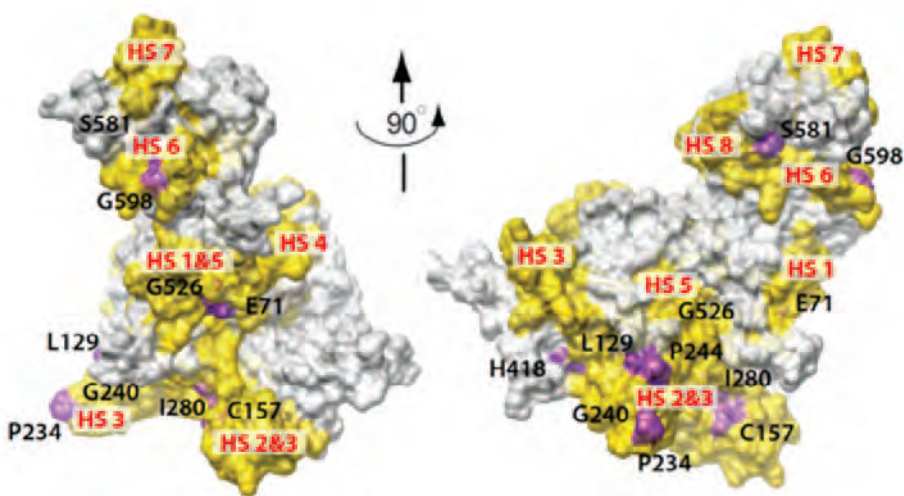


FIGURE 1. Map of the “hot spots” (in gold) that are opened up in all five tested CMT-causing mutants of the enzyme, glycyl transfer-RNA synthetase. That information was not evident from x-ray crystal structures.

the neomorphic structural change, and that the gain of function of the CMT mutants might be due to the loss of function of the WHEP domain as a regulator. Overall, the results demonstrate how spatially dispersed and seemingly unrelated mutations can perpetrate the same localized effect on a protein.

Acknowledgements

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Biology

Acquired Immunodeficiency Syndrome (AIDS) is a world-wide epidemic caused by HIV-1. Although numerous pharmaceuticals that are inhibitors against viral replication are effective in controlling AIDS, there is currently no cure or vaccine to prevent AIDS. Towards the goal of developing a vaccine for AIDS, the structural organization of viral envelope proteins within membranes was determined. These structural hierarchies form the basis of vaccine development for the prevention of virus entry into host cells.

- Published in *Nature Struct. Mol. Biol.* **18** (11), 1235-1243 (2011).
- Supported by the MagLab User Collaboration Grants Program

Antibody-Mediated Mechanics on a Membrane-Embedded HIV gp41 Segment by EPR

L. Song (NHMFL); M. Kim, Z.-Y.J. Sun, G. Wagner, E.L. Reinherz (Harvard Med. School); G. Ofek, P.D. Kwong (NIH, NIAID)

Introduction

A vaccine capable of stimulating protective anti-viral antibody responses is needed to curtail the global Acquired Immunodeficiency Syndrome (AIDS) epidemic caused by HIV-1. Broadly neutralizing antibodies (BNABs) such as 2F5 are directed against the HIV-1 gp41 membrane proximal external region (MPER) and recognize well-defined linear core sequences¹. How 2F5 interacts with its lipid-embedded epitopes and mediate anti-viral activity is unclear. Here, site-directed spin labeling and electron paramagnetic resonance spectroscopy (SDSL-EPR) were used to define 2F5 induced conformational changes in the MPER relative to the membrane, and the effect of key residue mutations.

Results and Discussion

EPR was used to determine membrane immersion depth changes of spin-labeled MPER residues upon wild type (wt) and mutant 2F5 Fabs binding. 2F5 wt lifts deeply buried residue L669R1 and W670R1 from the acyl chain region of lipid into the aqueous phase and the head group region, respectively (Figure 1A, only W670R1 is shown). In contrast to wt 2F5, 2F5 mutants (F100_BS, L100_AS and I100_PS) - induced immersion depth changes of L669R1 and W670R1 were attenuated. The reduced immersion depth

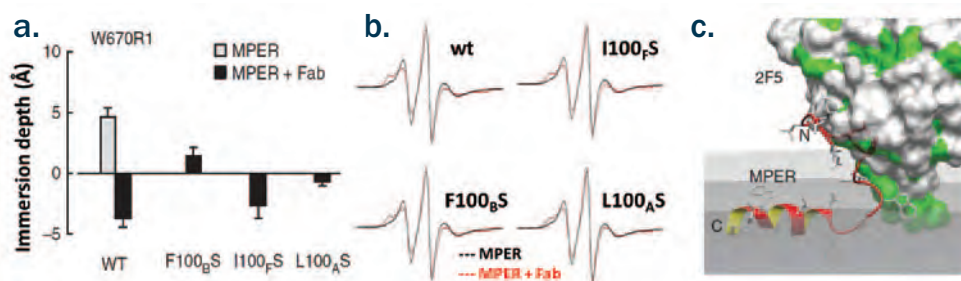


FIGURE 1. a. Wild type and mutant 2F5 Fabs-induced membrane immersion depth changes of MPER W670 R1 (spin labeled residue) by EPR. Depth values between -5 Å to 0 Å and larger than 0 Å correspond to lipid headgroup region and acyl chain region, respectively. b. EPR spectra showing 2F5 Fabs-induced W670R1 mobility changes. c. A model showing 2F5 lifting up the N-terminal segment of the MPER.

changes by 2F5 mutants are correlated well with their decreased neutralization potency comparing to wild type 2F5 (not shown). Of note, comparable EPR mobility spectra changes found for L669R1 and W670R1 indicate the presence of similar MPER conformations at the antibody binding interface for the wt and three 2F5m Fabs (Figure 1B). These results have been published in *Nature Struct. Mol. Biol.*².

Conclusions

The results suggest that mutations at different positions in 2F5 antibody differentially affect the degree of reorientation of the N-helix in the MPER. The apex of the 2F5 CDRH3

loop, including F100_B, L100_A and I100_P, is critical for mediating MPER reorientation and epitope extraction from membrane. The results have important implications for structure-aided HIV vaccine design.

Acknowledgements

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Biology

During cancer progression, especially after drug interventions, tumors develop new mechanisms permitting them to resist chemotherapeutic interventions. Consequently, there is a crucial need for a method to detect changes in tumor resistance. This study represents a discovery that sodium MRI has the capability to promptly and noninvasively detect changes in drug resistance prior to the initiation of tumor therapy. Thus, the method can predict and, therefore, avoid implementation of unsuccessful tumor therapies.

•Published in *Magnetic Resonance in Medicine* **67**, 1159-1166 (2012).

Tumor Resistance and *in vivo* Sodium MR Imaging at 21.1 T

V.D. Schepkin, F.F. Calixto-Bejarano, P.L. Gor'kov, W.W. Brey (NHMFL);

T. Morgan, M. Ozambela, S. Gower-Winter, C.W. Levenson (Florida State Univ., College of Medicine)

Introduction

Cancer progression, especially drug intervention, triggers tumors' cellular mechanisms permitting them to resist chemotherapeutic interventions. The same type of tumor in the same anatomical place can have a wide range of resistance to therapy. Unfortunately, resistance is usually diagnosed long after drug administration by noting changes in tumor volume. To formulate prompt and individualized treatments, it is important to evaluate tumor resistance before therapy. Mitochondria play a central role in energy metabolism as well as apoptosis and are directly associated with the changes in tumor resistance. We hypothesize that a shift to more efficient energy metabolism in resistant tumors is affecting tumor sodium homeostasis. In this way sodium MRI (Figure 1, left) has a unique potential to detect changes in tumor resistance. It is of the utmost importance that alterations in tumor resistance can be detected noninvasively and quickly prior to treatments¹.

Experimental

Six male CDF rats (weight ~ 150 g) were implanted intra-cranially with two types of 9L gliosarcoma cells. Later, in 10 days, the MRI experiments were conducted at the NHMFL 21.1 T MRI scanner using an NHMFL-designed double tuned sodium/proton *in vivo* MRI probe. Sodium 3D back-projection MRI scans with resolution of 0.5x0.5x0.5 mm, FID acquisition delay ~0.1 ms

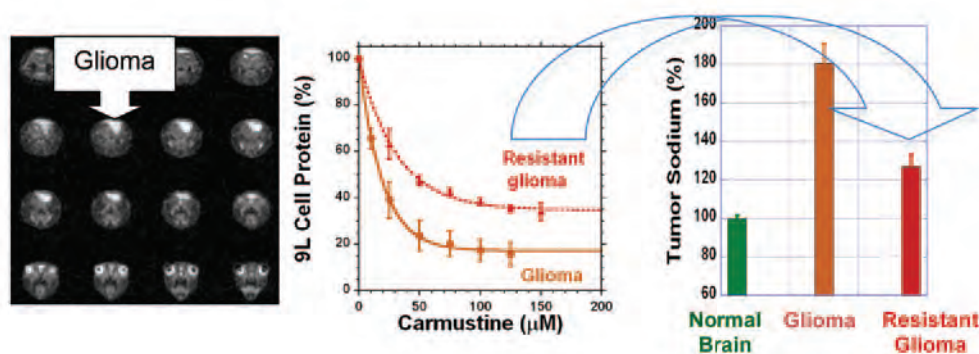


FIGURE 1. Sodium MRI of rat glioma (left), glioma cell survival assay (center) and *in vivo* shift in glioma sodium concentration due to an increased tumor resistance (right).

and scan time of 27 min were acquired using the Bruker Avance III console. All experiments were conducted according to the animal protocols approved by The Florida State University ACUC.

Results and Discussion

Sulforodamine assay of the resistant glioma cells (Fig. 1, center) performed before tumor implantation to animal showed a carmustine resistance of 24.7 μM, while for naïve glioma it was 7.8 μM. *In vivo*, sodium concentration in tumor from resistant tumor cells was 127% relative to a normal contra-lateral brain, while in tumor from the naïve glioma it was 173% (Fig. 1, right).

Conclusions

Changes in tumor resistance can be sensitively detected by sodium MRI and tumor response can be predicted prior to treatments, thus helping to

avoid unsuccessful therapies. The suggested approach is based on the energy status of tumors, indicating it may have a predictive capability for different chemotherapeutic drugs beyond carmustine used in this study. The finding warrants further investigation and confirmation for other tumor types.

Acknowledgements

The *in vivo* rodent studies were supported by NIH Grant R21 CA119177. Special thanks to A. Blue, R. Desilets, M. Elumalai and J. Kitchen for their valuable support during this project.

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Biology

Two common forms of cognitive disorders associated with aging that induce dementia are Alzheimer's disease (AD) and diffuse Lewy Body disorder (DLBD). Currently, confirmation of the disease pathology is diagnosed conclusively postmortem. Here non-invasive MRI methods based upon the iron content are being developed that can differentiate between healthy and diseased brain tissues.

• Supported by the MagLab User Collaboration Grants Program

High Resolution MRI at 21.1 T of the Hippocampus and Temporal Lobe White Matter in the Differential Classification of Alzheimer's Disease and Diffuse Lewy Body Disorder

P. Foroutan, S.C. Grant (NHMFL/Florida State Univ., Chemical & Biomedical Eng.); M.E. Murray, D.W. Dickson (Mayo Clinic, Pathology); S. Fujioka, K.J. Schweitzer, Z.K. Wszolek (Mayo Clinic, Neurology)

Introduction

The two most common forms of cognitive disorders that induce dementia are Alzheimer's disease (AD) and diffuse Lewy Body disorder (DLBD). Although these conditions differ histopathologically such that AD is associated with amyloid ($A\beta$) plaques and neurofibrillary tangles while DLBD is an α -synucleinopathy, clinical similarities make it difficult to distinguish between them. In pathological animal and human tissue¹⁻³, $A\beta$ plaques appear to coincide with iron-induced hypointensities observed in T_2 - and T_2^* -weighted MR images. Similarly, the presence of Lewy bodies, or rather α -synuclein, also has been linked to increases in iron content⁴.

Experimental

Fixed postmortem specimens harvested from sex- and age-matched patients displaying AD (n=13) and DLBD (n=7) were compared to healthy subjects (n=6). MR data were acquired using a 21.1-T, ultra-widebore (105-mm) vertical magnet. Utilizing a 33-mm birdcage coil, 3D Fast Low Angle Shot (FLASH) images were acquired at an isotropic resolution of 50 μm over 4.3 hours at 14 °C. T_2^* -weighted multiple gradient recalled echo (GRE) and T_2 -weighted spin-echo (SE) sequences were acquired over a range of echo times to generate relaxation maps.

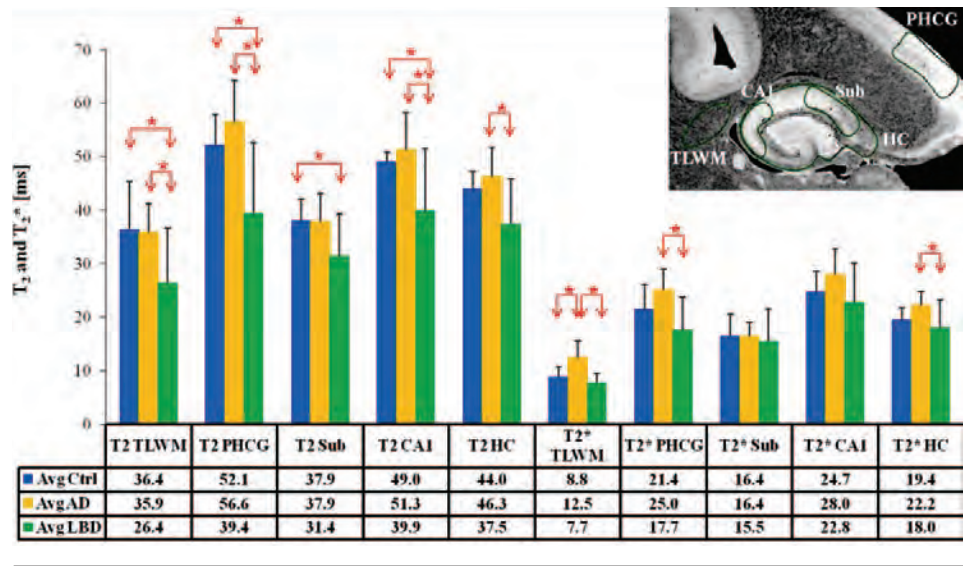


FIGURE 1. Quantified T_2 and T_2^* times displaying the differences between the various groups and in particular the opposite trend between AD and DLBD versus controls. Brackets indicate statistical significance from a one-way ANOVA and LSD test ($p < 0.05$).

Multi-slice diffusion-weighted spin echo (DWSE) sequences with four diffusion weightings (b values = 0-1500 s/mm^2) also were acquired. Separate manually drawn regions of interest (ROIs) were traced over the temporal lobe white matter (TLWM), parahippocampal gyrus (PHCG), subiculum (Sub), CA1 and the entire hippocampus (HC). Histology included stains for iron (Prussian Blue, PB) and ferritin-L. Neural density

and vacuolation were quantified with hematoxylin & eosin (H&E).

Results and Discussion

High resolution datasets, parametric relaxation maps and regional quantification of T_2 and T_2^* provided significant distinctions between healthy and pathological specimens diagnosed with AD or DLBD. With respect to T_2 and T_2^* , the largest difference from

controls and AD was identified TLWM while DLBD showed the largest impact on the PHCG. This data suggests that lower T_2 and T_2^* times are correlated with chronic DLBD rather than chronic AD or control sections while increased relaxation values and ADC coincide with chronic AD pathology. H&E for vacuolization indicated a larger loss of cells and neuropils in AD compared to both controls and DLBD. While T_2 times correlated with vacuolation in TLWM, PHCG and CA1 and inversely with ferritin in TLWM and CA1, neural count did not correlate with either T_2 or T_2^* .

Conclusions

This work suggests that it is possible to differentiate quantitatively between neurologically healthy brain tissue and pathological specimens diagnosed with AD or DLBD. Though histological findings correlate well with relaxation, relatively low %PB and high %Fer detected in AD and DLBD cases may indicate chronic brain iron deficiencies.

Acknowledgements

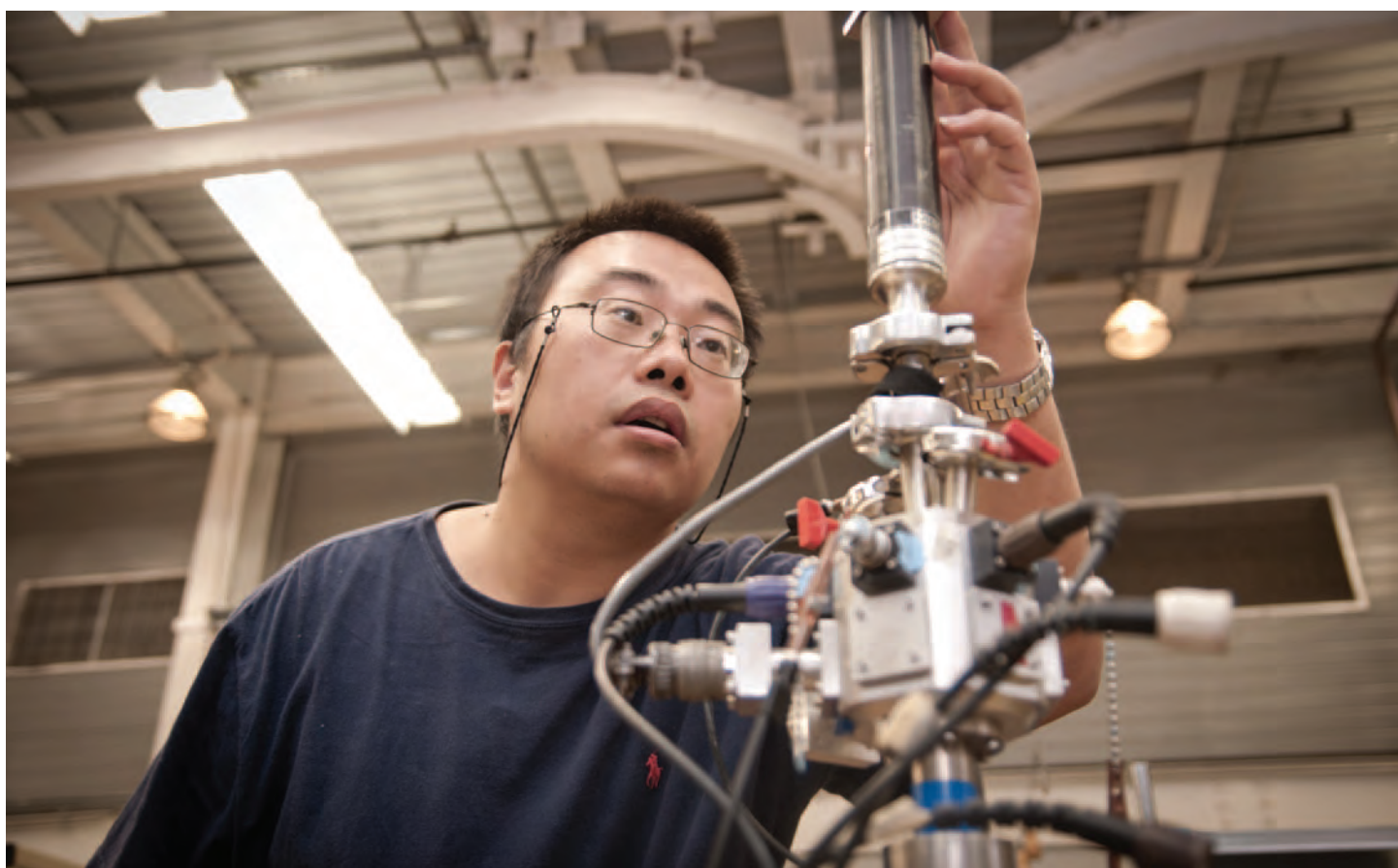
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CHAPTER 3

User Facilities



The strength of the Magnet Lab's User Program is built around the synergies of the highest field magnets, unique instrumentation, and exceptional support from highly qualified faculty and staff of the laboratory's seven user facilities—DC Field, Pulsed Field, High B/T, NMR-MRI @ FSU, NMR-MRI @

UF (AMRIS), EMR, ICR, and the nascent Geochemistry facility. In this chapter, each facility presents information about its research capabilities, developments, plans, productivity, and efforts to build the user community during 2011.

The Magnet Lab was extremely pleased to welcome requests for magnet

time from 81 new principal investigators in 2011: 25 in the DC Field Facility; 14 in the Pulsed Field; 1 in the High B/T; 6 in NMR-MRI@FSU; 7 in NMR-MRI@UF; 13 in EMR; and 15 in ICR. Some "frequently-asked-for" lab-wide user statistics are presented in **Tables 1 and 2**; details for each facility are presented in Appendix A.

TABLE 1

Magnet Lab User Profile¹ Calendar Year 2011

	Total	Women	Minority	NHMFL Affiliated Users ²	Local Users ²	University Users, U.S. ^{3,5}	Industry Users, U.S. ⁵	National Lab Users, U.S. ^{4,5}	Non-U.S. Users ⁵
Senior Investigators	691	82	38	140	95	390	13	94	194
Postdocs	180	33	11	43	46	108	1	30	41
Students	384	116	21	65	84	294	0	7	83
Technicians	44	7	1	12	16	31	2	0	11
TOTAL USERS	1299	238	71	260	241	823	16	131	329

1. The laboratory reports seven user facilities (DC Field, Pulsed Field, High B/T, NMR-MRI @ FSU, NMR-MRI @ UF [AMRIS], ICR, EMR) and the Geochemistry Facility, which is affiliated. A user is a member of a research group that is allocated magnet time. The user does not have to be "on site" for the experiment. Consequently, a researcher who sends samples for analysis; a scientist who uses new lab technologies to conduct experiments remotely; or a PI who sends students to the Magnet Lab, are all considered users.
2. NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on Web site/directory], even if they travel to another site. Local users are defined as any non-NHMFL-affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.
•The sum of NHMFL-Affiliated and Local users equals what was formerly referred to as "Internal Investigators".
3. In addition to external users, all users with primary affiliations at FSU, UF, or FAMU are reported in this category, even if they are also NHMFL associates.
4. In addition to external users, users with primary affiliations at NHMFL/LANL are reported in this category.
5. Four columns of users (university, industry, national lab, non-U.S.) will equal the Total Number of Users.

TABLE 2

Magnet Lab Facility Usage Profile Calendar Year 2011

	Number of Magnet Days ¹ Allocated	Condensed Matter Physics	Chemistry, Geochemistry	Engineering	Magnets, Materials, Testing, Instruments	Biology, Biochemistry, Biophysics
NHMFL-Affiliated ²	3243	486	982	548	389	838
Local ²	2415	1038	484	0	9	884
U.S. University	2950	1468	469	16	32	965
U.S. Govt. Lab.	410	345	46	0	6	13
U.S. Industry	52	0	50	0	0	2
Non-U.S.	1071	624	256	15	23	153
Test, Calibration, Set-up, Maintenance ³	900	61	132	193	314	200
TOTAL	11041	4022	2419	772	773	3055

- 1 User Units are defined as magnet days for four types of magnets. One magnet day is 7 hours in a water cooled resistive or hybrid magnet in Tallahassee. One magnet day is 12 hours in any pulsed magnet in Los Alamos and 24 hours in superconducting magnets in Tallahassee, Los Alamos, and the High B/T system in Gainesville. Magnet days for AMRIS instruments in Gainesville: Verticals (500, 600s, & 750 MHz), 1 magnet day = 24 hours (7 days/week); Horizontals (4.7, 11.1, and 3T), 1 magnet day = 8 hours (5 days/week).
- 2 Use by NHMFL-Affiliated and Local users as defined in Table 1, footnote 2.
- 3 In 2007 and prior years, not all facilities captured this information. Beginning in 2008, all groups collected this data so it is now included in the summary table.

DC Field Facility

2011 statistics on DC Field users, proposals, and magnet usage are presented in Appendix A.

The DC Field facility at the Magnet Lab's headquarters in Tallahassee continues to provide the user community with the highest and quietest slowly varying magnetic fields in the world. The magnets are coupled with state-of-the-art instrumentation resulting in a suite of powerful measurement environments for research. Expert experimental staff members provide users with scientific and technical support while using the DC facilities.

Facility Developments

A large number of improvements to the DC Field Facility have been in development for some time and are beginning

to come to fruition. The first of these is the **25 T Split-Bore magnet**, a revolutionary magnet with four large ports at field center through the mid-plane of the magnet where the stresses and temperatures are the highest. These ports, 11.5 degrees in the vertical direction and 45 degrees in the horizontal extending from a 5 mm volume at field center, are far larger than any similar magnet in the world. In addition to having larger access ports than any other split-bore magnet, its maximum field is significantly higher. In addition, this is our first 28 MW resistive magnet that makes full use of our upgraded power supplies. The Split-Bore Magnet is truly an

amazing engineering achievement.

An initial set of experiments has already been performed in this system (see the Science Productivity section below) and experimentalists are already planning an ever expanding suite of experiments that this system will make possible. To fully utilize this magnet, a unique variable temperature cryostat has been purchased that uses the magnet bore as part of the dewar vacuum space in order to eliminate the need for optical windows in high fields and simultaneously maximize the sample space. This cryostat is top-loading and is unlike any such system built before. This cryostat has been delivered, tested,

Florida-bitter and Hybrid Magnets

Field, Bore, (Homogeneity)	Power (MW)	Supported Research
45 T, 32 mm, (25 ppm/mm)	29.3	Magneto-optics – ultra-violet through far infrared; Magnetization; Specific heat; Transport – DC to microwaves; Magnetostriction; High Pressure; Temperatures from 30 mK to 1500 K; Dependence of optical and transport properties on field, orientation, etc.; Materials processing; Wire, cable, and coil testing. Low to medium resolution NMR, EMR, and sub/millimeter wave spectroscopy.
35 T, 32 mm	19.2	
31 T, 32 mm to 50 mm ¹	18.4	
29 T, 32 mm (~5 ppm/mm) ²	18.3	
20 T, 195 mm	20.0	
25 T, 52 mm, (1 ppm/mm) ²	18.6	
25 T, 32 mm bore (with optical access ports) ³	27	

Superconducting Magnets

Field (T), Bore (mm)	Sample Temperature	Supported Research
18/20 T, 52 mm	20 mK – 2 K	Magneto-optics – ultra-violet through far infrared; Magnetization; Specific heat; Transport – DC to microwaves; Magnetostriction; High pressure; Temperatures from 20 mK to 300 K; Dependence of optical and transport properties on field, orientation, etc. Low to medium resolution NMR, EMR, and sub/millimeter wave spectroscopy.
18/20 T, 52 mm	0.3 K – 300 K	
17.5 T, 47mm ³	4 K – 300 K	
17.5 T, 34 mm, (50 ppm/cm) ²	0.3 K – 300 K	

¹ A coil for modulating the magnetic field and a coil for superimposing a gradient on the center portion of the main field are wound on 32 mm bore tubes.

² Higher homogeneity magnet for magnetic resonance measurements.

³ Optical ports at field center with 4 ports each 11.4° vertical x 45° horizontal taken off of a 5 mm sample space.

and meets specifications. To support this dewar and the rest of the optical equipment a special c-shaped optical table has been ordered that will surround the magnet. This cell will eventually be fitted with walls and a ceiling to create a dark, clean, laser-safe space around the magnet. These walls will be configurable to allow other experimentalists to use the magnet system as well. In short this world record magnet will soon have the instrumentation and environment to allow measurements that could not be performed elsewhere.

Less exciting, but no less important, is the addition of a **fifth cooling water pump** for the resistive magnets that has a larger pumping capacity than the other four. Prior to this addition, running a 28 MW magnet required the use of more than two of our pumps and both of our cooling water circuits. The upgraded pumping capability and associated plumbing upgrades will allow us to run a 28 MW magnet on a single cooling loop while still running another full load on the second cooling loop. Additional piping and valves provide flexibility in connecting pumps to the cooling loops and a measure of redundancy if a pump should fail. An additional benefit of this upgrade is that in the future another resistive magnet can be run to half field while the hybrid magnet is running. Thus this upgrade will provide more flexibility and run time for our users.

For several years, we have been planning a very large improvement to our cryogenic infrastructure to meet the rising demand of liquid helium and to maximize our recovery efforts. This year the heart of these investments has been delivered, tested and is making liquid. A **custom Linde LR280 turbine liquefier** was delivered that makes over 200 l/hr of liquid helium when running without additional heat load. This liquefier exceeded its specified cooling power of 750 W at 4.2K, making 950 W as installed. In addition a large capacity purifier has been delivered and is currently being installed. A cryogenic central distribution box has also been ordered with delivery scheduled for the 2nd quarter of 2012. This central distribution box will allow the new liquefier to serve the 45 T hybrid, the series-connected hybrid, and the liquid helium needs of the rest of the laboratory. The improvements

coupled with upgrades in our recovery and storage systems will make our delivery of helium to the MagLab much more reliable and efficient while simultaneously making operation of large cryogenic magnets such as the hybrid and the coming series-connected hybrid more robust.

Finally, in Cell 9, **the top-loading cryostat has had its experimental probes completely replaced.** This system is the first of the top loading cryostats for the resistive magnets used here. The wiring on its existing probes had begun to degrade and because of their design could not be replaced without cutting the probes apart. Our staff designed new probes with titanium shafts that are much more robust and user friendly than the old stainless steel probe shafts. The probe heads feature multiple ports allowing specialty wires or coax to be easily inserted by users without replacing or damaging the existing wiring. These new probes will provide our users with improved experimental capabilities.

Facility Plans

A **new top-loading cryogenic system** that is optimized for the 45 T hybrid magnet was ordered last year and has recently been delivered. Initial testing is still underway, but preliminary tests are very positive, and we expect that this system will perform as good as or better than the top loading cryostats in Cell 12 (35 T, 32 mm bore) and Cell 9 (31 T, 50 mm bore). We expect that this system will be available for users in the summer of 2012.

Work on the Split-Bore magnet cell will continue to move forward as mentioned above. In addition to the cryostat



and optical tables, **additional instrumentation will be purchased to perform new experiments adding to the capabilities of this system.** An MRI will be submitted with PIs Steve McGill (NHMFL) and Madalina Furis (University of Vermont) to fund the purchase and development of some of these capabilities.

In addition, during the calendar year 2012 **we will push our low temperature calibration effort forward to improve our ability to provide calibrated thermometers to high fields.** We are currently able to calibrate thermometers to the PLTS-2000 standard. Extending calibrations to high fields is very difficult and requires many checks to ensure that one is not introducing errors with the addition of magnetic field to the experiment. We will continue on our past work and provide the time and resources to make this effort a higher priority.

Science Productivity

As mentioned above the Split-Bore magnet has raised the bar for scientific possibilities in magneto-optics. The first of these experiments was run at room temperature by **the group of Gleeson and**

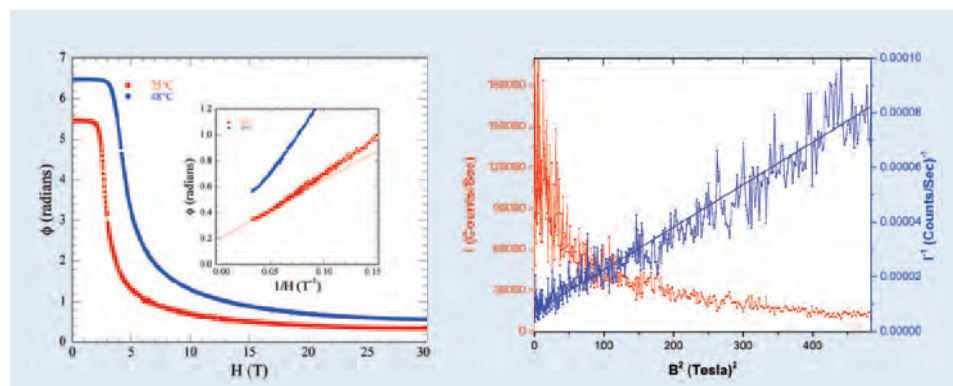


FIGURE 1. Using the Magnet Lab's new Split-Bore magnet, users from Kent State demonstrated that two normal modes, which are separate at low fields, are combined at high fields.

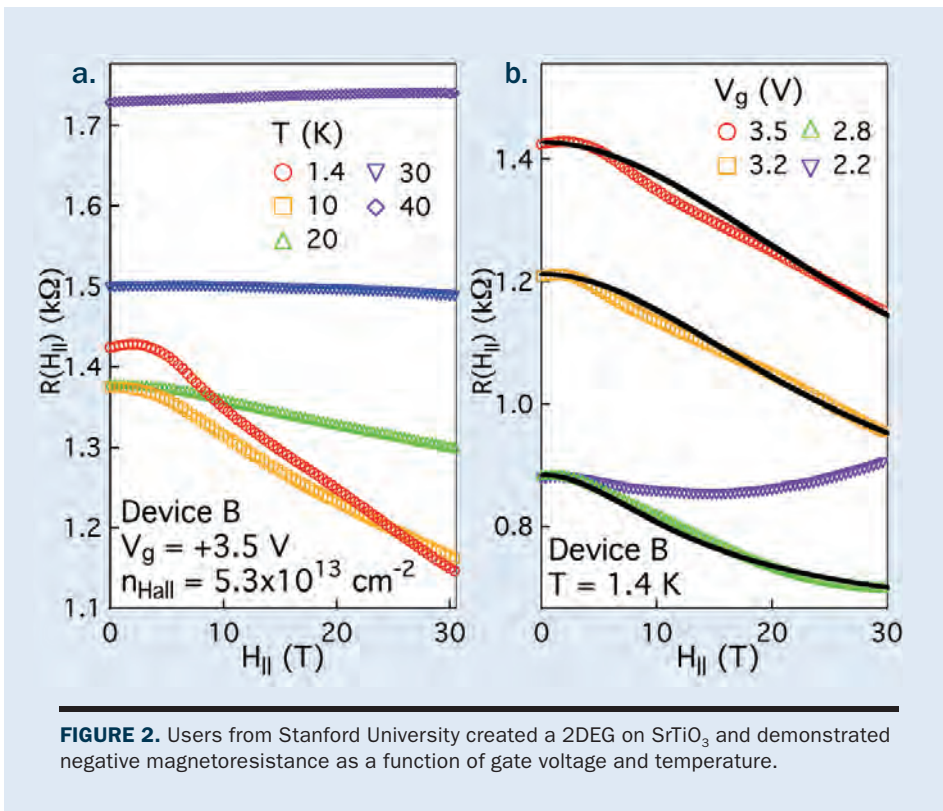


FIGURE 2. Users from Stanford University created a 2DEG on SrTiO₃ and demonstrated negative magnetoresistance as a function of gate voltage and temperature.

Sprunt at Kent State on liquid crystals. In this experiment, scattering at different angles could be collected simultaneously and correlated to determine structural changes in the crystals. It is clear from the graphs in **Figure 1** that two normal modes, which are separate at low fields, are combined at high fields. These measurements will provide the ability to extract key geometric factors and viscosity coefficients.

For many years Quantum Hall Effect research has been a large part of the research effort in high magnetic field facilities. Recently, graphene has entered the scientific arena as a new type of two-dimensional electron gas system with exciting new science and technical potentials. Following closely on graphene's heels has been the class of materials that exhibit conducting surfaces due to topological effects or Topological Insulators. Very recently a two-dimensional electron gas system formed at the interface of the oxide insulators SrTiO₃ and LaAlO₃ has been studied by a number of scientists including some NHMFL users. **The group of Goldhaber-Gordon at Stanford** has created a 2DEG on SrTiO₃ that can be

controlled with a gate electrode via the application of a surface gel. Very nice high-field work at the MagLab demonstrated negative magnetoresistance as a function of gate voltage and temperature (see **Figure 2**).

Progress on STEM and Building the User Community

The DC Field Facility continued to be oversubscribed in 2011 as can be seen the usage tables in Appendix A. In spite of this oversubscription, however, the DC facility has made bringing new investigators into the MagLab a priority. We are continuing our efforts to reach out wherever possible in order to expand our user program and enable principal investigators from backgrounds that are under-represented in the scientific community. In particular, the NHMFL sponsored a booth at the APS March Meeting and also the annual meeting of the National Society of Black Physicists / National Society of Hispanic Physicists to advertise our capabilities and opportunities.

In 2011 the DC Field Facility continued to attract new researchers. Appendix A, Table 8 shows **we attracted proposals**

from 25 new PIs: 16 received time in 2011 and 9 more are scheduled to get time in 2012. In addition to the 21 new PI's that we reported last year, there were an additional 11 that applied for time in 2010 and received time in 2011. These new PI's came from institutions as varied as Cambridge University (UK), Peking University (China), Massachusetts Institute of Technology, and Morehouse College. Of these new users, two were minorities and one was a female.

Pulsed Field Facility

2011 statistics on Pulsed Field users, proposals, and magnet usage are presented in Appendix A.

The National High Magnetic Field Laboratory - Pulsed Field Facility (NHMFL - PFF) is located in Los Alamos, New Mexico, at the Los Alamos National Laboratory (LANL) along with two other world class user programs. The center for Integrated Nano Technology (CINT) and the Los Alamos Neutron Science Center (LANSCE).

The NHMFL-PFF utilizes LANL and U.S. Department of Energy (DOE) owned equipment and resources to provide world record pulsed magnetic fields to users from the scientific and engineering community worldwide.

The pulsed field users program is

engineered to provide researchers with a balance of the highest research magnetic fields and robust scientific diagnostics specifically designed to operate in pulsed magnets. The connection with the DC Field Facility is strong and complementary in expertise.

Although achieving the highest research magnetic fields possible is a fundamental competency at the NHMFL-PFF, we also strive to create the very best high-field research environment possible and to provide users with support from the world's leading experts in pulsed magnet science. All of the user support scientists are active researchers and

collaborate with multiple users per year.

A fully multiplexed and computer controlled, 6-position 4.0 mega-Joule (32 mF @ 16 kV) capacitor bank system is at the heart of the short pulse magnet activities. Many thousands of shots are fired for the users program, which accommodates approximately 150 different users each year.

The LANL/DOE owned 1.4GW generator is unique in the world and provides users with the highest non destructive magnetic fields available.

The magnets available for users at the NHMFL- PFF are presented in the table below.

Capacitor-Bank-Driven Magnets

Field (T), Duration, Bore (mm)	Supported Research
Cell 1: 65 T Short Pulse, 25 msec, 15 mm Ultra low noise	Magneto-optics (IR through UV), magnetization, and magneto-transport from 350 mK to 300 K. Pressure from 10 kbar typical, up to 100 kbar. GHz conductivity, MHz conductivity, Pulse Echo Ultra-sound spectroscopy. IR & FIR transmission in the Single Turn Magnet. Specific heat capability in 60 T Long Pulse. Dilatometry up to 95T.
Cell 2: 65 T Short Pulse, 25 msec, 15 mm Rapid cool design	
Cell 3: 65 T Short Pulse, 25 msec, 15 mm Ultra low noise	
Cell 4: 65 T Short Pulse, 25 msec, 15 mm Rapid cool design	
Cell 294: Development test cell	
60 T Long Pulse Magnet, ~3 sec, 32 mm	
95 T Multi-shot, 10 msec, 10 mm / 85T Multi-Shot, 10 msec, 15 mm	
Single Turn (to 240 T so far), 0.06 msec, 10 mm	

Superconducting Magnets

Field (T), Bore (mm)	Supported Research
20 T magnet, 52 mm	Same as pulsed fields, plus thermal-expansion, specific heat, and 20 mK to 600 K temperatures. Heat Capacity, THz Resistivity, Heat Capacity, Magnetometry.
15/17 T magnet, 52 mm	
14 T-PPMS magnet	

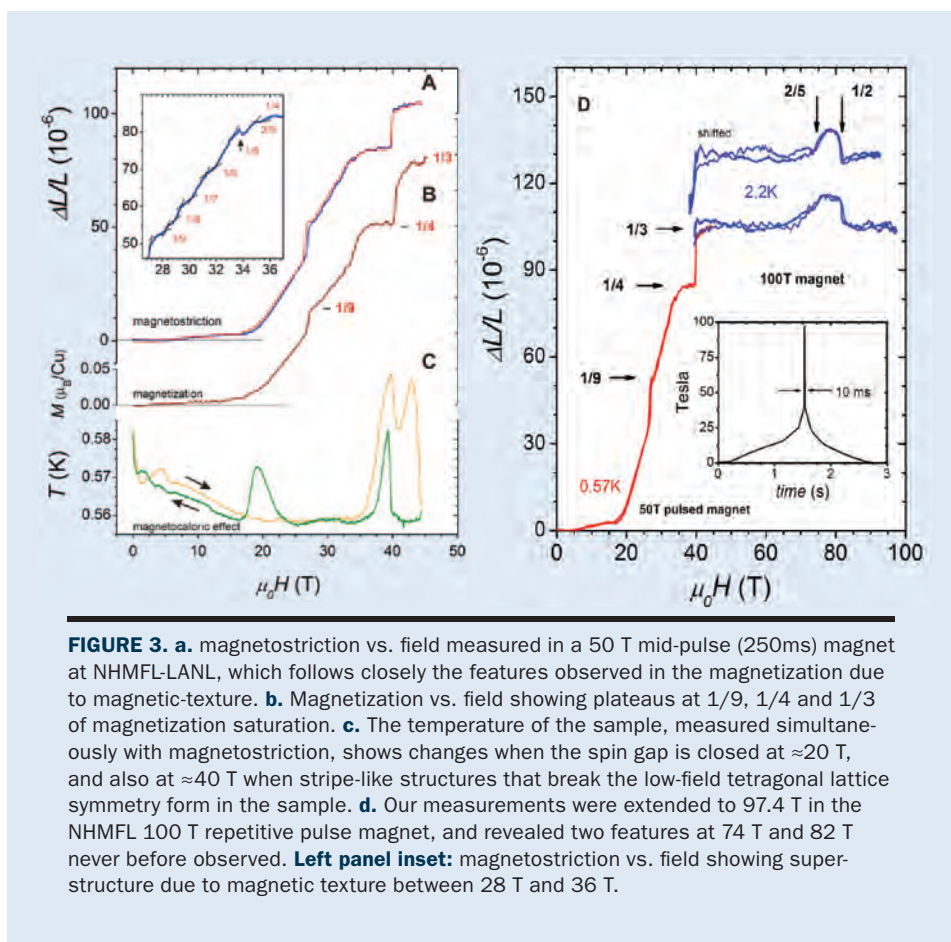


FIGURE 3. **a.** magnetostriction vs. field measured in a 50 T mid-pulse (250ms) magnet at NHMFL-LANL, which follows closely the features observed in the magnetization due to magnetic-texture. **b.** Magnetization vs. field showing plateaus at $1/9$, $1/4$ and $1/3$ of magnetization saturation. **c.** The temperature of the sample, measured simultaneously with magnetostriction, shows changes when the spin gap is closed at ≈ 20 T, and also at ≈ 40 T when stripe-like structures that break the low-field tetragonal lattice symmetry form in the sample. **d.** Our measurements were extended to 97.4 T in the NHMFL 100 T repetitive pulse magnet, and revealed two features at 74 T and 82 T never before observed. **Left panel inset:** magnetostriction vs. field showing superstructure due to magnetic texture between 28 T and 36 T.

Facility Developments

In 2011 the PFF has been focused on testing of the second generation of inserts for the 100 T multi shot magnet.

The 95 T multi shot magnet with a second generation 10mm bore insert was tested to 97.4 T in August 2011. The user program will utilize this magnet routinely to 92 T with 95 T shots being available for exceptional science-based cases.

Installation of the first pulse tube liquefier was completed in May 2011. The liquefier produces ~ 100 liters of liquid helium per week. All the pulsed magnet systems are connected to a recovery bag that feeds the liquefier.

The 20 T superconducting magnet system with an actively cooled helium reservoir was purchased in 2010 was installed and tested successfully to 20 T and is now available for users. The system has a top loading He^3 insert and a bottom loading vacuum or mixture dilution refrigerator. The magnet also has a modulation/gradient coil set available for users.

Science Productivity

To date 48 peer reviewed publications and 14 presentations and posters have been reported for 2011.

- **Microstrain-Sensitivity Magnetostriction of $\text{SrCu}_2(\text{BO}_3)_2$ to 97.4 Tesla**
R. Daou (HLD, Dresden), **S. Crooker** (LANL, NHMFL), **F. Weickert** (LANL, CMMS), **A. Uchida** (LANL, NHMFL), **H.A. Dabkowska** (McMaster, Physics), **B.D. Gaulin** (McMaster, Physics), **M. Jaime** (LANL, NHMFL)

The orthogonal-dimer geometry of the Shastry-Sutherland lattice and the ratio of next-nearest to nearest neighbor exchange interactions between the spin $1/2$ Cu^{2+} ions, $J_1/J_0 \sim 0.62$ ($J_0 \approx 74\text{K}$), make $\text{SrCu}_2(\text{BO}_3)_2$ a paradigm of frustrated quantum magnetism, where an external magnetic field can be used to induce magnetic texture. The strength of required magnetic fields has until now prevented, however, the unambiguous observation of magnetization fractions beyond $1/3$ of saturation.

Here the users report microstrain-sensitivity magnetostriction (MS) data obtained for a single crystal sample of $\text{SrCu}_2(\text{BO}_3)_2$ in pulsed magnetic fields to 97.4 T using a recently developed fiber Bragg gratings (FBG) technique. The magnetostriction was measured with the magnetic field $H//c$ -crystallographic axis (**Figure 3**) and with $H//c$ -axis (not shown) at different temperatures down to $T = 0.5\text{K}$. We found a remarkable correspondence between magnetostriction and magnetization vs. field data, that confirms previously discussed magnetic texture following the series $1/n$ with $n = 3, 4, \dots, 9$ in $\text{SrCu}_2(\text{BO}_3)_2$. The users also found two new features at $\mu_0 H = 74$ T and 82 T that they attribute to superstructure corresponding to $2/5$ and $1/2$ ($n=2$) of magnetization saturation respectively.

- **Superconducting Critical Current Measurements in Pulsed Magnets**
Philip J.W. Moll, **Nikolai D. Zhigadlo**, **Janusz Karpinski**, **Bertram Batlogg** (Laboratory for Solid State Physics, ETH Zurich, Switzerland), **Fedor F. Balakirev** (LANL)

High temperature superconductors show great promise for real world applications compared to existing conventional low-temperature superconductors and resistive conductors. It is particularly important for the development of superconducting magnets to know their critical current (j_c) capacity in high field regime that is projected to exceed the maximum field available in DC magnets, making it imperative to expand j_c measurements to pulse magnet systems. Measurements of critical current in single crystals of high temperature superconductor using pulsed magnetic fields up to 95 T are tricky due to short time scale, fast field sweep rate and sheer absolute current values in restricted sample space. (See **Figures 4 and 5**)

- **Multiple Quantum Oscillation Frequencies from Nodal Pocket in Underdoped Cuprates**
S.E. Sebastian, **G.G. Lonzarich** (U. of Cambridge, Physics); **C.H. Mielke**, **N. Harrison** (LANL); **R. Liang**, **W.N. Hardy**, **D.A. Bonn**

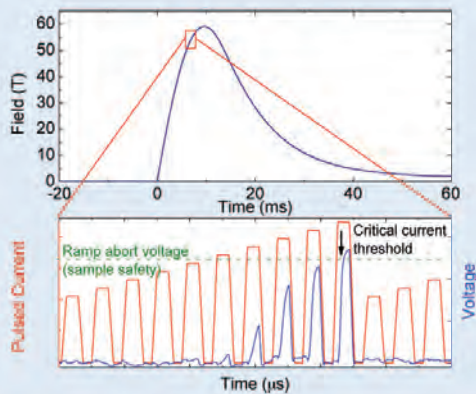
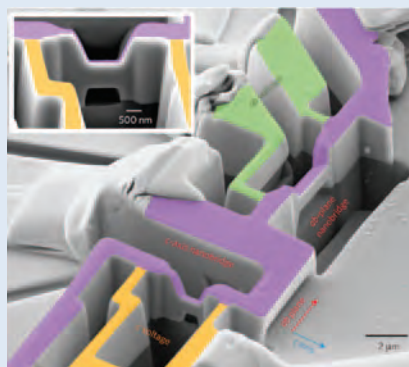


FIGURE 4. (Above left) Nano-bridge jc samples (cross-section 600 nm by 600 nm, length of narrow part $\sim 1\text{--}3\ \mu\text{m}$) cut into a $\text{SmFeAsO}_{0.7}\text{F}_{0.25}$ single crystal lamella using Focused Ion Beam lithography technique.

FIGURE 5. (Above right) Top: variation of magnetic field in pulsed magnet as a function of time. **Bottom:** expanded time scale: incremental sequence (ramp) of sample current pulses (red), generated by FPGA logic. Sample voltage response (blue) is detected by FPGA logic.

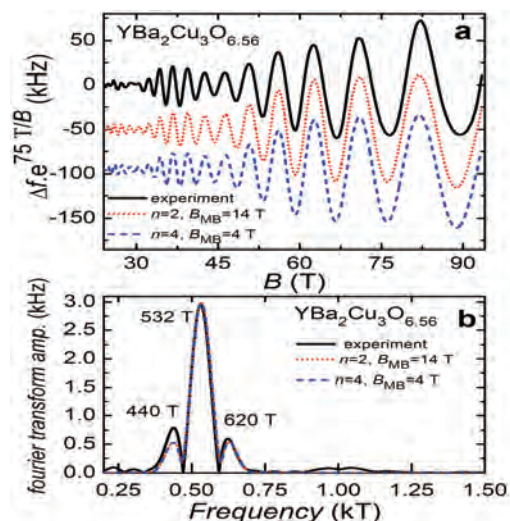


FIGURE 6. Quantum oscillations from 24–94 T in (a), the Fourier transform in (b) shown by black lines. Red and blue dotted lines are simulations for an elliptical and diamond nodal pocket.

(U. of British Columbia, Physics)

Discerning the electronic structure of the underdoped cuprates poses a pressing conundrum. Among key questions to be addressed are the issue of whether the electronic structure comprises multiple pockets, and whether any of these are located at the antinodal region of the Brillouin zone where photoemission experiments reveal a significant gap in density of states at the Fermi Energy. (See **Figure 6**.)

Facility Plans

- Installation of the Linde helium liquefier will commence in the summer of 2012 and should be complete by the beginning of 2013.
- Winding of the next generation of 100 T multishot outsert coils will begin in 2012.
- Development of the next generation short pulse magnets will begin utilizing *Los Alamos duplex technology*.

Progress on STEM and building the user community

The NHMFL-PFF provided magnet time for 144 distinct experiments in 2011, with 56 different PIs, **14 of whom were new user PIs**.

Several students from underrepresented groups were involved in the pro-

gram this year providing mutual benefits to the students and the PFF mentors. Four of these students were from the Materials Development Institute funded by LANL.

Travel support may be granted to the new users, which has been helpful in growing the new user base considering the relatively remote location of the PFF in Los Alamos.

PFF staff members continue to make considerable efforts toward outreach. In 2011 the third summer school was organized by Albert Migliori and Eric Palm and held at the DC facility in Tallahassee. The school, which included both lectures and hands-on practicals, helped new users and students understand the complexity of conducting experiments in all of the Magnet Lab facilities. Many scientists from the NHMFL-PFF gave their time to teach at this event.

During the year, the PFF has hosted tours of the facility for over 500 people, including students from the Northern New Mexico Pueblo school and the underrepresented college science program at New Mexico State University



ABOVE: The NHMFL-PFF was represented by Vivien Zapf at the American Indian Science and Engineering Conference (AISEC) in Minnesota.

High B/T Facility

2011 statistics on High B/T users, proposals, and magnet usage are presented in Appendix A.

The High B/T Facility provides users with access to a unique combination of high magnetic fields (up to 16 T) and ultra-low temperatures (down to 0.04 mK) simultaneously. Two nuclear demagnetization stages are available, one using PrNi₅ to provide high cooling power down to 0.4 mK and a second using a Cu nuclear refrigerator capable of reaching 0.07 mK. In addition a fast turn-around 10 mK-10 T facility is available for testing experimental probes and sample properties prior to using the nuclear refrigerators. The nuclear refrigerators are housed in high quality electromagnetic shielded rooms in the University of Florida Microkelvin Laboratory and provide the ultra-quiet environments needed for high sensitivity measurements at very low temperatures.

Equipment is available to carry out measurements of magnetic and electric susceptibilities, ultrasound propagation, nuclear magnetic resonance and transport studies at sub-millikelvin temperatures.

Facility Developments

In order to probe the electro-magnetic interactions in organic quantum

magnets high precision ultra-low temperature capacitance bridges have been developed. This new capability has revealed the existence of new magneto-electric effects following the introduction of disorder in magnetic systems that display Bose-Einstein condensation of magnetic excitations.

Facility Plans

In response to user requests the High B/T facility is developing new capabilities to extend the available parameter space at low temperatures to moderately high pressures (2-3 GPa). This capability will permit the exploration of the density dependence of the ordered states of novel magnetic systems such as low dimensional frustrated magnets.

Science Productivity

The High B/T facility reported 10 peer reviewed publications for 2011, including three significant publications, and there were 9 research reports for a total of 8 independent experiments in 2011. One Ph.D. thesis was completed. Three examples of exceptional science include:



- **Novel Fractional Quantum Hall Effect in Two-Dimensional Electron Systems**
W. Pan (Sandia Nat. Lab.), J.S. Xia (UF, Physics), N. Masuhara (UF, Physics), N.S. Sullivan (UF, Physics), K.W. Baldwin, K.W. West, L.N. Pfeiffer and D.C. Tsui (Princeton U.), *Phys. Rev. Lett.*, **106**, 206806 (2011).

High B/T Research Magnets

Superconducting Magnets	Refrigerator	Research Supported
15.5 T at 4 K (16.5 T at 1.2 K) 2.5 cm DSV experimental space Bay 3 Microkelvin Laboratory	PrNi ₅ nuclear refrigerator 0.4 mK, 10 nW cooling power	Magnetic and electric susceptibility measurements, NMR to 1000 MHz, transport, fQHE
8 T at 4K (10 T at 1.2 K) 3.25 cm DSV experimental space Bay 2 Microkelvin Laboratory	Cu nuclear refrigerator 0.07 mK, 1 nW cooling power (lowest attained temperature 0.04 mK)	Magnetic and electric susceptibility, NMR/NQR to 1000 MHz, transport, fQHE, dHVA studies, ultrasound absorption
10 T 2.5 cm DSV experimental space Williamson Hall Annex	Dilution refrigerator 10 mK	Fast-turn-around facility for testing samples

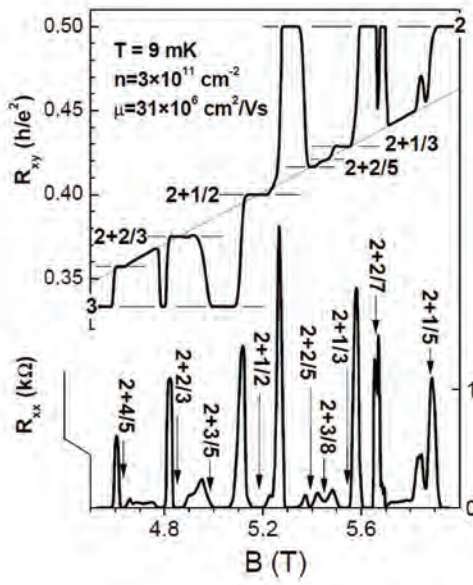


FIGURE 7. R_{xx} and R_{xy} between $\nu = 2$ and $\nu = 3$ at 9 mK. Major FQHE states are marked by arrows. The horizontal lines show the expected Hall value of each FQHE state. The dotted line is the calculated classical Hall resistance.

Studies of the quantum Hall effect in ultra-high mobility quantum well samples, at very low temperatures of 9 mK have revealed several new FQHE liquid states, as shown in **Figure 7**. For example, the low temperature measurements show well quantized FQHE states at $\nu = 2 + 1/3$ and $2 + 2/3$ in coexistence with the so-called re-entrant integer quantum Hall effect and, quite importantly, a new, clearly quantized FQHE state at $\nu = 2 + 2/5$, the nature of such a state being theoretically intensely explored. It could be a so-called parafermionic FQHE state, whose excitations also obey the non-Abelian statistics. Compared to the $5/2$ state, the $12/5$ state is believed to be superior in quantum computation in that one can perform universal topological quantum computing using the $12/5$ state.

• **Magnetic Susceptibility Measurements of the Bose-Glass Phase in $\text{NiCl}_{1.85}\text{Br}_{0.15}\text{-4SC}(\text{NH}_2)_2$ at Low Temperatures**

L. Yin (UF, Physics), J.S. Xia (UF, Physics), C. Huan (Georgia Tech & UF, Physics), N.S. Sullivan (UF, Physics), V.S. Zapf (LANL), A. Paduan-Filho (Univ-eridade de Sao Paulo), T. Roscilde (Ecole Normale Supérieure de Lyon), R. Yu (Rice University), *arXiv:1109.4403* (2011).

Measurements of the AC susceptibility of a bond-diluted quantum magnet $\text{NiCl}_{1.85}\text{Br}_{0.15}\text{-4SC}(\text{NH}_2)_2$ down to 1 mK and for magnetic fields up to 15 T have shown that below a crossover temperature $T_c = 100\text{--}200$ mK, the critical fields H_c for Bose-Einstein condensation obey the scaling relation $|H_c(T) - H_c(0)| \sim T^\alpha$, with a novel and universal scaling exponent $\alpha \sim 0.9$ (see **Figure 8**), which is in agreement with numerical results from a theoretical model for the effects of the introduction of disorder in a Bose Einstein condensate. The results provide strong evidence of the existence of a Bose glass phase in $\text{NiCl}_{1.85}\text{Br}_{0.15}\text{-4SC}(\text{NH}_2)_2$, and they display a quantitative signature of the transition between a Bose glass and a Bose Einstein condensate.

• **NMR Probe of the Lattice Dynamics of Solid Helium at Low Temperatures**

D. Candela (U. Massachusetts), S.S. Kim, C. Huan (Georgia Institute of Tech.), L. Yin, J.S. Xia and N.S. Sullivan (UF, Physics), *Phys. Rev. Lett.*, **106**, 206806 (2011).

High sensitivity NMR experiments were employed to measure the nuclear spin-lattice relaxation times of very dilute samples of ^3He in solid ^4He in the same temperature range as that for which anomalies appear the torsional oscillator and shear modulus studies of solid ^4He . The results reveal a sharp peak in the nuclear spin-lattice relaxation times (T_1) at $T=170$ mK for ^3He concentrations of 16 and 24 ppm (see **Figure 9**). No such peak is seen for concentrations above 200 ppm, which are known to suppress the so-called supersolid effects.

The nuclear spin relaxation in dilute $^3\text{He}\text{-}^4\text{He}$ samples is driven by the tunneling of the ^3He impurities in the solid. The tunneling rates are critically dependent on the lattice properties and small changes in the ^4He lattice such as that due to stiffening at low temperatures can lead to large changes in the relaxation rates. These results are believed to be associated with the strong unusual changes in the lattice dynamics of ^4He at low temperatures and not with the onset of superflow as the latter would lead to critical fluctua-

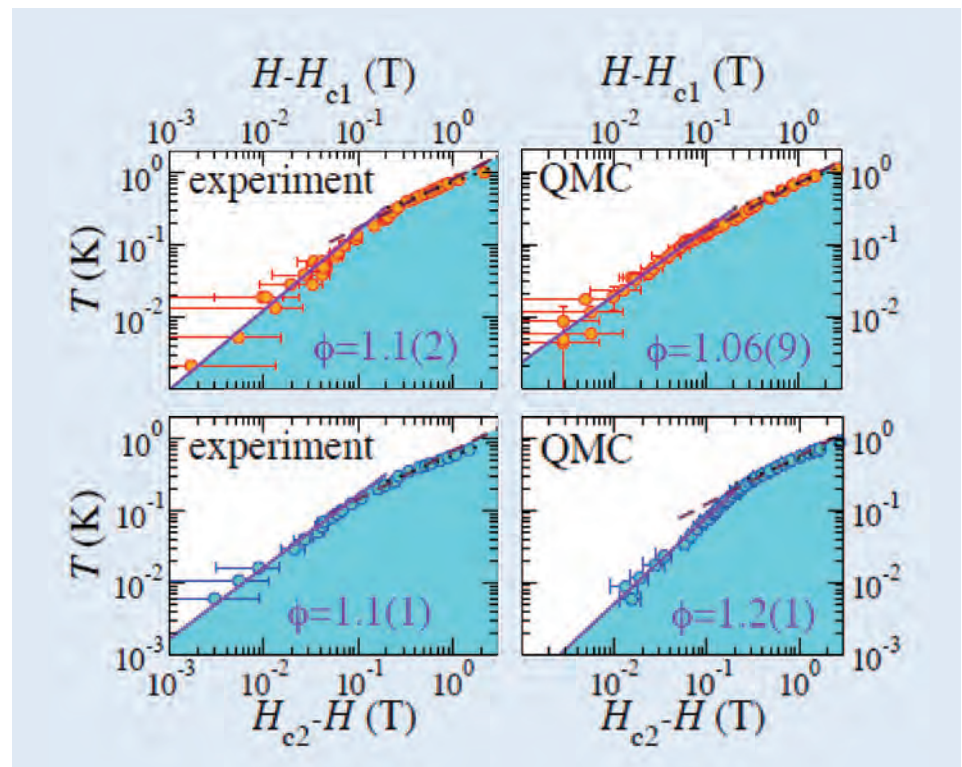


FIGURE 8. Scaling of the critical temperatures with the distance from $T = 0$ critical fields, exhibiting a crossover between various exponents.

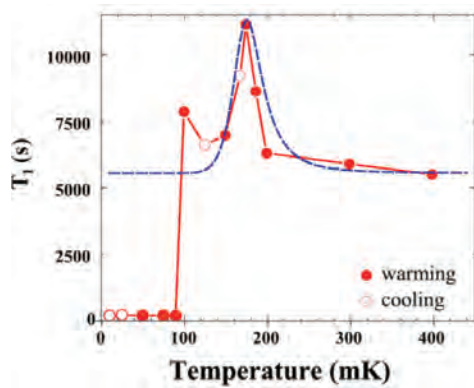


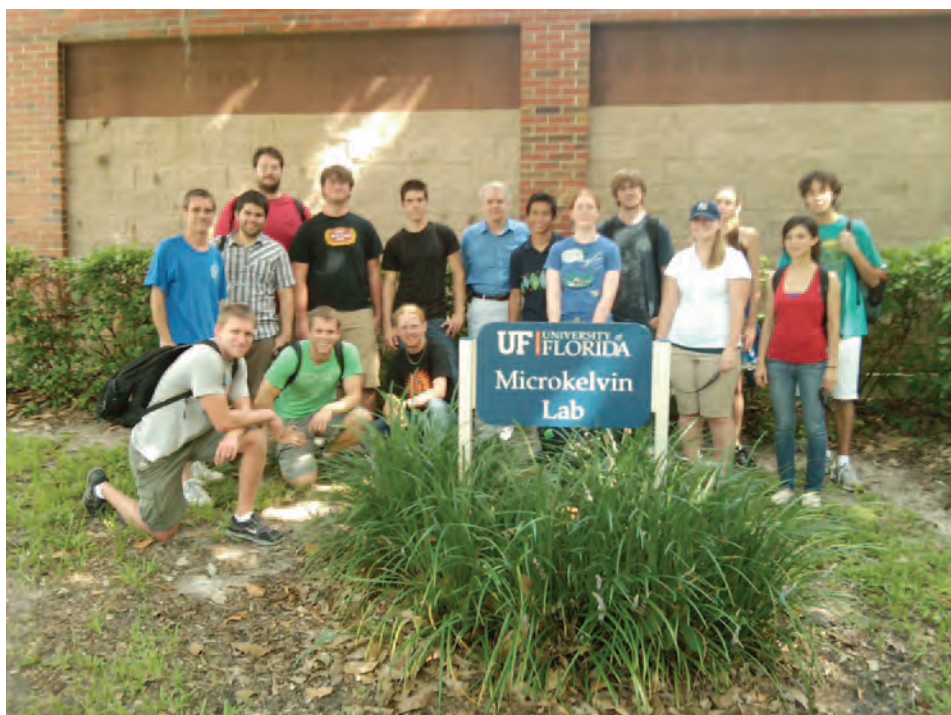
FIGURE 9. Temperature dependence of the nuclear spin relaxation rates for 24 ppm of ^3He in solid ^4He . The dashed blue line is a fit for a lattice induced relaxation.

tions resulting in very sharp peaks for the values of T_1 and sharp minima for T_2 at well defined critical temperatures, which are not seen.

Progress on STEM and Building the User Community

One new user (Xuefeng Sun of Hefei National Laboratory for Physical Sciences, University of Science and Technology of China) requested magnet time in 2011 and magnet time was awarded for 2012. A special high sensitivity AC magnetic susceptibility bridge is being developed for Professor Sun's proposed experiment to explore the properties of the geometrically frustrated pyrochlore material $\text{Tb}_2\text{Ti}_2\text{O}_7$, which is the only material with a pyrochlore structure that retains the properties of a dynamic cooperative paramagnet down to 50 mK.

Faculty members of the High B/T facility supervised three students under the NSF-supported Research for Undergraduates program in the summer of 2011, and throughout the year staff members hosted several visits from high school students and their teachers.



ABOVE 2011 Research Experiences for Undergraduates (REU) participants at the University of Florida.

NMR & MRI Facility at FSU

2011 statistics on NMR-MRI@FSU users, proposals, and magnet usage are presented in Appendix A.

The NMR and MRI User Program in Tallahassee offers user scientists access to the highest magnetic fields along with the latest NMR techniques and probe technology. Our flagship 900 MHz ultra-wide bore spectrometer is the world's highest field instrument for *in vivo* imaging and also offers leading capabilities in materials and biological solid state NMR. Lower field instruments offer users additional capabilities such as solution NMR and ultra-fast sample spinning as well as opportunities for additional experiment time. Our technology efforts are now focused on the development of innovative probes for triple resonance solid state and high field *in vivo* imaging. Efforts are also underway to develop rf probes and associated NMR instrumentation that will be needed for a ground-breaking new powered magnet, the 36 T series connected hybrid, which will have record-setting capabilities for NMR.

Facility Developments and Plans

In 2011, P. Gor'kov and coworkers completed development of a triple resonance (^1H , ^{13}C and ^{15}N) magic angle spinning probe utilizing the Magnet Lab's "Low-E" technology for the 900 MHz UWB NMR spectrometer. This extends a similar capability developed in 2010 for our 600 MHz instruments. These highly efficient and sensitive probes make it possible to use very high irradiation fields without damaging the NMR sample. They are very popular with users and are in great demand for protein structure determination experiments. In 2012, a similar triple-resonance probe for static experiments on proteins in membrane mimetic environments will be made available for users. The Magnet Lab is an international leader in the development of biological solids probes.

For *in vivo* imaging users, the Magnet Lab now offers a number of specialized imaging probes in addition to our excellent ^1H , ^{23}Na and $^1\text{H}/^{23}\text{Na}$ double tuned volume coil probes for studies of rodents. Quadrature ^{23}Na and quadrature ^{35}Cl probes were added in 2011 to obtain higher sensitivity for these physiologically important nuclei. A ^1H -free solenoid is also now available for imaging of materials and of bound water.

The narrowbore 830 MHz magnet has always been very useful for high sensitivity single-resonance MAS experiments on low- γ nuclei. In late 2012, we plan to introduce a new capability to this system for double resonance experiments. By using a probe based on the Low-E cross coil approach, we expect



NMR & MRI Systems at the Magnet Lab at FSU

NMR Frequency	Field (T)	Bore (mm)	Homogeneity	Measurements
1.7 GHz	40	32	10 ppm	Solid State NMR
1066 MHz	25	52	1 ppm	Solid State / Solution NMR
900 MHz	21.1	105	1 ppb	Solid State NMR, MRI
830 MHz	19.6	31	100 ppb	Solid State NMR
800 MHz	18.7	52	1 ppb	Solution NMR, Cryoprobe
720 MHz	16.9	52	1 ppb	Solution NMR
600 MHz	14	89	1 ppb	MRI and Solid State NMR
600 MHz	14	89	1 ppb	Solid State NMR
600 MHz	14	52	1 ppb	Solution NMR
500 MHz	11.75	89	1 ppb	Solid State NMR
500 MHz	11.75	89	1 ppb	NMR Microscopy
400 MHz	9.4	89	1 ppb	Solid State NMR
300 MHz	7	52	1 ppb	Instrument Development
300 MHz	7	89	1 ppb	Solid State NMR

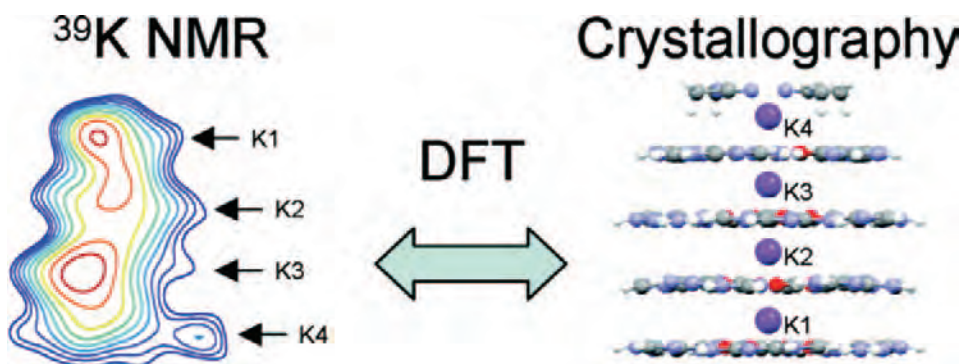


FIGURE 10. ^{39}K multiple-quantum magic-angle-spinning (MQMAS) obtained at 19.6 T resolves four potassium sites inside a lipophilic G-quadruplex structure.

to offer similar sensitivity for low- γ detection as our single coil probes but with an added ^1H irradiation channel.

Another significant enhancement planned for 2012 is the addition of PISEMA capability for aligned membrane proteins to the solution 720 MHz Varian spectrometer. This should help ease pressure on the 600 MHz solid state instruments that has been growing for several years due to the availability new Magnet Lab-designed triple resonance probes.

Finally, our staff continues to prepare for NMR experiments on the upcoming 36 T series connected hybrid magnet. A set of solid state rf probes and a new console are in the works. When the magnet becomes available it will be a unique and record-setting facility for 1 ppm resolution NMR.

Science Productivity

Work at the NMR-MRI Facility in Tallahassee led to 60 annual research reports, five theses, and 41 peer-reviewed publications in 2011. These publications appeared in high-impact journals such as *Trends in Biochemical Sciences* (1), *Journal of the American Chemical Society* (4), *Biomaterials* (1) and *Nature Chemistry* (1), as well as in more specialized publications such as *Journal of Magnetic Resonance* (5), *PLoS Computational Biology* (1), and *Inorganic Chemistry* (1).

• ^{39}K NMR

G. Wu and (Queen's University) and **Z. Gan** (NHMFL) have utilized the Magnet Lab's high magnetic fields, efficient NMR probes, and pulse

sequences and have implemented for the first time ^{39}K multiple-quantum magic-angle-spinning (MQMAS) method to bio-organic molecules [G. Wu *et al.*, *J. Am. Chem. Soc.*, **133**, 19570–19573 (2011)]. The MQMAS experiment achieved sub-ppm isotropic resolution separating the four potassium sites inside a lipophilic G-quadruplex structure. The measured chemical shift and electric-field-gradient parameters are compared with DFT calculation for so-called NMR crystallography without the need for large single crystals. High magnetic fields are essential to facilitate solid-state NMR of the insensitive low- g quadrupolar nuclei that can be found in many catalysts and bio-molecules.

• ^{23}Na Functional MRI

M. Harrington (Huntington Medical Research Institutes), **E. Chekmenev** (Vanderbilt) and **V. Schepkin** (NHMFL) used the ultra-high magnetic field of 21.1 Tesla for *in vivo* sodium MRI to investigate the pathophysiology of a rat migraine model. Intraperitoneal injection of nitroglycerin (NTG) decreased pain withdrawal threshold ($p = 0.0003$), caused eyelids to close ($p < 0.0001$), and increased central neuron activation ($p < 0.0001$) compared to saline injections. These behavioral changes correlated with sodium increases in brain, intracranial CSF, and vitreous humor ($p < 0.05$), ranging from 7.5 to 17%, as illustrated in the **Figure 11**. Sodium increases in 8 locations of rat brain were found but not in extra-cranial muscles. Regions of interest were quantified against a sodium calibration curve. Simulated neurons exposed to these higher sodium levels have more frequent and earlier spontaneous action potentials, and corresponding earlier sodium and potassium currents.

The investigators propose that rising sodium in CSF surrounding trigeminal nociceptors increases their excitability and causes pain, and that rising sodium in vitreous humor increases retinal neuronal excitability and causes photosensitivity. These results

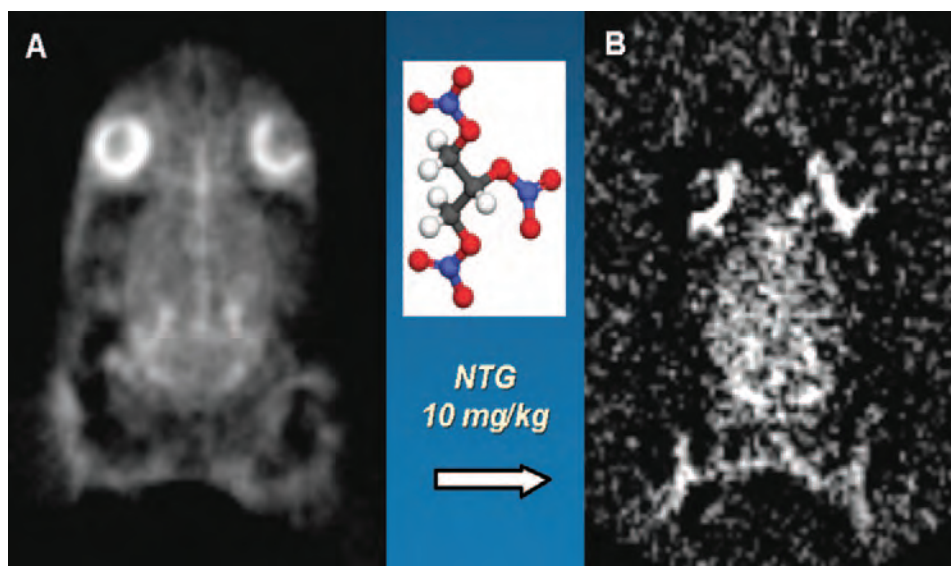


FIGURE 11. Initial *in vivo* sodium MR image of a normal rat head is presented on the left side. The right side demonstrates the changes in sodium throughout rat brain initiated by migraine (25 minutes after NTG injection). Distinct increases from 7.5 to 17% in sodium are revealed throughout brain regions.

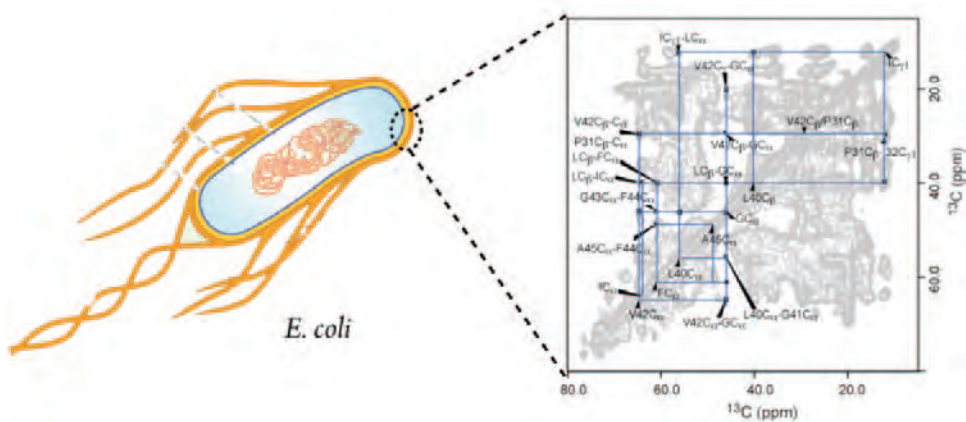


FIGURE 12. *In situ* NMR analysis of membrane proteins shows promise to allow structure determination in a native environment.

reveal that sodium rises to levels that increase neuronal excitability in this rat migraine model [M.G. Harrington *et al.*, *Cephalalgia*, **31** (12), 1254-1265 (2011)].

• ***In Situ* Protein Structure Determination**

F. Tian (Penn State Univ.) and **R. Fu** (NHMFL) evaluated the feasibility of using solid state MAS NMR for *in situ* structural characterization. They studied the transmembrane domain of recently identified protein LR11 in native *E. coli* membrane. LR11 interacts with the human amyloid precursor protein (APP), a central player in the pathology of Alzheimer's disease. Approximately 50% of LR11 TM residues were assigned, allowing for comparisons of the secondary structure of LR11 TM in native membrane environments and in commonly used membrane mimics (e.g. micelles). Such *in situ* spectroscopy bypasses several obstacles in the preparation of membrane proteins for structural analysis, and offers an opportunity to investigate the consequences of membrane heterogeneity, bilayer asymmetry, chemical gradients, and macromolecular crowding on the protein structure [R. Fu *et al.*, *J. Am. Chem. Soc.*, **133** (32), 12370 (2011)].

principal investigators leading research projects (**six of the proposals were submitted in 2011**; one proposal was submitted in late 2010; all received magnet time in 2011). To attract new users and projects we continue to add new capabilities such as Low-E triple resonance solid state NMR and multi-nuclear imaging coils and to communicate these capabilities to the scientific community through posters and talks at national and international scientific conferences.

Progress on STEM and Building the User Community

The NMR-MRI Facility in Tallahassee had 196 users during 2011: 20% were female and 6% were minorities. Of the 101 senior investigators in 2011, 24 were new to the NHMFL, of which 7 were **new**

Advanced Magnetic Resonance Spectroscopy Facility at UF

2011 statistics on NMR-MRI@UF (AMRIS) users, proposals, and magnet usage are presented in Appendix A.

The AMRIS facility at the University of Florida supports nuclear magnetic resonance studies of chemicals, biomolecular systems, tissues, small animals, large animals, and humans. We currently offer eight systems with different magnetic fields and configurations to users for magnetic resonance experiments. AMRIS has eight professional staff members to assist users, maintain instrumentation, build new coils and probes, and help with administration.

Several of the AMRIS instruments offer users unique capabilities: the 750 MHz wide bore provides outstanding high-field microimaging for excised tissues and live mice; the 11.1 T horizontal MRI is the largest field strength magnet in the world with a 400 mm bore; the 600 MHz 1-mm HTS cryoprobe is the most mass-sensitive NMR probe in the world and is ideal for natural products; the 3 T human whole body has 32 channels for rapid parallel imaging and is the only whole body instrument in the state of Florida dedicated to research. These systems support a broad range of users from natural product identification to solid-state membrane protein NMR to cardiac studies in animals and humans to tracking stem cells and gene therapy *in vivo* to functional MRI in humans.

Facility Developments

With funding from an NIH shared instrumentation grant and the Magnet Lab, in 2011 we were able to purchase new consoles and gradients for our two oldest

instruments, the 500 MHz solution/solid state NMR and 600 MHz solution/solid state NMR and MRI spectrometers. This equipment is scheduled for installation in early 2012 and will replace 12-15 year old RF technology; with this upgrade we will have replaced all the consoles that were installed in the AMRIS facility when it opened in 1998. The new consoles will allow us to capitalize on state-of-the-art digital technology for pulse sequence generation and data acquisition and to offer stronger gradients for diffusion sensitive measurements and MR microscopy.

In May of 2011 we said farewell to **Barbara Beck**, who had overseen RF coil development and testing within the AM-

RIS facility since its inception. After her retirement from AMRIS, Barbara finds she is able to spend much more of her time in area schools helping with STEM activities and is very much enjoying this next phase of her life. In January of 2012, **Malathy Elumalai** joined us as head of RF coil development and testing after spending over two years at the NMR-MRI user facility in Tallahassee developing coils for the UWB 900.

Three of the technology cores funded by the Magnet Lab, in HTS probe technology, microimaging, cell and molecular imaging are now leveraged with NIH individual investigator grants. A next generation 1.5 mm HTS probe for natural

NMR & MRI Systems at the AMRIS Facility at UF

¹ H Frequency	Field (T)	Bore (mm)	Homogeneity	Measurements
750 MHz	17.6	89	1 ppb	Solution/Solid State NMR & MRI
600 MHz	14	52	1 ppb	Solution/Solid State NMR & MRI
600 MHz	14	52	1 ppb	1-mm HTS Cryoprobe
600 MHz	14	54	1 ppb	5-mm Cryoprobe
500 MHz	11.7	52	1 ppb	Solution/Solid State NMR
470 MHz	11.1	400 ¹	0.1 ppm	MRI and NMR of animals
200 MHz	4.7	330	0.1 ppm	MRI and NMR of animals
130 MHz	3	900 ²	0.1 ppm	Whole body MRI and NMR of humans and large animals

¹ 290 mm useable bore

² 600 mm useable bore

products and metabolomics optimized for both ^1H and ^{13}C detection, developed by **Art Edison** and **Bill Brey** in collaboration with Agilent, Inc., is in final testing and will become available to users in 2012. This probe will be installed on the 600 MHz NMR spectrometer which was added to the AMRIS user facility in fall 2010. New microimaging coils ranging in size from 50-100 μm , developed by **Steve Blackband** in collaboration with Bruker Biospin, Inc., have also been added for ultra high resolution microimaging. NIH funding is allowing him to further develop this technology for microimaging of live tissue slices. **Glenn Walter** has developed a number of genetic and molecular MRI probes that are used to look at cell function and fate in bone marrow, muscle, tumors, brain, and in the heart. In addition, all three cores have provided user training and outreach through workshops partially funded by the Magnet Lab.

Finally, through generous support of human imaging initiatives by the UF McKnight Brain Institute, the 3T / 90 cm imaging system was upgraded to 32 receive channels in early 2011 and two 32-channel coils, for cardiac and fMRI studies, were installed. **Joy Kidder**, our former radiology tech for the 3T, retired and **Tammy Nicholson** joined our staff as her replacement. Tammy comes with over 15 years of experience in clinical MRI. Through UF support of the human imaging initiative, we are currently recruiting for a faculty position to spearhead the human MRI research program.

Facility Plans

In spite of the challenging budgetary

climate, our users have consistently successfully pursued federal funding to support their research programs and assisted the AMRIS facility in writing proposals to upgrade instrumentation. The successful partnership of the Magnet Lab user program with individual investigator research grants also provides constant scientific motivation for our continued technology development, particularly for the three technology cores of the NHMFL in multimodal nanoparticles specifically designed for use at high magnetic fields, microimaging, and high sensitivity NMR.

As part of the Magnet Lab's renewal proposal that was submitted in August, 2011, we have developed a new Dynamic Nuclear Polarization (DNP) initiative in collaboration with the EMR and NMR-MRI user programs in Tallahassee. While NMR and MRI are unique in their ability to non-perturbatively provide element-, site- and space-specific information, their uses are limited by the fact that overall nuclear polarization remains very small even at the highest magnetic fields available today. DNP is a technique that seeks to overcome this limitation by transferring to nuclei the much higher polarizations of electrons, via irradiation at the latter's Larmor frequency. When implemented at cryogenic temperatures and high fields, DNP can lead to $\geq 10,000\times$ increases in the nuclear polarization and NMR signal. The polarized sample can then be rapidly melted and injected into animals for *in vivo* imaging and spectroscopy of metabolites, a technique known as dissolution DNP. We are undertaking the construction of a dissolution-based DNP polarizer for solution and *in vivo* NMR

and MRI applications in order to provide users with a reliable technology to measure metabolism in living cells or animals.

Science Productivity

The AMRIS facility users reported 37 peer-reviewed publications and 11 theses for 2011. Some of the notable research highlights from 2011 include:

- Mitra, R.N.; Doshi, M.; Zhang, X.L.; Tyus, J.C.; Bengtsson, N.; Fletcher, S.; Page, B.D.G.; Turkson, J.; Gesquiere, A.J.; Gunning, P.T.; Walter, G.A.; Santra, S., *An activatable multimodal/multifunctional nanoprobe for direct imaging of intracellular drug delivery*, *Biomaterials* **33**(5), 1500-1508 (2012)
- Tallury, P.; Santra, S.; Sharma, P.; Matos, B.M.D.; Bengtsson, N.; Biswas, S.; Saha, A.K.; Walter, G.A.; Scott, E.A.; Moudgil, B.M., *Fluorescent and paramagnetic chito-san nanoparticles that exhibit high magnetic resonance relaxivity: synthesis, characterization and in vitro studies*, *Journal of Biomedical Nanotechnology* **7**(5), 724-729 (2011)
- Bengtsson, N.E.; Kim, S.; Lin, L.; Walter, G.A.; Scott, E.W., *Ultra-high-field MRI real-time imaging of HSC engraftment of the bone marrow niche*, *Leukemia* **25**(8), 1223-1231 (2011)

Multifunctional nanoparticles integrating imaging modalities (such as magnetic resonance and optical) and therapeutic drugs are promising candidates for future cancer diagnostics and therapy. While targeted drug delivery and imaging of tumor cells have been the major focus in engineering nanoparticle

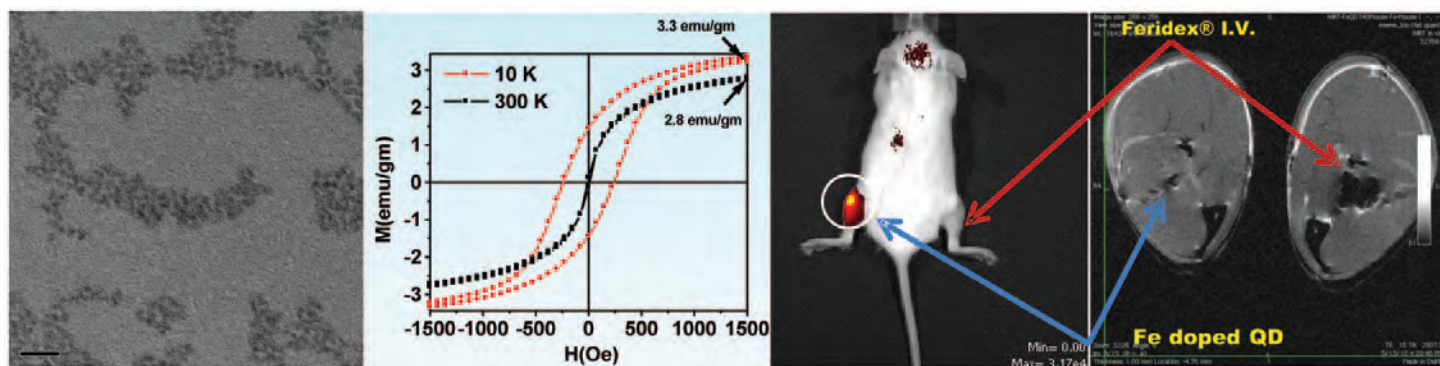


FIGURE 13. (Left) High resolution TEM of Fe doped CdTeS Q Dots (Middle) Magnetization loop measurements using a SQUID. (Right) NIR Optical and MR Imaging of cells labeled with Fe-CdTeS.

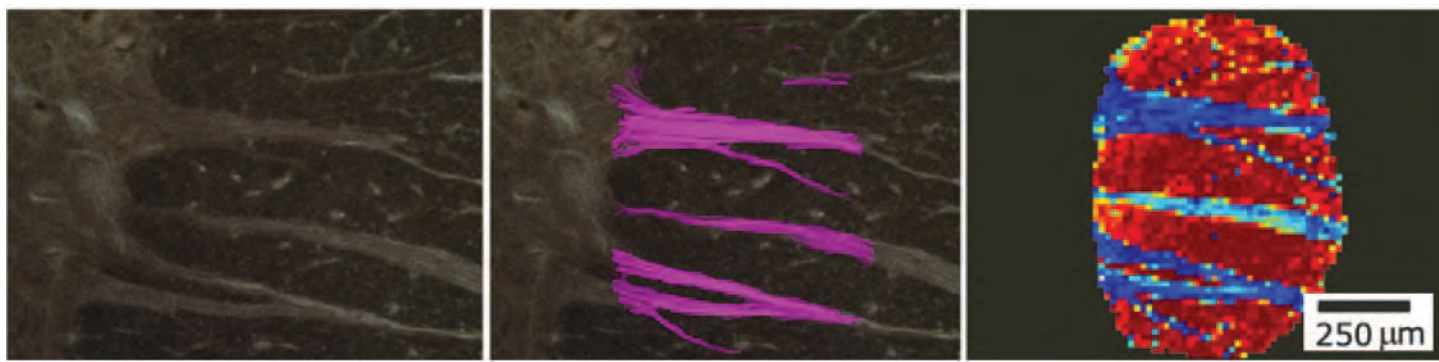


FIGURE 14. Comparison of Black-Gold II stained histology (**Left**) and a corresponding superimposed tractography overlay (**Middle**). Black-Gold II stain exhibits specific binding to myelin structures. (**Right**) Variation in the component of the primary eigenvector orthogonal to the image plane (through-plane). Blue colors represent the smaller components while warmer colors represent the larger. This component of the primary eigenvector is seen to reflect tissue structure closely.

probes, no extensive efforts have been made towards developing sensing probes that can confirm and monitor intracellular drug release events. Development of multimodal/multifunctional nanocomposite probes that are optically and magnetically imageable, targetable and capable of reporting on intracellular drug release events have been demonstrated using several platforms within the AMRIS facility. (See **Figure 13**.)

- Hansen, B.; Flint, J.J.; Heon-Lee, C.; Fey, M.; Vincent, F.; King, M.A.; Vestergaard-Poulsen, P.; Blackband, S.J., *Diffusion tensor microscopy in human nervous tissue with quantitative correlation based on direct histological comparison*, *Neuroimage*, 57(4), 1458-1465 (2011)
- Vestergaard-Poulsen, P.; Wegener, G.; Hansen, B.; Bjarkam, C.R.; Blackband, S.J.; Nielsen, N.C.; Jespersen, S.N., *Diffusion-weighted MRI and quantitative biophysical modeling of hippocampal neurite loss in chronic stress*, *PLOS ONE* 6(7) e20653(2011)

Diffusion tensor tractography (DTT) is regularly employed as a means of delineating white-matter tracts. While successful efforts have been made to validate tractographic predictions, comparative methods which would permit the validation of such predictions at microscopic resolutions in complex biological tissues have remained elusive. Using newly developed micro-surface coils, planar gradients and an improved slice preparation technique for correlative histology, improved quantitative analysis methods

can be used to determine the accuracy of DTT through comparative histology and to apply these techniques for the first time to human tissue (spinal cord) samples. In our experiments, we find that on average 89% of imaging pixels predicted by DTT to contain in-plane white-matter tract structure correspond to physical tracts identified by histology. In addition, angular analysis comparing the orientation of fiber tracts measured in histology to their corresponding in-plane primary eigenvector components is possible. This robust agreement between imaging datasets taken at microscopic resolution confirm the primary eigenvector's role measured by DTT as a fundamental parameter with clear physical correlates in the microscopic regime. (See **Figure 14**.)

Progress on STEM and Building the User Community

The AMRIS facility received proposals from **7 new user principal investigators in 2011**, and all received magnet time in 2011.

Art Edison, professor and director of NHMFL Chemistry & Biology, travels to underrepresented colleges and universities as part of the Magnet Lab's CO-WIN program. In 2011 he visited Claflin University in South Carolina to give a series of lectures and a lab on introductory NMR to undergraduate chemistry students. Three Claflin students, all underrepresented minorities, spent the summer doing metabolomics research in Dr. Edison's lab. The students have taken the projects back to Claflin, where they are all pursuing the

studies with a new assistant professor at Claflin, **Dr. Arezue Boroujerdi**, who is an expert in metabolomics. Dr. Edison has collaborated on an NSF proposal with Claflin so that they could obtain a cryoprobe and sample changer, and he has also provided support for a new biofuels initiative that they have submitted to the NSF.

Electron Magnetic Resonance Facility

2011 statistics on EMR Facility users, proposals, and magnet usage are presented in Appendix A.

The Electron Magnetic Resonance (EMR) facilities at the Magnet lab offer users several home built, high field and high frequency instruments providing continuous frequency coverage from 10 GHz to ~1 THz, with additional frequencies available up to 2.5 THz using a molecular gas laser. Several transmission probes are available for continuous-wave (c.w.) measurements, which are compatible with a range of magnets at the lab, including the highest field 45 T hybrid magnet. Some of the probes can be configured with resonant cavities, providing enhanced sensitivity as well as options for *in situ* rotation of samples in the magnetic field. Quasi-optical (QO) reflection spectrometers are also available in combination with dedicated high-resolution 12/17 T superconducting magnet systems; a simple QO spectrometer has also been developed for use in the resistive magnets (up to 45 T).

In addition to c.w. capabilities, the EMR group boasts the highest frequency pulsed EPR spectrometer in the world, operating at 120, 240 and 336 GHz with 100 ns time resolution. A commercial Bruker Elexsys 680 operating at 95 GHz is available upon request. In the general science building, two superconducting magnets currently serve three spectrometers, as presented in the table below. EMR staff members also assist users in the DC facility using broadband tunable homodyne and heterodyne spectrometers. The combination of instruments may be used for a large range of applications, including the study of optical conductivity, cyclotron resonance, paramagnetic impurities, molecular clusters, antiferromagnetic and ferromagnetic compounds and thin films, optically excited paramagnetic states, radicals, catalysts, model complexes and other biologically relevant species, etc.

New in 2011: EMR instruments/capabilities/personnel Bio Lab

A newly renovated wet biochemistry lab supporting biological EPR user operations is located at the C-wing of the Magnet Lab, in close proximity to the EMR facilities' spectrometers. The laboratory has approximately 300 square feet of space that can accommodate 3 to 5 users and students. The laboratory has a fume hood, a chromatography refrigerator and freezers (-20 and -80 °C). The laboratory is equipped for a range of biochemical sample preparation, purification, and analysis, including an UV-Vis spectrophotometer, centrifuges, incubators, etc.

Frequency domain magnetic resonance spectrometer (FDMRS)

The new spectrometer consists of a variety of tunable backward wave

EMR Systems at the Magnet Lab in Tallahassee

Spectrometer	Frequency (GHz)	Field range (T)	c.w. - EPR	Pulsed	Time Resolved	ENDOR	Rotation	Absolute Sensitivity ¹ at 290 K (spins/mT)	Concentration Sensitivity at 290 K (spins/cm ³ mT)	Max. sample size (μl)
Transmission	23-660	0-17	✓					10 ¹³	5x10 ¹³	200
Homodyne QO	190-670	0-17	✓			✓		5x10 ¹¹	2x10 ¹³	10
Heterodyne QO & Transmission	120, 240, 336	0-12.5	✓	✓	✓	✓	✓	10 ⁹ (in cavity) 2x10 ¹¹	5x10 ¹³ 2x10 ¹²	0.1 100
DC Field ² QO & Transmission	50-900	0-45	✓		✓		✓	10 ⁹ (in cavity) 10 ¹³	5x10 ¹³	200
Bruker W-band	95	0-6	✓	✓		✓	✓	5x10 ⁹	10 ¹²	0.4

¹ The Absolute sensitivity is the minimum number of detectable spins per mT linewidth and a 1Hz bandwidth at room temperature.

² In combination with a far-infrared laser, select frequencies up to 2500 GHz are available.

oscillators (BWOs) operating in the frequency range of 50 GHz to 1.2 THz. The frequency is controlled through applying variable voltage via a computer interface. The same interface collects the voltage from the Golay cell detector. The arrangement of the spectrometer is an optical one, i.e. involving a propagation of the sub-THz or THz beam through open space. The beam is focused on the sample and then directed to the detector through high-density polyethylene lenses. The signal is detected as the difference of transmission through the disk-shaped solid sample (pellet), and through the empty cryostat. The sample is typically cooled to below the LHe lambda point, although can be also measured above LHe boiling point. The first experimental results obtained with this spectrometer have been published: J. Krzystek; D. Smirnov; C. Schlegel; J. van Slageren; J. Telser; A. Ozarowski, *J. Magn. Reson.*, **213**, 158-165 (2011).

Vector Magnet System for high-pressure EPR studies

A superconducting vector magnet was delivered to the Hill lab in 2011. This magnet consists of three orthogonal superconducting split-solenoids that can be driven independently, thus enabling full field rotation about two axes relative to the sample under investigation, and without any mechanical adjustments to the setup. This magnet is thus ideally suited to cavity-based studies, particularly those involving the application of high pressures that were described in last year's annual report. We expect this capability to have a major impact on experiments during the coming years. Development of new probes for performing EPR measurements under pressure has very recently been completed and we report the first results further below. It should be noted that the ability to rotate the applied field is absolutely critical to the recently developed single-crystal high-pressure EPR capability. This has been possible about a single-axis up to this point. The ability to rotate about two axes will be truly transformational.

THz-to-IR Workshop

Stephen Hill organized an NSF-

funded workshop in Washington, D.C., in April 2011, entitled Applications of Terahertz to Infrared Probes in Molecular and Materials Sciences. This workshop was attended by about 30 leading scientists from many fields of research (materials science, condensed matter physics, chemistry and biology), from across the United States and abroad (from universities, national and government labs). The meeting was also well attended by officials from the National Science Foundation. A detailed report on the workshop will be submitted to the NSF later this year.

Schuler Postdoctoral Fellow

Christopher Beedle (PhD from UC San Diego, 2010) joined the EMR group in 2011. His position is funded through the Schuler Fellowship Postdoctoral Program, named in honor of Mr. and Mrs. John N. Schuler of Longboat Key, Florida, who have given generously to Florida State University. Beedle has devoted considerable effort to EMR user support activities during 2011 and will remain with the group in 2012.

Plans for 2012

Magnetism School

A workshop has been organized for April 2012 (23rd to 26th), focusing on experimental studies of magnetostructural correlations in magnetic materials. This is a topic that is of major interest to many of the users of the EMR facility and the subject of many publications from the EMR group. The workshop is aimed primarily at students and postdocs. Indeed, with the exception of a few tutorial talks on EPR theory, all other presentations will be given by students and postdocs. The tutorial talks are intended to provide our users with a better understanding of the kind of information that is obtained from an EPR experiment performed here at the Magnet Lab. The workshop is partially supported by a separate NSF award focusing on the development of instrumentation for performing EPR at high pressures. We are expecting around 30 participants from various locations: Canada, France, England, Scotland, as well as from various locations around the United States.

HiPER

Construction of HiPER (see 2010 annual reports) remains on schedule, and we anticipate delivery and installation in the fall of 2012. After a period of commissioning and testing, we anticipate user operations to start in mid-2013.

Humboldt Postdoctoral Fellow

Komalavalli Thirunavukkuarasu

will join the EMR group in May 2012, supported by a prestigious Feodor Lynen fellowship from the German Alexander von Humboldt Foundation. Thirunavukkuarasu received this award on the basis of a proposal focused on using the high-pressure EPR facilities developed at the Magnet Lab to study problems in magnetism and correlated electron physics.

Science Productivity

In 2011 a large number of research groups and projects were accommodated by the EMR group, resulting in the submission of 48 research reports, up from 38 in 2010. In addition, 36 peer-reviewed journal articles were reported by our users, as well as numerous presentations at conferences. Many publications appeared in high-impact journals including: *Nature* and *Nature Structural Biology*; *Angewandte Chemie*; 2 in the *Proceedings of the National Academy of Sciences*; 2 in *Physical Review Letters*; 2 in the *Journal of the American Chemical Society*; 2 in *Chemical Communications*; 3 in *Physical Review B*; 3 in *Inorganic Chemistry*; and 1 in *Dalton Transactions in Chemistry*. Projects spanned a range of disciplines from applied materials research to studies of proteins. A few examples are given here.

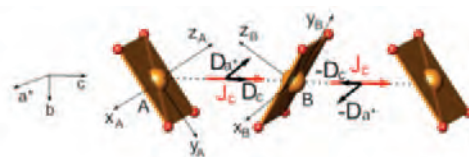


FIGURE 15. Linear-chain crystal structure in CuSe_2O_5 . Local coordinates of the staggered g tensor, the staggered DM vector $\mathbf{D}=(D_{ax}, 0, D_c)$, and the axis of the symmetric anisotropic exchange J_c .

- **Exchange anisotropies revealed by ESR**
M. Herak (Ljubljana/Zagreb), **A. Zorko** (Ljubljana), **D. Arčon** (Ljubljana), **A. Potočnik** (Ljubljana), **M. Klanjšek** (Ljubljana), **J. van Tol** (NHMFL), **A. Ozarowski** (NHMFL), and **H. Berger** (Lausanne)

The ground state of quasi-1D spin $S = 1/2$ systems is extremely sensitive to the presence of symmetric and/or anti-symmetric anisotropic exchange [Dzyaloshinskii-Moriya (DM) interaction]. Effects on the EPR spectra of these anisotropies along with the staggered g tensor of 1D spin-1/2 systems were studied by Oshikawa and Affleck

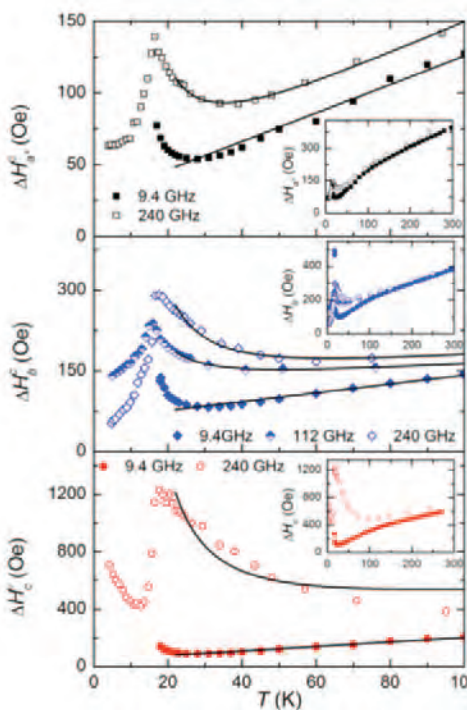


FIGURE 16. T-dependence of the ESR linewidth fits to results of the OA theory.

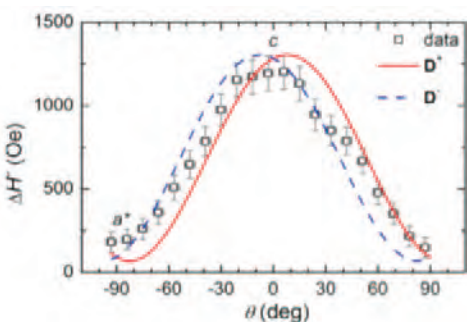


FIGURE 17. Angular dependence of ESR linewidth at 5 K. Solid lines are fits to the OA theory.

(OA). We use their theory to explain the ESR results on CuSe_2O_5 , a quasi-1D spin-1/2 system with intrachain interaction $J = 160$ K, in which the staggered g tensor and the DM interaction are allowed by symmetry (**Figure 15**).

Electron spin resonance (ESR) presents one of the most powerful techniques for studying such systems since the presence of anisotropies is reflected in the linewidth of the measured spectra, which are also affected by the staggered field and DM interaction (see **Figure 16**). For these reasons, performing the high-field measurements at the Magnet Lab was crucial for this project. Combining the ESR results with the OA theory, we discovered that both the symmetric and antisymmetric (DM) anisotropic exchange interactions are present in CuSe_2O_5 , with $J_c = 0.04J$ and the DM vector $\mathbf{D} = (-0.044, 0, \pm 0.0255)J$ (**Figures 16 and 17**).

Facilities: 12.5 and 17 T magnets.

Acknowledgements: Slovene Human Resources Development and Scholarship fund (11013-57/2010-5), Croatian Science Foundation (O-191-2011), Croatian Ministry of Science, Education and Sports (035-0352843-2846). Slovenian Research Agency (J1-2118 and BI-US/09-12-040)

M. Herak, A. Zorko, D. Arčon, A. Potočnik, M. Klanjšek, J. van Tol, A. Ozarowski, and H. Berger, *Symmetric and antisymmetric exchange anisotropies in quasi-one-dimensional CuSe_2O_5 as revealed by ESR*, *Physical Review B* **84**, 184436 (2011).

Related publication: A. Zorko, M. Pregelj, A. Potočnik, J. van Tol, A. Ozarowski, V. Simonet, P. Lejay, S. Petit, R. Ballou, *Role of Antisymmetric Exchange in Selecting Magnetic Chirality in $\text{Ba}_3\text{NbFe}_3\text{Si}_2\text{O}_{14}$* , *Phys. Rev. Lett.* **107**, 257203 (2011).

- **Decoherence in Crystals of Quantum Molecular Magnets**

Susumu Takahashi (University of Southern California), **Igor S. Tupitsyn** (University of British Columbia), **Johan van Tol** (NHMFL), **Christopher C. Beedle** (NHMFL), **David N. Hendrickson** (University of California

at San Diego), and **Philip C. E. Stamp** (University of British Columbia)

Quantum decoherence is a central concept in physics; for applications such as quantum information processing, it represents a crucial parameter. In systems like molecular magnets, the decoherence is dominated by environmental processes due to phonons, nuclear spins, and from intermolecular dipolar interactions. Pulsed EPR measurements at 240 GHz and high magnetic field at the Magnet Lab show a strong dependence of the decoherence as a function of the temperature and field, which allows a direct comparison with theory. In this way, one can quantify the environmental contributions to the decoherence times. A very good agreement of the experimental results with theory is obtained, and it is found that, in this temperature range, the decoherence is dominated by phonons and dipolar interactions. The results suggest that by optimizing the magnetic field and temperature, decoherence times in the range of 50-500 μs can be achieved, depending on the isotopic composition. (See **Figure 18**.) This work is published in *Nature* [S. Takahashi, I. S. Tupitsyn, J. van Tol, C. C. Beedle, D. N. Hendrickson, and P. C. E. Stamp, *Decoherence in Crystals of Quantum Molecular Magnets*, *Nature* **476**, 76 (2011)].

- **Single-crystal EPR studies of pressure-induced orbital reorientations in a $\text{CuF}_2(\text{H}_2\text{O})_2(\text{pyz})$ magnetic framework material**

Powder Xray measurements of the magnetic framework material, $\text{CuF}_2(\text{H}_2\text{O})_2(\text{pyz})$ (pyz = pyrazine), have revealed a sequential reorientation of the elongated Jahn-Teller axis from the N—Cu—N (<9 kbar), to the O—Cu—O (9–31 kbar), to the F—Cu—F bonds (>31 kbar; see lower right panel in **Figure 19** below). This orbital reordering leads to a drastic change in the magnetic properties whereby the magnetic structure changes from two-dimensional to one-dimensional above 9 kbar. The aim of the work reported here was to verify the above findings using a technique that is sensitive to the magnetoanisotropy of the sample, which should follow the reorientation of the Jahn-Teller elongation. A Cu^{II}

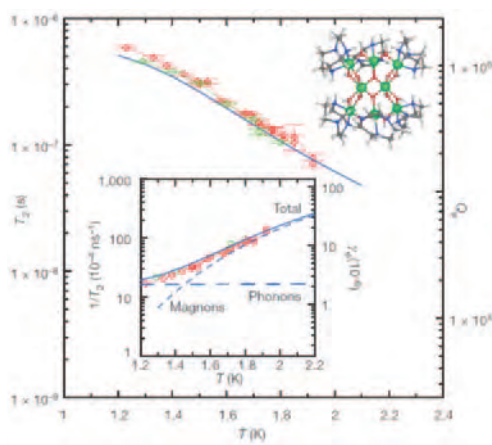


FIGURE 18. Measured and calculated decoherence times T_2 in an Fe_8 single crystal with the magnetic field along the y -direction of the zero-fields splitting tensor. [Adapted from *Nature* **476**, 79 (2011)]

system also represents the ideal system with which to test the high-pressure EPR technique due (i) to its $S = \frac{1}{2}$ spin which typically gives rise to sharp EPR peaks, and (ii) to the significant anisotropy of its spectrum, which makes it easy to discriminate the signal coming from the crystal from those of other paramagnetic species in the pressure cell.

Angle-dependent EPR spectra were recorded for a single-crystal sample at three different pressures (measured *in situ* from ruby fluorescence at low temperatures), as shown in the top panel of **Figure 19**. At pressures below the transition from phase I to II (see lower right figure), a single sharp, symmetric peak is observed, with a g -anisotropy that is typical for Cu^{II} , in agreement with ambient pressure measurements; the maximum $g \sim 2.42$ corresponds to the parallel component ($//a$), while the minimum g (~ 2.08) corresponds to the perpendicular component ($//bc$). As the pressure is increased to 18 kbar, a 2nd broader peak emerges at the location perpendicular g -component (~ 2.25 T). This peak exhibits very little angle-dependence. At the highest pressure, all of the EPR intensity transfers to the weakly angle-dependent peak, suggesting that the Jahn-Teller axis that defines the axial direction has fully re-oriented to a direction perpendicular to the field rotation plane, i.e., the c -axis. The lower left panel of **Figure 19** plots the angle-

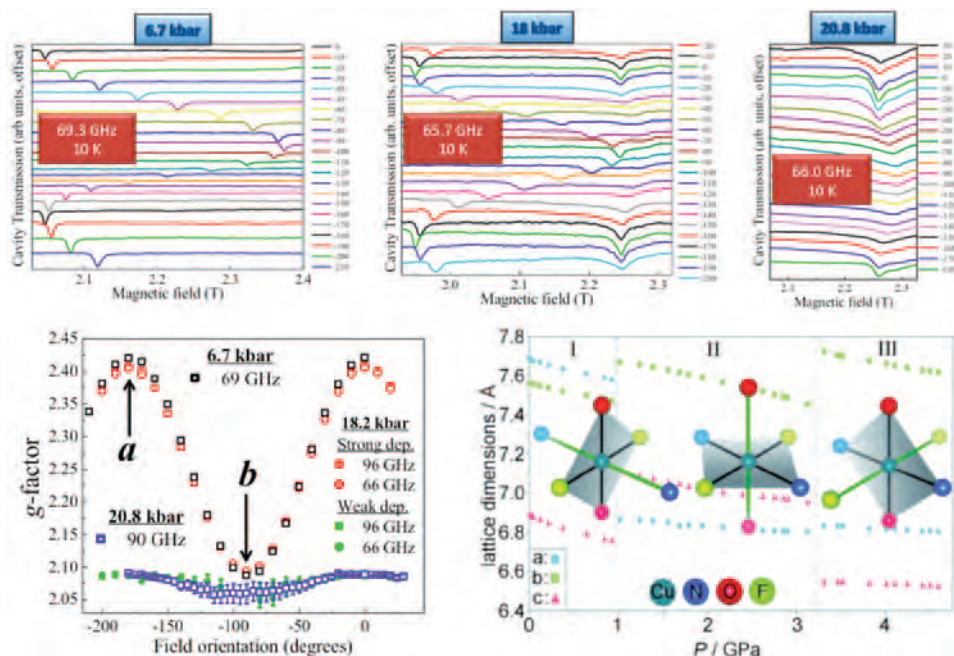


FIGURE 19. Top panel: Angle dependent spectra recorded at 10° intervals at three pressures. **Lower left panel:** Angle-dependence of the g -factors at the three different pressures. **Lower right panel:** Illustration of the coordination around the Cu^{II} ion in the three phases. [G.J. Halder, K.W. Chapman, J.A. Schlueter, J.L. Manson, *Angew. Chem. Int. Ed.* **49**, 419-421 (2010)].

dependence of the g -factors corresponding to the resonances observed at the three different pressures.

The high-pressure EPR studies are in full qualitative agreement with the conclusions of the powder X-ray studies in terms of the first transition between phases I and II. The only discrepancy is in the pressure at which the sample fully converts to phase II, which was found to be ~ 20 kbar in the present investigation, rather than the 9 kbar in the powder studies. These differences may be ascribable to several factors, including the different pressure mediums employed in the two studies, and the fact that crystals were studied in the present case. A paper describing this work has been submitted for publication.

Progress on STEM and Building the User Community

In 2011, the EMR group received **13 proposals from first time new PIs** out of a total of 40, i.e., 33% of our applications were from first time users, which is almost identical to 2010. 113 researchers visited the EMR facility in 2011, of which roughly a quarter were either female (15%) or minority (7%). In

an effort to attract new users, the EMR group continues to provide up to \$500 of financial support to first time visitors to the lab. In addition, members of the EMR group made aggressive efforts to advertise the facility at international workshops and conferences. These efforts included attending conferences outside of our own immediate research areas. The group also organizes several workshops and symposia and provided financial support in the form of student travel grants for the two main EPR conferences in the United States. We plan to continue this series of student workshops in the coming years as a means of outreach to the international EPR community. Finally, the EMR group has participated in several outreach activities, including the mentorship of summer REU students, RETs and local high-school interns.

Ion Cyclotron Resonance Facility

2011 statistics on ICR Facility users, proposals, and magnet usage are presented in Appendix A.

During 2011, the Fourier Transform Ion Cyclotron Resonance (ICR) Mass Spectrometry program continued instrument and technique development as well as pursuing novel applications of FT-ICR mass spectrometry. These methods are made available to external users through the NSF National High-Field FT-ICR Mass Spectrometry Facility. The facility features five staff scientists who support instrumentation, software, biological applications, petrochemical and environmental applications, and user services as well as a machinist, technician, and several rotating postdocs who are available to collaborate and/or assist with projects.

Facility Developments

An actively-shielded 14.5 T, 104 mm bore system offers the highest mass measurement accuracy (<300 parts-per-billion rms error) and highest combination of scan rate and mass resolving power available in the world (*Protein Sci.*, **19**, 703-715 (2010)). The spectrometer features electrospray, atmospheric pressure photoionization (APPI), atmospheric pressure chemical ionization sources (APCI); linear quadrupole trap for external ion storage, mass selection, and collisional dissociation (CAD); and automatic gain control (AGC) for accurate and precise control of charge delivered to the ICR cell. The combination of AGC and high magnetic field make sub-ppm mass accuracy routine without the need for an internal calibrant. Addition of new reagents enhances liquid chromatographic separation for intact proteins and increases the charge states of proteins

up to 78 kDa [*Anal. Chem.*, **82**, 7515-7519 (2010)]. Mass resolving power > 200,000 at m/z 400 is achieved at one scan per second, which is ideal for LC-MS [*Int. J. Mass Spectrom.*, **305**, 116-119 (2011)] and facilitates automated data reduction for H/D exchange experiments [*J. Am. Soc. Mass Spectrom.*, **21**, 550-558 (2010)]. Robotic sample handling allows unattended or remote operation. An additional pumping stage has been added to improve resolution of small molecules. Simultaneous infrared multiphoton (IRMPD) and electron capture dissociation (ECD) are under development.

The 9.4 T, 220 mm bore system offers a unique combination of mass resolving power ($m/\Delta m = 8,000,000$ at mass 9,000 Da) and dynamic range (>10,000:1), as well as high mass range, mass accuracy, dual-electrospray source for accurate internal mass calibration, efficient tandem mass spectrometry (as high as MS⁸), and long ion storage period. A redesign to the custom-built mass spectrometer coupled to the 9.4 T, 200 mm bore

superconducting magnet designed around custom vacuum chambers improved ion optical alignment, minimized distance from the external ion trap to magnetic field center and facilitates high conductance for effective differential pumping. [*J. Am. Soc. Mass Spectrom.* **22**, 1343-1351, (2011)]. The length of the transfer optics is 30% shorter than the prior system, for reduced time-of-flight mass discrimination and increased ion transmission and trapping efficiency at the ICR cell. The ICR cell, electrical vacuum feed-throughs, and cabling have been improved to reduce the detection circuit capacitance (and improve detection sensitivity) 2-fold. When combined with compositionally complex organic mixtures such as dissolved organic matter [*Anal. Chim. Acta*, **706**, 261-267 (2011)] and petroleum [*Int. J. Mass Spectrom.*, **300**, 149-157 (2011)], mass spectrometer performance improves significantly, because these mixtures are comprised of mass “splits” that are readily separated and identified by FT-ICR MS. The magnet is passively shielded to allow proper

ICR Systems at the Magnet Lab in Tallahassee

Field (T), Bore (mm)	Homogeneity	Measurements
14.5, 104	1 ppm	ESI, AP/LIAD-CI, APPI FT-ICR, Therospray Ionization, DART
9.4, 220	1 ppm	ESI, AP/LIAD-CI, APCI, APPI FT-ICR, Therospray, DART, DAPPI
9.4, 155	1 ppm	FD, LD FT-ICR
7, 155	1 ppm	EI, CI FT-ICR

function of all equipment and safety for users. The system features external mass selection prior to ion injection for further increase in dynamic range and rapid (~100 ms timescale) MS/MS [*Anal. Chem.*, **75**, 3256-3262 (2003)]. Available dissociation techniques include collision-induced (CID), infrared multiphoton-induced (IRMPD), and electron capture-induced (ECD). Development and design of an Atmospheric Pressure Laser-Induced Acoustic Desorption Chemical Ionization (AP/LIAD-CI) source enables facile and independent optimization of analyte desorption, ionization, and sampling events, and can be coupled to any mass analyzer with an atmospheric pressure interface [*Anal. Chem.*, **83**, 1616-1623 (2011)]. Baseline resolution for an intact 147.7 kDa monoclonal antibody set the current world record for unit mass resolution and facilitates future characterization of large biomolecules by FT-ICR MS. Adduct dissociation, optimization of detected total ion number, and optimization of ICR cell parameters resulted in long ICR transient lifetime (up to 20s) and resulted in magnitude-mode resolving power ~ 420,000 at m/z 593 for the 57+ charge state, the highest mass for which baseline unit mass resolution has been achieved [*Anal. Chem.*, **83**, 8391-8395 (2011)].

The 9.4 and 7 T actively shielded FT-ICR instruments are available for analysis of complex nonpolar mixtures and instrumentation development. The 9.4 T magnet is currently used for field desorption [*Anal. Chem.*, **80**, 7379-7382 (2008)] and for elemental cluster analysis. The 7 T magnet is optimized for volatile mixture analysis [*Rev. Sci. Instrum.*, **77**, 025102 (2006)] and can be used to develop ion optics and ICR ion traps. Samples are volatilized in a heated glass inlet system (at 200-300 °C) and externally ionized by an electron beam (0-100 eV, 0.1-10 μ A). The ions are collected in a linear multipole ion trap and injected into the FT-ICR cell. Mass resolving power ($m/\Delta m$) greater than 10^5 and mass accuracy within 1 ppm have been achieved with both systems.

Science Productivity

Automated broadband phase correction of FT-ICR data can in principle

produce and absorption-mode spectrum with mass resolving power as much as a factor of 2 higher than conventional magnitude-mode display, an improvement otherwise requiring a more expensive increase in magnetic field strength. We have developed and implemented a robust and rapid automated method to enable accurate broadband phase correction for all peaks in the mass spectrum and present experimental FT-ICR absorption-mode mass spectra with at least 40% higher resolving power, increased number of resolved peaks, and higher mass accuracy relative to magnitude mode spectra and produce more complete and more reliable elemental composition assignments for complex organic mixtures such as petroleum [*Anal. Chem.*, **82**, 8807-8812 (2010)]. Phase correction applied to complex petroleum fractions facilitates resolution and identification of ionic species that differ in mass by roughly the mass of an electron [*J. Mass Spectrom.*, **46**, 337-343 (2011)], and provides accurate elemental composition assignment to establish compositional boundaries for fossil hydrocarbons [*Energy Fuels*, **25**, 2174-2178 (2011)].

Implementation of an **electrically compensated** Fourier transform ion cyclotron resonance cell for the 9.4 T instrument enables separation and identification of isobaric species in complex natural organic petroleum mixtures, and preserves ion cloud coherences for longer transient duration by a factor of 2 [*Anal. Chem.*, **83**, 6907-6910 (2011)]. The improved performance of the compensated ICR cell provides more symmetric peak shape and better mass accuracy through tunable compensation electrodes, critical for optimal performance.

Investigation into observed nonlinear response at low excitation electric field magnitude due to Coulombic shielding reported an excitation voltage threshold that increases concurrent with the number of shielded ions, and determine that shielding results in reduced transient duration at low excitation voltage [*Int. J. Mass Spectrom.*, **301**, 220-223 (2011)]. Ion transfer efficiency through radiofrequency multipole ion guides used to transfer ions through strong magnetic field

gradients between source and analyzer regions of FT-ICR mass spectrometers results in reduced ion transfer efficiency. The analytical basis for ion resonance in radiofrequency multipole ion guides immersed in a strong magnetic field gradient compared to simulated ion trajectories determined that ion losses due to transient cyclotron resonance occur at cyclotron frequency equal to the multipole rf drive frequency divided by the multipole order [*J. Am. Soc. Mass Spectrom.* **22**, 591-601, (2011)].

The **Predator data station** is the first FT-ICR MS data station comprised solely of fast data acquisition hardware (PCI, PXI and PXI Express) that facilitates rapid data transfer speed, required for extended transient duration for complex petroleum samples, and can be implemented to any FT-ICR MS instrument [*Int. J. Mass Spectrom.*, **306**, 246-252 (2011)].

A novel **“walking” calibration equation** for complex petroleum mixtures divides the mass spectrum into dozens of adjoining segments and applies a separate calibration to each segment thereby eliminating systematic error with respect to m/z and increases the number of assigned peaks by as much as 25% while reducing the rms mass error by as much as 3-fold for significant improved confidence in the elemental composition assignment [*Anal. Chem.*, **83**, 1732-1736 (2011)].

Unit mass baseline resolution for an intact 148 kDa monoclonal antibody provided the current world record for unit mass resolution of an intact protein by FT-ICR MS [*Anal. Chem.*, **83**, 8391-8395 (2011)]. Dissociation of noncovalent adducts, optimization of detected total ion number, and optimization of ICR cell parameters to minimize space charge shifts, peak coalescence, and destructive ion cloud Coulombic interactions resulted in achieved magnitude-mode resolving power ~ 420,000 at m/z 2593 for the 57+ charge state, the highest mass for which baseline unit mass resolution has been achieved. Automated phase correction of time-domain FT-ICR signal [*Anal. Chem.*, **82**, 8807-8812 (2010)] yields a narrower mass spectral peak

width at half-maximum peak height an concomitant improvement (~80%) in resolving power for the absorption-mode spectrum (~530,000) relative to magnitude-mode spectrum (~290,000).

Development of novel ionization techniques such as Atmospheric Pressure Laser-Induced Acoustic Desorption Chemical Ionization (AP/LIAD-CI) decouples analyte desorption from subsequent ionization and enables rapid and independent optimization and generates analyte ions which are efficiently thermalized by collisions with atmospheric gases thereby reducing fragmentation. Novel ionization techniques that facilitate molecular characterization of intact biochar without sample preparation or pretreatment have been developed for characterization of natural organic matter unobtainable by conventional ionization techniques due to solubility limitations [*Anal. Chem.*, **83**, 1616-1623 (2011)].

Biomolecular sequence verification continues to be in high demand. Protein and oligonucleotide masses can be determined with ppm accuracy [*Rapid Comm. Mass Spectrom.*, **24**, 2386-2392 (2010)]. Molecules can be fragmented (by collisions, photons, or electron capture by multiply-charged positive ions) to yield sequence-specific products. Sites and nature of post-translational modification (e.g., glycosylation, phosphorylation, etc.) are readily determined [*J. Proteome Research*, **9**, 2098-2108 (2010)]. In-house software has been developed for rapid data analysis. We devised a method to distinguish N-terminal from C-terminal peptides by use of electron capture dissociation MS/MS [*Anal. Chem.*, **79**, 7596-7602 (2007)], as well as the first large-scale characterization of hundreds of membrane lipids from cell cultures [*Anal. Chem.*, **79**, 8423-8430 (2007)].

Tertiary and quaternary structure can also be probed. Automated **hydrogen/deuterium exchange** has been improved by depletion of heavy isotopes ($^{13}\text{C}/^{15}\text{N}$) for protein subunits of a complex can greatly simplify the mass spectra, increase the signal-to-noise ratio of depleted

fragment ions, and remove the ambiguity in assignment of m/z values to the correct isomeric peptides [*Anal. Chem.*, **82**, 3293-3299 (2010)]. Details of biomolecular conformation and surface contact between molecules in a noncovalent complex can be deduced. Solution-phase hydrogen/deuterium exchange monitored by FT-ICR MS applied to study structural dynamics and the calcium-induced conformational changes of the cardiac isoform of troponin [*Int. J. Mass Spectrom.*, **302**, 116-124 (2011)]. Fast exchange rates were observed for the N-terminal extension of Tnl, specific to the cardiac isoform. Results corroborate prior X-ray crystallography and NMR interpretations and illuminated previously unresolved domains.

On-line LC separation of lipids isolated from **brain cancer** improves identification of phospholipid and glycosphingolipid compositions required for lipid profiling studies in disease mechanism [*Int. J. Mass Spectrom.*, **305**, 116-119 (2011)]. Changes in gene and polar lipid expression due to chemotherapy treatment in glioblastoma cells exposed significant changes in sulfonated glycolipids (sulfatides) and indicated post-transcriptional control of sulfatide synthesis [*Glycoconj. J.*, **27**, 27-38 (2010)]. Differential phosphoprotein levels determined by reverse-phase nano-LC coupled to FT-ICR MS identified phosphoproteins involved in breast cancer signal transduction pathways [*Biochem. Biophys. Res. Commun.* **412**, 127-131 (2011)].

The 7, 9.4, and 14.5 T instruments are primed for immediate impact in **environmental, petrochemical, and forensic analysis**, where intractably complex mixtures are common. The field of "petroleomics" has been developed largely due to the unique ability of high-field FT-ICR mass spectrometry to resolve and identify all the components in petroleum samples. A comprehensive review article catalogues recent advances in mass spectrometry, comprehensive gas chromatography, and hybrid analytical platforms that have led to an explosion in molecular-level compositional

information for petroleum [*Anal. Chem.*, **83**, 4665-4687 (2011)]. Characterization of an unusual blue crude oil indicated an enhanced concentration of perylene, a polycyclic aromatic hydrocarbon known to fluoresce, was identified with various analytical techniques and confirmed with FT-ICR MS [*Energy Fuels*, **25**, 172-182 (2011)]. Further, fossil fuel samples can be analyzed and components resolved without chromatographic separation. Selective ionization of acidic crude oil components, such as naphthenic acids, by negative-ion electrospray ionization combined with tandem mass spectrometry (collision-induced dissociation (CID) and infrared multiphoton dissociation (IRMPD) provided detailed identification and structural characterization of acids isolated from naphthenate deposits [*Int. J. Mass Spectrom.*, **300**, 149-157 (2011)].

Biofuel characterization established the polar lipid profile of fatty acids, glycolipids, phospholipids, and betained lipids for *Nannochloropsis oculata*, a green algae highly prized for its oils suitable for biodiesel production. The first application of online liquid chromatography-mass spectrometry (LC-MS) characterization of algae polar lipids provides highly accurate mass measurement and resolves monoisotopic peaks from interfering components for unique determination of lipid elemental compositions [*Energy Fuels*, **25**, 4770-4775 (2011)].

Progress on STEM and Building the User Community

The ICR program had **15 new principal investigators in 2011**. The ICR program also enhanced its undergraduate research and outreach program for 3 female undergraduate scientists along with two female high school students. One high school student was selected as one of 40 finalists in the National Intel Science Talent Search, and presented her research from the ICR facility at the National Academy of Sciences in Washington, D.C. The ICR program in 2011 supported the attendance of scholar-scientists, postdoctoral associates, graduate, undergraduate and high school students at numerous national conferences to present current results.

Geochemistry Facility

2011 statistics on Geochemistry Facility users, proposals, and magnet usage are presented in Appendix A.

The geochemistry facility has six mass spectrometers of which four are available to outside users. One instrument is a multi collector thermal ionization instrument (Finnegan MAT 262/RPQ), which is used for measurements of isotopes of elements with low first ionization potential. The second instrument is a single collector inductively coupled plasma mass spectrometer (ICP-MS), ELEMENT, which is used for trace metal abundance determinations. A separate laser ablation system can be interfaced for *in-situ* trace element analyses on solid materials. The third instrument is a multi collector inductively coupled plasma mass spectrometer (NEPTUNE) used for determination of isotopic abundances of metals. The fourth instrument is a mass spectrometer designed for the measurement of the light stable isotopes (C, N O, S).

The facility is run with the support of external grants and in the last year individual principal investigators had funding from NSF (five divisions of the GEO directorate), NASA, NOAA, EPRI (Electrical Power Research Institute), as well as BP oil spill funding.

Facility Developments

Our 17 year-old thermal ionization mass spectrometer has become a niche instrument, and we will not report on it after this year. In October of this year the replacement for the 14 year-old ELEMENT1 ICP-MS (ELEMENT2) was installed. We switched our Argon supply to a large Dewar outside the Magnet Lab building, which saves us from maneuvering 200 lbs. dewars through the laboratory. We also filled the technical position for a Scientific Research Specialist to support the mass spectrometry facility.

Facility Plans

No plans exist for changing the instrumentation or laboratories.

Science Productivity

In 2011, we published 20 peer-reviewed publications and made 18 presentations at international meetings. In addition, three students defended their Ph.D.s, and two students received Master of Science degrees. We have broadened our funding with a NSF grant from the atmospheric sciences program. The new ICP-MS instrument is supported by three NSF programs: Chemical Oceanography, Marine Geology and Geophysics in Ocean Sciences, and Instrumentation and Facilities in Earth Sciences.

Science highlight: Carbon isotope analyses of fossil teeth performed in our laboratory by **Y. Wang** contributed to the conclusion that Pleistocene megafauna evolved at high altitude. Ice Age megafauna have long been known to be associated with global cooling during the Pleistocene, and their adaptations to cold environments, such as large body size, long hair, and snow-sweeping structures, are best exemplified by the woolly mammoths and woolly rhinos. These traits were assumed to have evolved as a response to the ice sheet expansion. Wang and co-workers discovered a new Pliocene mammal assemblage from a high-altitude basin in the western Himalayas, including a primitive woolly rhino. These new Tibetan fossils suggest that some megaherbivores first evolved in Tibet before the beginning of the Ice Age. The cold winters in high Tibet served as a habituation ground for the megaherbivores, which became pre-adapted for the Ice Age, successfully expanding to the Eurasian mammoth steppe.

Progress on STEM and Building the User Community

The facility is open to users of all disciplines, and we have a long-time collaboration with the USGS Volcano Monitoring Program. During the summer we hosted two undergraduate students from the REU program. We participated in the annual open house. As our facilities are mainly supported through external grants, external users have to be able to contribute to the cost of the lab use, but we continue to help people get preliminary data for use in proposals etc., free of charge. Also, training of new users on the instruments is done free of charge. This year saw again an increase in users from FSU's Chemistry and Biochemistry Department.

CHAPTER 4

Magnets & Materials

A central feature of the NHMFL's mission is the provision of unique high-performance magnet systems for our users that exploit the latest materials and magnet design developments. During 2011 the MagLab made significant progress on all fronts: delivering new resistive and pulsed magnets to the user community along with making significant development in new superconducting and resistive-superconducting hybrid magnet projects as well as completing promising new demonstrations of the potential for High-Temperature Superconducting materials and coils. As we move forward, the balance of development of new magnet systems with development of new technology to keep us at the forefront is of critical importance. Collaborations with other leading industrial, academic and government groups that develop these new magnet technologies are built into many of these thrusts. The most immediate impact to the user community in 2011 was the delivery of *a novel split resistive magnet that provides a world-record magnetic field (25 T vs. 18 T elsewhere) along with uniquely large mid-plane ports for scattering experiments!* Several scientists have now used the magnet to conduct experiments not possible elsewhere (see Chapter 3. The User Program, DC Field Facilities).

In the **pulsed magnet** facility at the Los Alamos branch, 2011 saw the

completion of an upgrade to the 100 T system that set a new record of 97.4 T in August and is routinely available to users at 94 T (see Chapter 3 for details). Further upgrades to 100 T are being considered; further information appears later in this chapter.

In late 2009 we received funding from the NSF's Major Research Instrumentation program to design and build an **all-superconducting magnet to provide 32 T** to the scientific community. While superconducting demonstration coils have been built that provide as

much as 34.6 T, the highest field available worldwide today in a user facility is 23.5 T in Lyon, France. Achieving a 36% increase in field for a superconducting user magnet requires development of numerous scalable technologies such as: uniformity of YBCO tape properties, ultrathin insulation systems, quench detection and protection algorithms, high-strength joints, reinforcement procedures, coil winding equipment, etc. 2011 saw tremendous progress on all of these fronts culminating with *testing of two separate small coils* that use one and



LEFT TO RIGHT Just some of the people that helped make the 25 T split magnet a reality: Kenny Braverman, Scott Gundlach, Scott Bole, John Farrell, Morgan Oliff, Michael Hicks, James Slade, Randy Helms, Russell Bonninghausen, Jim O'Reilly, Daniel G. McIntosh, Jingping Chen, Vince J. Toplosky, Richard Brooks, Jack Toth, Willie Nixon, Bryon Dalton, Edward Rubes, Vaughan Williams, Steven Carter, Mark Bird, Raymond Lewis, Kevin Gamble, Scott Hannahs, Chris Ray and Jimmy Payne.



ABOVE Users Jamie Munson of Eastern Washington University and John Schlueter of Argonne National Lab pose for a picture on top of the 100 T.

six double-pancakes, respectively. The coil size was chosen to be large enough to address full scale features of the 32 T coils, yet small enough to conserve conductor and fit the available test facilities. The coil construction includes winding mandrels, inside and outside crossovers, in-line joints, co-wound reinforcement, terminals, overbanding reinforcement and insulating spacers that are full featured components for 32 T. *The coils both contained protection heaters embedded in the spacers that separate the double-pancake modules. We believe this is the first time that a protection system compatible with a real user magnet system has been demonstrated in a YBCO coil.* We anticipate ordering the Nb-based outer coils and YBCO tape for the inner coils in early-2012 with the system operational in late 2013. This magnet will not only serve as a unique user facility at the NHMFL but will also serve as a stepping stone in the development of a 30 T NMR magnet as advocated by the Committee on Opportunities for High Magnetic Field Science (COHMAG) report (2005) which laid out ambitious 10 – 15 year goals for magnet technology.

The NHMFL is one of the world's leading institutions in the design and fabrication of magnets using **cable-in-conduit conductor** (CICC). Presently we

are constructing new hybrid magnets for the NHMFL and for the Helmholtz Center Berlin (HZB), Germany. The NHMFL magnet will be used for NMR experiments in addition to more traditional high field experiments, and the HZB magnet will be used for neutron-scattering experiments. *2011 brought many milestones, principally:* (1) the delivery of the last of the Nb₃Sn cable-in-conduit conductors (CICCs) required for the HZB and NHMFL magnets, (2) completion of winding of the model coils, (3) start of winding of the CICC coil for HZB, (4) delivery of the refrigerators for both the MagLab and HZB. The HZB system is expected to be complete in 2013 with the NHMFL system following in 2014.

Present magnet designs for pulsed, resistive, and superconducting systems are limited by either the critical current density, strength, stiffness, or fatigue life of the available **materials**. For many years we have been nurturing high temperature superconductors (HTS) as the route to a transformational magnet technology that is bringing superconducting magnets closer to the field limits that can be achieved by DC resistive technology. Cuprate HTS materials have been developed as conductors for electric utility use since the late 1980's, but it is only in the last 4-5 years that they have emerged

into viable consideration for making high field magnets that extend beyond Nb₃Sn. In 2009 we started, consistent with COHMAG's recommendation for greater inter-institutional collaboration in new magnet technologies, a new collaboration of 6 institutions, Very High Field Superconducting Magnet Collaboration (VHFSMC), jointly led from the NHMFL and Fermilab, to evaluate round wire Bi-2212 for high field superconducting magnets suitable for High Energy Physics applications. This work has demonstrated paths to much higher conductor critical current density and makes a good case for round wire Bi-2212 as a viable new HTS conductor technology for high field magnets.

Despite 2011 being the 50th anniversary of the discovery of Nb₃Sn as a high-field superconductor, the behavior of filamentary Nb₃Sn conductors particularly in the transposed, open-space environment of CICC conductors has needed detailed exploration, both for the series-connected hybrid and for the International Thermonuclear Experimental Reactor (ITER) magnet systems. Understanding the mechanical and cracking performance of filaments has been one facet of our work for ITER this year, as has been an understanding of the low temperature crystallographic state.

The vortex-pinning mechanisms that determine the upper limit to J_c , as well as the current-limiting mechanisms that degrade this limit, were studied for industrial YBa₂Cu₃O_{7-x} (or more generally their rare-earth variants REBCO) and Bi-2212 conductors at fields up to 31 T. The potential of the low anisotropy and still very high upper critical field (well over 50 T) ferropnictide superconductors remain under study as potential future conductors. Mechanisms affecting the strength and conductivity of high-strength copper alloys for resistive and pulsed magnets were discovered. Work studying the conductors needed to understand fatigue and embrittlement of stainless steels for the CICC magnets of ITER continued. Theories and experiments to understand the huge variability of superconducting RF cavity performance were developed.



FIGURE 1. World Record 25 T Split Magnet at full field during the first user experiment in June 2011.

Resistive Magnets & Materials

DC Magnets

A novel split magnet for photon scattering experiments at the Magnet Lab is operational! Fabrication and assembly of all system components was finished in May (under budget and on schedule) and the magnet was successfully charged to a *world record magnetic field* in June 2011. The magnet has been used successfully at the design field of 25 T (**Figure 1**), but routine operations will be limited to 22 T until spare coils are available. In addition to being the highest-field split magnet in the world, this magnet also has an unusually large scattering space consisting of four elliptical ports at the mid-plane which combined provide 0.5 steradians of solid angle for scattering! By choosing the location of the light source appropriately, any scattering angle can be studied!

The magnet consists of 4 coils electrically in series. The innermost coil consists, in turn, of two sub-coils electrically in parallel. In a split solenoid, the magnet must accommodate numerous conflicting constraints; over half the mid-plane must be devoted to vacuum space. The remainder must include (1)

sufficient structure to support ~500 tons of force between the two halves of the magnet, (2) sufficient conductor to carry 160 kA between the two halves, and (3) sufficient free space to carry 220 liters per second of cooling water. To address these constraints a new magnet technology, the Split Florida-Helix, has been developed and patented for use in this magnet and is employed at the mid-plane of the two innermost coils (**Figure 2**). Due to the high complexity of these parts, we were unable to identify an appropriate commercial supplier and developed in-house capability to perform 5-axis wire electro-discharge machining (EDM)

In order to minimize the overall cost, disks for the three outer coils are fabricated from a single sheet of copper (parts nested concentrically). However, discs for different coils used different manufacturing technology being performed by different vendors on different continents. The outermost *D*-coil discs have utilized existing stamping dies located in France. The *C*-coil was manufactured from the “drop” from the *D* via chemical etching in the

United States and finally the *B*-coil discs were manufactured in a U.S. stamping house. This logistic coupling provided a considerable challenge for the schedule which was only met by maintaining exceptionally active communications with the various vendors. Other important milestones included the successful pressure tests of the vacuum chamber (10e-6 torr) and hydro-testing the split magnet housing (40 bar) as well as completion of the 4 split Florida Helix parts (fabricated in house by new 5-axis wire EDM).

As of early 2012, the new 25T Split Magnet has been successfully used in various user experiments operation for over 1200 MWhrs. Currently, the Magnet Lab is building a spare set of the innermost, highly-stressed coils that should be complete in spring 2012. This magnet housing was built with a bearing allowing it to be operated either with the bore vertical or horizontal. In coming years a few pieces of peripheral equipment will be built to allow operation in either mode. We have also submitted a proposal to build another set of inner coils with a larger gap to allow a cryostat to be installed perpendicular to the bore so that samples can be rotated about an axis perpendicular to the field direction.

Due to the heavy workload associated with the split magnet, only 6 spare coils for the resistive solenoids were constructed in 2011, only 60% of that of typical years. In early 2012 we intend to catch up on construction of spare coils.

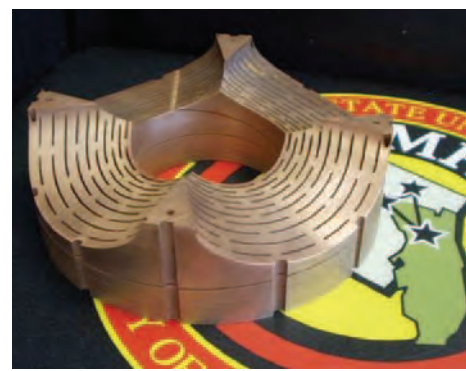


FIGURE 2. The Split Florida-Helix technology incorporates high-current-density conductor, cooling passages, bus bars, and structure in a very compact package to allow very high current-density coils to be located quite close to the vacuum space.

Pulsed Magnets

The NHMFL pulsed magnet group is responsible for development and operation of both generator-driven and capacitor-driven pulsed magnet systems. The mission is in direct response to the NSF charges to provide the highest fields for science, and to develop new materials and magnet technology.

Work in 2011 focused on: (1) enhancing generator-magnet operations and diagnostics to improve system reliability, (2) production and testing of the **Insert Magnet Upgrade to achieve a record field of 97.4 T in August with user operations at 95 T**, (3) production of user magnets for the NSF Pulsed Field Facility, and (4) the resumption of a pulsed magnet materials program via a summer school in Los Alamos.

Generator Magnet Operations and Diagnostics

The NHMFL Pulsed Field facility in Los Alamos has operated an 85 T science program since 2006. This science program is a long-term partnership jointly funded by the U.S. Department of Energy – Office of Basic Energy Science, and the National Science Foundation – Division of Materials Research. The division of responsibility has been that the DOE-BES program supports the science and that the NSF-NHMFL program supports the magnet operations and development. The 85 T science magnet held the world-record for maximum nondestructive pulsed magnetic field, 88.9 T, from October 2006 through June 2011. The magnet system still holds the record for continuous non-destructive pulsed operations above 85 T, at >257 pulses. The magnet system is a unique unmatched resource for high field scientific research.

Activities in year 2011 focused on the implementation of improved diagnostics in preparation for the introduction of the 10-mm Insert Upgrade. Diagnostics work focused on the systematic monitoring of coil resistances to ensure more reliable operations and improved prediction of insert magnet faults. Additional work included the development and implementation of an *in-situ* strain and vibration monitoring system on the outsert magnet. The new vibration



FIGURE 3. (Above left) Three-quarters section view of 10-mm insert upgrade magnet. **FIGURE 4. (Above right)** 10-mm insert upgrade magnet in final preparation.

diagnostic enhanced our understanding of the multi-coil mechanics during pulsed operations; and was successfully implemented with the 10-mm insert upgrade magnets.

Production and Testing of the Insert Magnet Upgrade

Construction of two upgraded insert magnets began in August of 2010. The upgraded inserts were completed in March and July 2011. (See **Figures 3 and 4.**)

A review examining the feasibility of extending the outsert magnet's field from 37 T to 42 T was completed to determine base-plateau fields for insert operations. The analysis factored in the 2008 coil upgrades to determine the risks associated with increasing outsert magnet field production to 42 T. We determined that 95 T operations were feasible with an outsert plateau field of 37 T, and that 39 T outsert fields were acceptable for operations between 95 T and 97 T.

Commissioning of the first insert upgrade was completed in August 2011. A world-record field of 97.4 T was achieved on August 19, 2011. Magnetic field measurements were made by detecting De Haas-van Alphen oscillations in poly-crystalline copper. (See **Figure 5.**) Scientific operations were approved at

pulsed fields up to 95 T. Seven separate physics experiments were completed above 92 T in 2011. Six separate scientific publications were in process of acceptance as of January 2012. 92 T – 95 T science operations are planned for 2012. The facility has spare insert upgrade magnets, and a spare 85 T capable insert to support the high field science program.

NSF User Magnet Production

The pulsed magnet group supports the operation of five scientific user stations and inserts for high-field operations up to 95 T. The 2011 work for the NSF Science Program entailed the delivery of three 65 T pulsed magnet assemblies and two insert upgrade magnets.

Pulsed Magnet Materials Program

The NHMFL Pulsed Field Facility conducted a summer-school focusing on high yield-strength, high-conductivity materials for pulsed magnet applications. The effort is intended to rejuvenate the research and development focus on materials for pulsed magnets. Such activities are critical to the long term development of pulsed magnet technology for the NSF Pulsed Magnet Program's future. The summer school students examined electro-mechanical

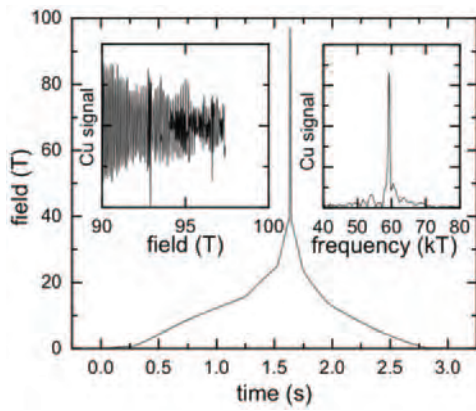


FIGURE 5. Waveform of 97.4 T record pulse achieved at NHMFL Pulsed Field Facility August 19, 2012.

properties of alumina dispersion hardened copper alloys Glidcop™, and silver alloys using equal-channel angular-extrusion processing methods. The school was attended by four students. Two students returned to work at LANL over the 2011 winter break. One student has taken a temporary internship studying materials science at Los Alamos before attending graduate school.

Planned Activities for 2012

Planned pulsed magnet group activities will focus on the following issues to improve the quality of magnets supporting science programs at the NHMFL-PFF: (1) insert magnet production and diagnostics to increase the frequency and reliability of 95T operations, (2) the delivery of duplex magnets for the NSF user program to attain 70 to 80 T operations with a capacitor bank, (3) the procurement of outsert magnet conductors and the industrial production of spare outsert coils, (4) the evaluation of new materials and conductors for future pulsed magnets, and (5) further development of *in-situ* magnet diagnostics compatible with pulsed fields.

High-Strength Materials

The high strength materials program plays an important role in building high field user magnets, particularly for new generation magnets. To provide users with the highest field possible and to ensure the safe and reliable performance of the high field magnets, it is necessary to develop

new high strength materials and establish a relationship among fabrication procedures, microstructure and properties of the magnet materials. This section reports our activities in characterization and development of high-strength normal conductors and structural materials for high field magnets. Some insulation-development activities are also included.

Conductors

Currently, for materials with electrical conductivity higher than 70% of the International Annealed Copper Standard (IACS), composite conductors achieve the highest strength. Cu-Nb and Cu-Ag composites are used in pulsed and DC resistive magnets, respectively.

The conductors are fabricated by cold rolling or drawing that introduces lattice distortions and high densities of interfaces in the material. During operations in magnets, the conductors are regularly exposed to temperatures higher than ambient, which may affect the characteristics of the lattice distortions and the interfaces and the mechanical properties of the conductors, such as the tensile and yield strength, as well as the electrical conductivity of the composites. Understanding the performance of the conductors after they are exposed to high-temperature heat-treatments helps one to make good use of them for magnets and to manufacture conductors to meet the requirements of the magnets, particularly when the magnetic stress reaches the limit of the mechanical strength of the conductors. This portion

of research uses the Cu16at%Ag sheet as a template to relate microstructural features to mechanical tensile strength and electrical conductivities after the composites are heat-treated at various temperatures. The examinations are undertaken both parallel and perpendicular to the rolling direction of the sheets.

The curves in **Figure 6** demonstrate that the heat treatment of the samples up to 300° C result in no change of the elastic properties of the materials. Within strains of 1.8 % or before the yield, the strain hardening rates, $d\sigma/d\varepsilon$'s, of all the samples are almost the same, where the σ and ε are the stress and strain, respectively. The dislocation activities control the $d\sigma/d\varepsilon$ of the materials. When materials have a strong ability to accumulate dislocations, the materials usually have high strain hardening rate. Therefore, the stress-strain curves of the materials in **Figure 7** indicate that the stress variations are not directly related to the activities of high densities of dislocations.

The accumulation of dislocations by deformation is an effective approach to make high yield-strength conductors because it introduces a limited increase in electrical resistivity. However, the storage of dislocations at room temperature is limited by recovery, i.e. dislocation/defect annihilation, and hence the strength reduces when the materials are thermally heat-treated at elevated temperatures. For instance, Cu was reported to recover at temperatures as low as 150° C and significant strength/hardness reductions occur at this temperature or higher for strain-hardened Cu. **Figure 7** shows that the compos-

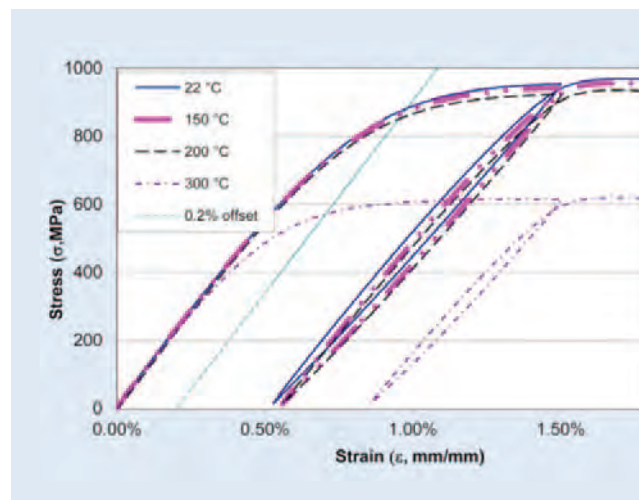


FIGURE 6.

A comparison of stress-strain curves of reduced cross-section samples heat treated at various temperatures (in Celsius, C). The thin straight dashed line is used to indicate and estimate the engineering yield stress (stress levels at 0.2% strain of offset).

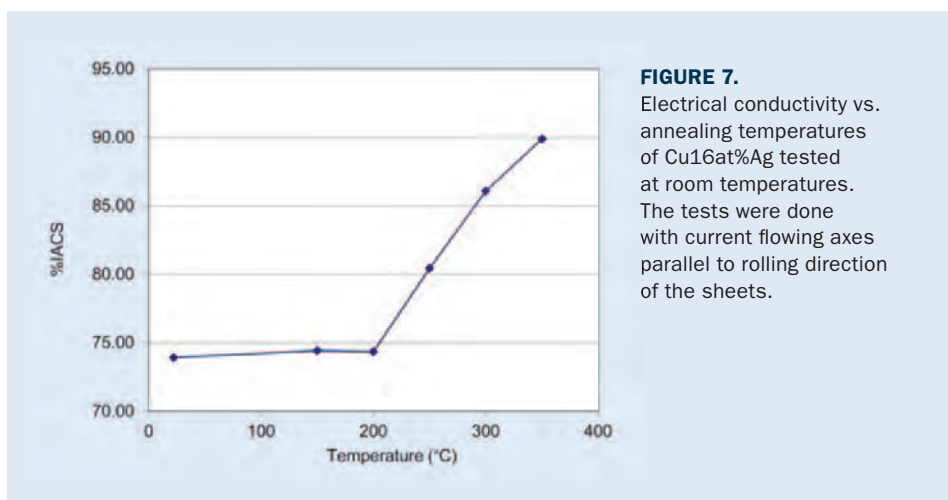


FIGURE 7.

Electrical conductivity vs. annealing temperatures of Cu16at%Ag tested at room temperatures. The tests were done with current flowing axes parallel to rolling direction of the sheets.

ite conductor starts to soften only marginally at about 150° C for samples tested in longitudinal directions. No softening can be detected in samples tested in transverse directions. Therefore, in Cu-Ag composite, dislocation /defect annihilation plays far less important role that in pure Cu.

The as-deformed samples give electrical conductivity slightly below 75 IACS%. **Figure 7** shows a relationship between the electrical conductivity and annealing temperatures. The electrical conductivity shows almost no change below 200° C, which starts to increase with annealing temperatures when temperatures reach 200° C or higher. At temperatures above 200° C, the rate of the conductivity increase with temperature appears to drop. A comparison of the CuAg composites annealed at different temperatures reveals a correlation among the microstructure and properties. The composites show anisotropy in both mechanical strength and electrical conductivities.

The major parameters in our material are the density of the interfaces in unit volume and lattice distortions because the dislocation density is relatively low and plays a relatively minor role. The shear bands that are related to lattice distortion in the materials can only be observed in transverse direction in the sheets but not in the cross-section perpendicular to rolling direction. The anisotropy of material properties can be related to the anisotropy of microstructure described by both the shear bands and texture. The property variations with temperature can be described by change of the micro-

structure parameters of the strengthening component. Increase of the annealing temperature up to 200° C results in no significant change of the microstructure that can be resolved by the scanning electron microscopy (SEM). When temperature reaches 250° C, local spheroidization can be observed. The composite can be divided into eutectoid and proeutectoid components. The major spheroidization occurs in Ag in proeutectic regions but it can also be found in eutectic regions. Increasing the temperature up to 350° C spheroidizes both components in more areas. (**Figure 8**) In some of the areas, complete circular Ag particles can be observed. At this stage, the strengthening effects via nanostructure are dramatically reduced, resulting in a reduction of mechanical strength to 500 MPa, that is close to the strength achievable by accumulation of dislocations in pure Cu. However, in samples examined after being heat treated at all the temperatures, the traces of shear bands can still be observed. Therefore, all samples before and after annealing with the temperatures prescribed in this report show higher tensile and yield strength but lower electrical resistivity in transverse directions than those in rolling direction, indicating the anisotropy in the materials even after the annealing.

GlidCop is another type of composite conductor composed of Cu and nanosized Al₂O₃ and being used for pulsed magnets. The conductors in pulsed magnets operate in the plastic deformation range in cyclic mode and fatigue properties have been addressed by fatigue tests in 2011, mainly for reaching 97 T in the LANL facility.

The fatigue life depends on the operation mode. If the operating conditions for the conductors in the magnets are stress-controlled, the designed stress values in magnets can be used directly as the stress levels for fatigue tests. Even if the magnets are operated in displacement-controlled mode, stress-controlled fatigue test data is a necessary step for further displacement-controlled tests. In 2011 we generated a large amount of data on GlidCop in stress-controlled mode suitable for pulsed magnets. The data are conservative with respect to magnet design because this load case is equivalent to no reinforcement material being present in the magnet system. Our magnet uses strong materials with high strength and elastic modulus as reinforcements that operate in their elastic ranges and the conductor is constrained by the reinforcement materials, resulting in an operating mode close to a displacement control mode. Later in 2011, we did cyclic tests using the displacement-controlled mode. The test results help us to estimate the maximum field and life achievable of our “100 T” pulsed magnet.

The other high strength normal conductors we have been working on are the electro-deposited Cu. We were able to reproduce the Cu with high density of twins with [111] texture, that is the twinning plane for the conductors, using electro-deposition. Similar electro-deposited Cu is currently used as stabilizer for ReBCO conductors for 32 T all-superconductor magnets and other magnets. The research in this area helps us to understand the performance of the Cu stabilizer in a timely manner.

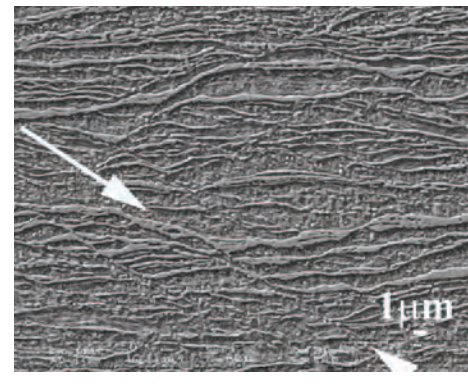


FIGURE 8. SEM transverse direction images of samples annealed at 350° C. Two arrows indicate the trace of a share band. Significant spheroidization can be observed in the image.

Structural Materials

The researchers at the Magnet Lab continue to make efforts in production of high strength MP35N strips for pulsed magnets. In 2011, about 10 coils of MP35N were heat treated at the NHMFL with reproducible quality, and large numbers of tests (usually at least eight samples are tested for each coil) were conducted at both room and cryogenic temperatures. MP35N (35wt%Co-35wt%Ni-20wt%Cr-10wt%Mo) is one of the reinforcement materials with high Young's modulus (>220 GPa). Traditionally, MP35N is described as a multiphase cobalt nickel alloy because some cobalt-nickel alloys are work-hardened by formation of the stress-induced hexagonal-close-packed (hcp) phase in platelets within a face-centered-cubic (fcc) matrix^{1,2}. However, other studies on the role of fcc to hcp transformation suggest that work hardening of the MP35N alloys is not due to the formation of the hcp phase, and for the alloys with Co:Ni ratios (wt%) less than 45:25, it was not possible to detect the stress-induced hcp phase by X-ray diffraction techniques³. Instead, the materials were considered to be strengthened by formation of deformation twins in the fcc matrix⁴.

Recently, it has been recognized by researchers at the NHMFL that deformation introduces mainly planar defects or stacking faults in the fcc matrix⁵ and we will continue to make efforts to understand this material in order to serve the users better. The cold-deformed MP35N multiphase alloys can be further hardened by aging or heat treatment. After the materials reach the maximum strength at a defined temperature range, additional aging time contributed no further increase of the strength. Most applications use the materials aged between 540° C to 600° C for four hours⁶. However, other sources reported that when swaged multiphase alloys were aged for more than four hours at 699° K, further increase of yield strength was able to be achieved⁷. Therefore the optimum aging temperature and time remain a topic of research and appear difficult to control. Therefore, the vendors usually supply the materials in cold-deformed form and the NHMFL develops the aging procedure, performs the heat treatment and conducts the mechanical tests for user pulsed magnets.

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HTS Magnets & Materials

So far, the low temperature superconductors Nb-Ti and Nb₃Sn have been used for virtually all superconducting magnets. Their maximum field, however, is limited by their upper critical fields (H_{c2}) of about 15 T for Nb-Ti and 30 T for Nb₃Sn, which limits their highest practical field to about 23.5 T. This limit is imposed by the rapid decrease in critical current density J_c as H_{c2} is approached.

The cuprate-based high temperature superconductor (RE)Ba₂Cu₃O_{7-x} (REBCO, RE = Rare Earth) has the capability to substantially transform the technology

of high field magnet systems. REBCO has an H_{c2} that exceeds 100 T at 4.2° K, removing the H_{c2} and J_c limit that restricts usage of Nb₃Sn in high-field magnet systems. REBCO conductors were initially developed for power transmission cables, but there is great interest nationally and internationally in the application of REBCO to high field magnets.

Powder-in-tube (PIT) processed Bi₂Sr₂CaCu₂O_{8+x} (Bi-2212) round wire is another very promising HTS conductor for high field magnet applications: its upper critical field reaches beyond 100 T, and it still retains a J_c of nearly 105 A/cm²

at least up to 45 T. Ag-alloy clad Bi-2212 round wire is advantageously magnetically isotropic and easily adaptable to a Rutherford-cable geometry. To efficiently apply Bi2212 round wire in a magnet application, thorough understanding and control of the thermal processing of the conductor is an absolute necessity.

The recently discovered Fe-based superconductors (FBS) exhibit intrinsic properties that turn out to be potentially of interest for applications. In fact they have critical temperatures T_c up 55° K, upper critical fields H_{c2} exceeding 100T and low anisotropy.

The Magnet Lab is active in developing all three of these conductors and the associated coil technologies to enable a transformation in high-field superconducting magnet technology, not just for general purpose solenoids, but for NMR magnets and accelerator magnets.

32 T All-Superconducting Magnet

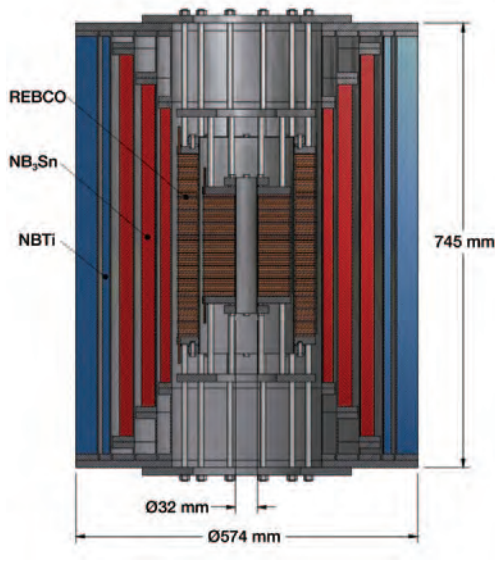


FIGURE 9. Cross-section of the 32 T magnet with pancake wound REBCO coils in the bore of an LTS outer magnet.

The Magnet Lab is engaged in the development, design, and fabrication of a 32 T all-superconducting magnet based on REBCO High Temperature Superconductor (HTS). The development of magnet technology to utilize REBCO conductors is still very much in the development phase. The 32 T project at the laboratory, while strongly development-oriented, has the obligation of producing a substantial magnet system for installation in the milliKelvin facility as a user magnet. The 32 T magnet is shown in **Figure 9**.

The specifications of the 32 T magnet were chosen as a balance between providing a fully useful magnet for the science program, while limiting the size, cost and risk of this first-of-a-kind magnet. The clear cold-bore is 32 mm, large enough for an eventual dilution refrigerator with sample diameter of 25 mm. The field uniformity specification is 500 ppm in a 1 cm spherical volume. The ramp-time objective of the magnet is one hour to full field. In addition to the inner high-field REBCO coil section, the magnet includes a large Low Temperature Superconductor (LTS) outer magnet that will be procured commercially. Experience with REBCO test coils shows them to be very stable, which is attributable to the large critical

temperature, but the ramp rate objectives of 32 T are not automatically assumed. While the outer magnet at 15 T central field contribution is well within the range of application of LTS conductors, the outer magnet is relatively large and the ramp characteristics are difficult to design and anticipate. And even the inner REBCO coils will experience an internal energy dissipation upon ramping that is not entirely known. The thermal conduction of the REBCO coils will determine the extent to which the internal energy dissipation results in a temperature rise in the windings, and any related limitation to the ramp rate.

The 32 T magnet will be built at a large capital cost relative to conventional resistive magnets of the same field range. This will continue to be the case for REBCO magnets after the cost of technology development is reduced. But 32 T is the bottom of the expected field range of application of REBCO conductors, and the broader technology is expected to enable large magnets that are outside the field range of resistive and hybrid magnet technologies in their present form.

A variety of limitations need to be addressed in the 32 T project. Fundamentally, there is a general lack of experience with REBCO coils. The conductor is relatively expensive. The 32 T project is not simply technology development, but the end result must be a usable magnet. The lack of experience influences design decisions to limit risk. There are technical limitations in the conductor as well. The critical current is strongly field-orientation dependent, with the result that the radial field at the solenoid ends greatly limits the achievable current in the magnet. There are work-arounds to this problem, including the use of wider conductor at the coil ends, or the use of a separate power supply with different currents in coil sections, but all such approaches come at a cost and risk. A fundamental solution to conductor field orientation dependence has been difficult to achieve. Another technical limitation associated with the conductor, and the downside of the desirable increase in coil stability, is difficulty with quench protection. The very stability of the

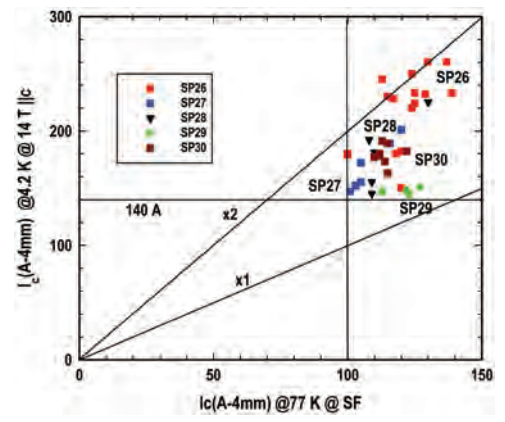


FIGURE 10. Correlation between critical current at 77 K self-field and 4.2 K, 14 T.

conductor limits the natural propagation of quench in a coil, and thereby limits the effectiveness of conventional quench protection procedures. The ability to quench a magnet quickly is related to the amount of stabilizer copper that is needed on the conductor, which in turn is related to the overall current density, the compactness of a magnet, and the ability of the design to manage stress. There are indications that design approaches will be possible with REBCO conductor that limit the amount of needed stabilizer copper and that provide the highest current density in the windings. This aspect of REBCO magnet technology is presently unresolved in general and is the subject of ongoing development. A protection concept was selected for 32 T that has now been demonstrated in test coils that, while not resulting in the highest imaginable current density, appears to be a practical present solution.

The general lack of knowledge and the early stage of development of REBCO magnet technology are being addressed at the MagLab in a broad program of technology development. The 32 T project identified the areas of conductor electrical characterization, conductor mechanical characterization, conductor and turn insulation, and small coil development. The output of this effort has already greatly expanded our understanding of REBCO conductor and magnet technology.

Extensive characterization of conductor has been made on the latest production of REBCO tapes from SuperPower. We focused on relatively

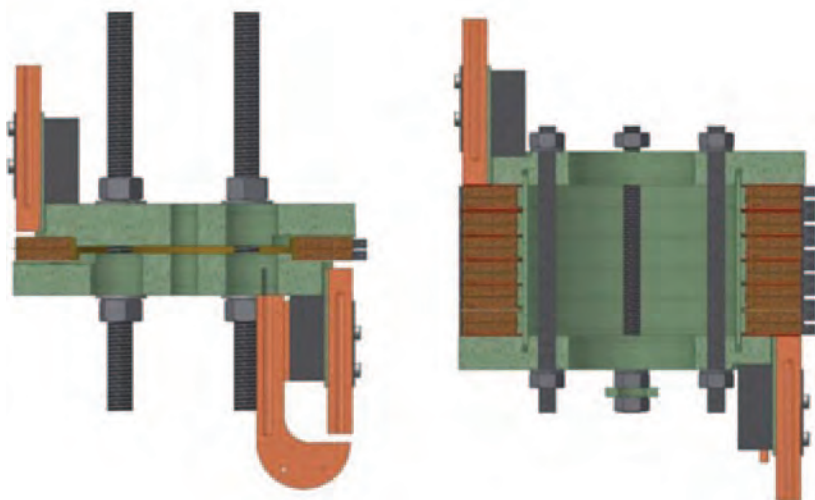


FIGURE 11. Designs of Coil 1 with single module (left) and Coil 2 with 6 modules (right).

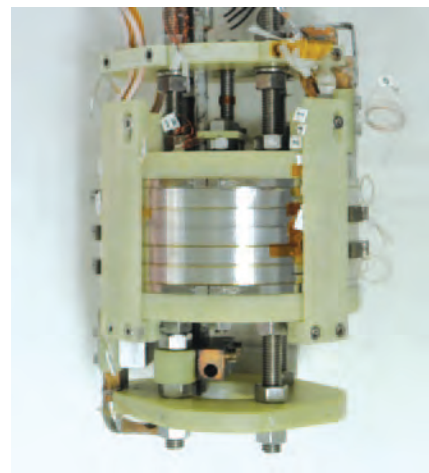


FIGURE 12. Coil 2 on test support structure.

inexpensive and fast methods of testing long lengths of tapes, explored correlations between 77 K and 4.2 K properties, characterized tapes at elevated temperatures for quench models, and investigated their strength under high currents and high magnetic field conditions. We built several new probes to make fast characterization at fixed angles between field and conductor, especially at the critical angle of 18° expected at the ends of the magnet. To collect broad statistics, we measured critical currents for a large number of samples, as well as in long lengths of tapes using the YateStar reel-to-reel method at 77 K. These data were then compared to the values collected at 4.2 K. Sadly we found only a weak correlation between 77 K and 4.2 K critical current values, as shown in **Figure 10**. This must be due to different vortex pinning mechanisms dominating at high and low temperatures, a factor that we are still working to understand better, since this may give important guidance on how best to develop these tapes for future high field magnet use.

Two REBCO development coils have been fabricated and tested in the 20 T background field of the Large Bore Resistive Magnet in the DC Field facility of the NHMFL. The coils, shown in **Figures 11 and 12**, have one and six double-pancake modules respectively. The coil size was chosen to be large enough to

address full scale features of the 32 T coils, yet small enough to conserve conductor and fit the available test facilities. The coil construction includes winding mandrels, inside and outside crossovers, in-line joints, co-wound reinforcement, terminals, overbanding reinforcement and insulating spacers that are full featured components for 32 T. The coil fabrication required fixtures and processes for joint, crossover and terminal soldering, and reinforcement co-winding and overbanding. The conductor used had $50\ \mu\text{m}$ copper per side, essentially as would be used in 32 T, to provide experience in the fabrication, handling and performance of conductor with this amount of copper stabilizer. The coils both contained protection heaters embedded in the spacers that separate the double-pancake modules. Coil 1 heater elements were varied in size for initial tests. Coil 2 heaters began to demonstrate a design and fabrication of the heater elements that will be used in 32 T.

Both coils were tested in a similar manner in a 20 T background field. Their operating current at 32 T will be 170 – 180 A. This current level was simulated by operating the test coils to 200 A. At this level, the protection heaters were studied by activating the heaters and quenching the coils numerous times. Following the heater tests, higher currents were introduced into the coils to study the effect of higher stress in the windings.

Both coils generally performed well, were extremely stable, and provided valuable information on heater behavior and other aspects of the coil design.

Other REBCO Coils Layer Winding

One of the goals at the NHMFL is to develop the necessary technology for the next generation of high-field magnets including Nuclear Magnetic Resonance (NMR) quality magnets. To reduce the number of resistive joints and achieve the required field homogeneity for NMR, layer-winding is highly desirable. A series of small test solenoids have been wound using REBCO coated-conductor tape made by SuperPower Inc. One of these coils was recently tested in a 31.2 T resistive magnet, generating an additional and steady magnetic field of 4.2 T for a total of 35.4 T (**Figure 13**). The introduction of a thin-walled heat-shrink tube around the conductor that mechanically decoupled the HTS tape from the epoxy encapsulant significantly contributed to the success of this coil. The coil demonstrates that layer-winding a very high-field superconducting coil, working at high stress levels $>340\ \text{MPa}$ and conductor current density $J_c > 500\ \text{A/mm}^2$, is possible. The coil was quenched safely multiple times without any measurable degradation of its



FIGURE 13. Layer-wound coil mounted on the probe. The coil is 64.5 mm long, with an inner diameter of 14.3 mm, and an outer diameter of 38 mm. The total length of conductor used is ~100 m.

performance (Figure 14)^{8,9}.

This layer-wound coil and earlier prototype pancake-wound coils demonstrate that REBCO coated conductors have developed into a suitable basis for a new superconducting magnet technology that allows major advances in magnetic field generation at 4.2 K. Because of its low anisotropy and high irreversibility field at temperatures well above 50 K, this REBCO conductor may also allow a cryo-cooled magnet technology for generating fields of 5 – 15 T in the 30 – 50 K range. The terminal design and conductor insulation approach have resulted in two patent applications.

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Insulation

Insulation technology is essential for very high field magnets. However, finding a reliable insulation system is very challenging due to the required

minimal thickness, the extreme working environment and potentially high voltage in addition to high mechanical strength. In 2011, MagLab researchers continued to make efforts to develop insulation materials focusing on ceramic SiO₂ insulation strengthened by Al₂O₃. Currently the insulation can be applied to stainless steel. The advantage of this scheme is that there is no restriction on insulation process temperature such as in the direct coating on the surface of the conductors with a possible damage by high-temperature coating-process. The Al₂O₃-SiO₂ films are coated through a sol-gel process which is a novel coating method where fine ceramic powders are dispersed in a type of suspension solution which is dip-coated on the substrate and heated to bind the powder phase internally and overall coating to the substrate. This method combines

properties of the conventional sol-gel technique with the ability to produce much thicker and adherent films through the control of microstructures and avoid cracking in thin coating during the densification. The final product is a ceramic composite material consisting of a SiO₂ thin-film strengthened by Al₂O₃ dispersed particles. The technology will be used for construction of the insert of 32 T all-superconducting magnets and potentially useful for other high field magnets.

Bi2212 Conductors

Powder-in-tube (PIT) processed Bi₂Sr₂CaCu₂O_{8+x} (Bi-2212) round wire is one of the two most promising HTS conductors for high field magnet applications: its upper critical field reaches beyond 100 T, and it still retains a J_c of nearly 105 A/cm² at least up to 45 T. Ag-alloy clad Bi-2212 round wire is advantageously magnetically isotropic and easily adaptable to a Rutherford-cable geometry. To efficiently apply Bi2212 round wire in a magnet application, thorough understanding and control of the thermal processing of the conductor is an absolute necessity. Various short and intermediate size samples have been heat-treated and characterized regarding superconducting and microstructural properties. A key finding is that the critical-current density, J_c , depends on the time in the melt rather than on the maximum applied processing

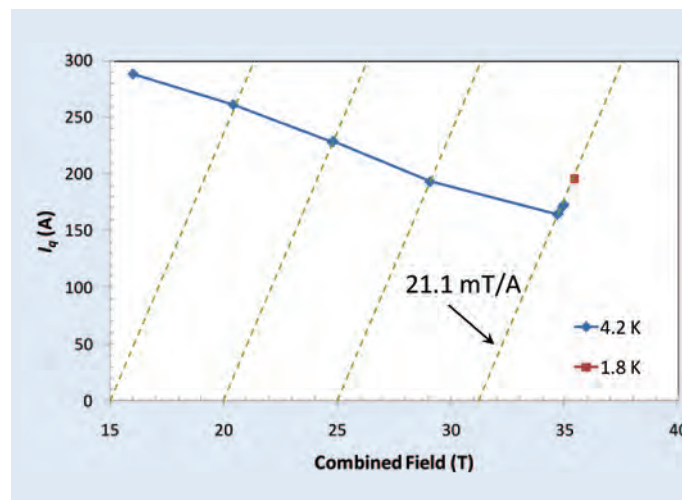
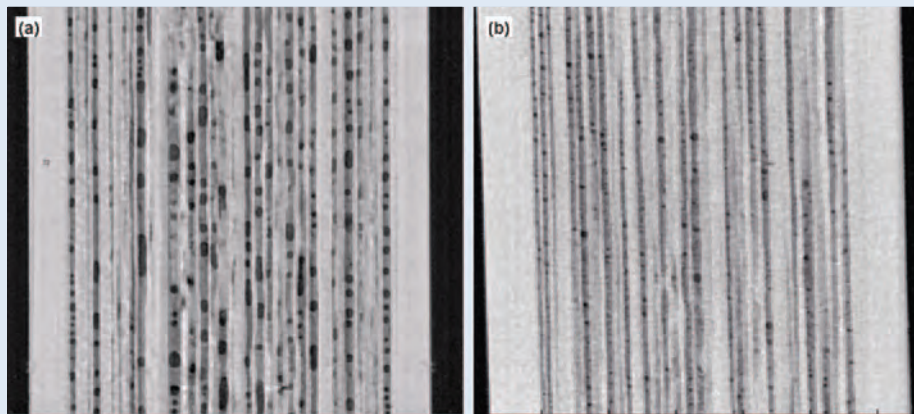


FIGURE 14.

Plot of the quench currents vs. magnetic field for two bath temperatures: 4.2 K and 1.8 K. Helium gas trapping close to the terminal of the coil caused some heating and reduced quench currents in the field region above 20 T.

**FIGURE 15.**

Cross sectional synchrotron radiation, microtomographs of (a) as received wire and (b) the same wire that was CIPed at 2 GPa showing bubbles that formed during the melt stage of the heat treatment. The outer light gray regions are the Ag sheath, the individual filaments run vertically, and the black regions in the filaments are bubbles. The images were taken during an *in situ* heating experiment where the wires were melted while diffraction data were collected. (Tomography by CERN, Scheuerlein et al.)

temperature. This is important because the prevalent thinking in the magnet building community was that it would require furnace temperature control of 1 – 2° C to be able to achieve the maximum J_c in coils with large thermal masses, which is difficult to achieve. With this understanding, it is possible to design heat-treatments that will be manageable for a large thermal mass inside a large industrial furnace. These studies also addressed another serious issue that is the disruption of the current path caused by bubble formation in the Bi2212 filaments, which occurs during the melt stage of the heat treatment. To visualize the bubble formation and their impact, a variety of methods were used: Filaments were extracted from a specially designed wire with a 27x7 filament count. Electromagnetic properties and microstructures of these filaments clearly show the significant impact bubbles play in limiting J_c . In another approach that was carried out in collaboration with CERN, x-ray tomographs were taken while samples were being heat treated (Figure 15). This allowed visualizing the evolution of void-space during all stages of the thermal processing. There are indications that the bubble-formation is due to gas expanding in the wire and that the gas might be N_2 from the atmosphere, and/or CO_2 and H_2O picked up as CO_2 and H_2O from the atmosphere, or formed from organic impurities in the powder or introduced when the wire is fabricated. We started chemical analysis of the 2212 powder and wires to determine what

may be causing the expansion and even bursting of the wire. Preliminary results show that the C and H contents are much higher than the 20 – 50 ppm wt. levels typically seen in AMSC 2223 wire.

We hypothesized that decreasing the bubble density in the filaments would increase the active cross section of current-carrying 2212 in the core of the filament, which would increase J_c . To test this hypothesis we used 2 GPa CIPing (cold isostatic pressing) to densify the filaments in green wire. Short samples showed that CIPing increased J_c and J_e by about a factor of two compared to non-CIPed samples. An alternative approach applied by OST using swaging to densify the samples showed very promising results too. Our studies indicate that removing void space and bubbles requires distinct operations: (1) controlling gases and (2) densifying the 2212 powder in

the wire. High current coils with low inductance will require some sort of cabling of the conductor. We heat-treated Rutherford cable samples that were manufactured from OST wire at LBNL and FNAL to test for the occurrence and location of leakage. Of particular importance is the finding that we did not see leakage from the edges of the wires where the cabling processes deforms the filaments the most¹⁰.

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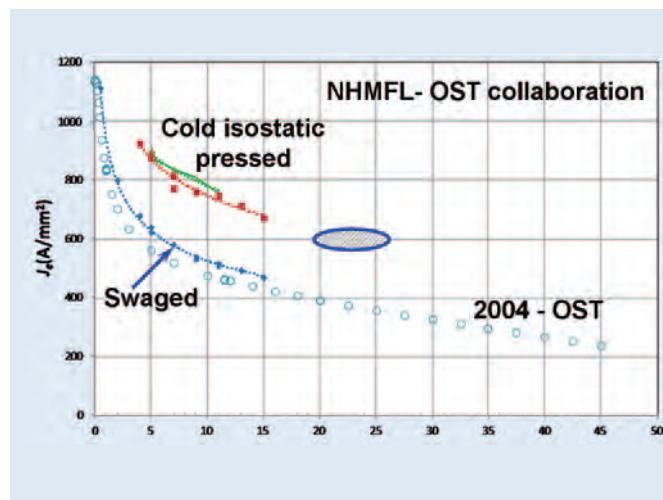


FIGURE 16. $J_e - H$ plot for 2212 conductor. Extrapolating J_e in CIPped wire shows that it will be possible to achieve $J_e = 600$ A/mm² (4.2 K, 20 T), which is the current density needed for racetrack coils.

Bi2212 Coils

Bi-2212 round wire has significantly improved compared with Bi-2212 tape conductor from a few years back. Bi-2212 conductor is available in the most versatile round wire geometry in batch lengths of around 300 m. Virtually leak-free wind-and-react coils are now possible and show fairly consistent performance in high fields. Due to the complexity of the Bi-2212 phase-formation in combination with the wind-and-react approach, however, there is still understanding to be developed in order to process coils with even more consistent performance and higher critical current densities. Coils of various sizes have been wound, heat-treated and tested in high background fields. Various coil processing and engineering issues have been addressed and solutions have been found. Coils can be manufactured and heat treated yielding homogenous transport properties throughout the winding pack. One Bi-2212 coil generated 1.1 T in a 31 T background field, making it the first wire-wound coil to reach beyond 30 T. The transport current densities, J_c , of coils, however, are still consistently lower than those of short samples. In addition winding current densities, J_w , are reduced

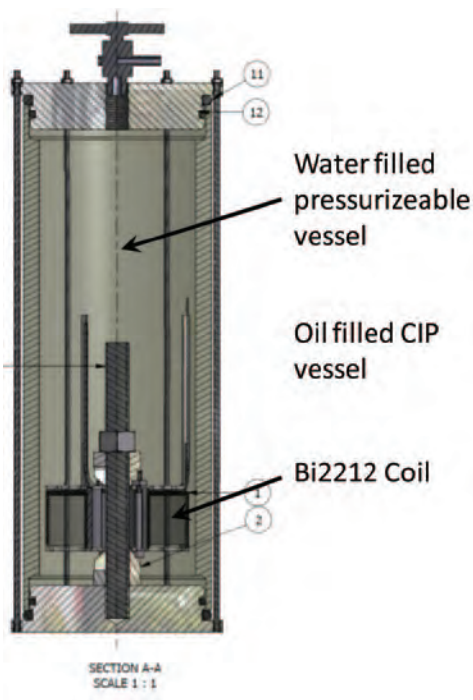


FIGURE 17. Water-filled pressurizable vessel with coil to be inserted into oil-filled CIP chamber.

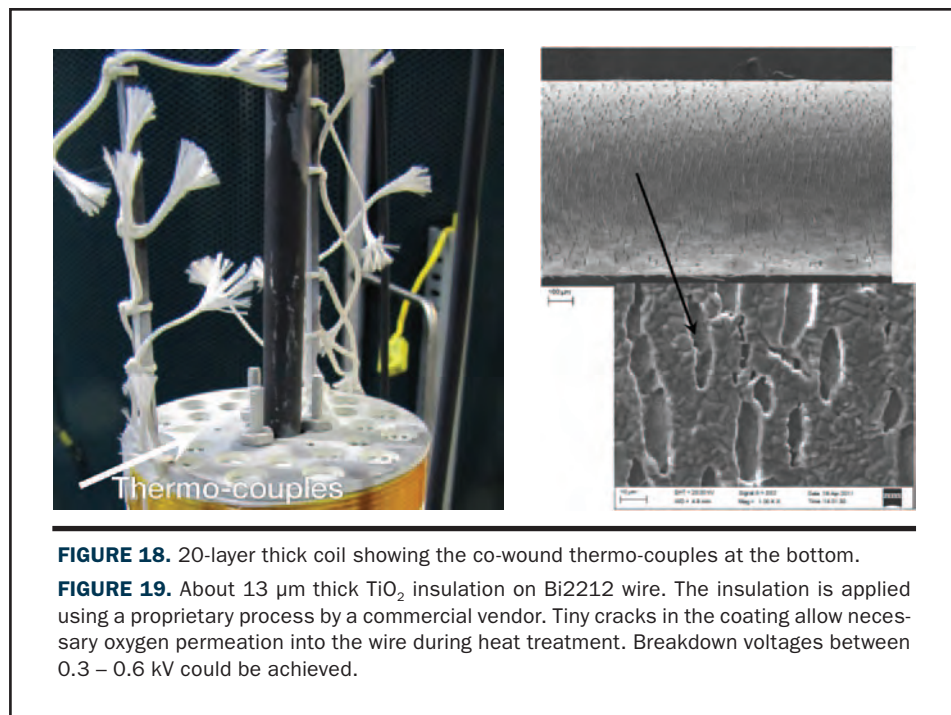


FIGURE 18. 20-layer thick coil showing the co-wound thermo-couples at the bottom.

FIGURE 19. About 13 μm thick TiO_2 insulation on Bi2212 wire. The insulation is applied using a proprietary process by a commercial vendor. Tiny cracks in the coating allow necessary oxygen permeation into the wire during heat treatment. Breakdown voltages between 0.3 – 0.6 kV could be achieved.

due to the significant thickness added by the alumino-silicate braid insulation. From the results of the conductor R&D work it is now known that porosity inside of the conductor is a leading cause of reduced transport-properties in long conductor-lengths and approaches have been identified and applied to successfully reduce porosity and consistently increase transport properties. Coil-processing concepts that target the reduction of porosity have been developed and are currently waiting to be tested in coils: Among these concepts are the use of Cold Isostatic Pressing (CIP) to densify a complete coil as well as the use of swaged or otherwise densified conductor before coil winding. The use of swaged conductor is an approach that is being developed in close collaboration with the conductor manufacturer Oxford Superconducting Technologies (OST) (Figures 16 and 17).

A 20 layer thick and 21 turn tall coil, made with alumino-silicate braid as insulation and instrumented with a set of thermocouples on various coil radii, has been wound and heat treated (Figure 18). The measured heat-treatment profile clearly showed that the time constant of the coil fit well with the standard heat-treatment parameters and the coil could be processed homogeneously throughout

all of its layers. In-field testing is anticipated for the next available time slot in the large-bore resistive magnet.

To address low J_w in coils, part of the R&D work focused on finding alternatives to the thick and also chemically incompatible alumino-silicate braid conductor insulation. Three alternative insulation routes are pursued, two sol-gel coating routes are being pursued, one in collaboration with the University of Harran, Turkey, and one in-house. A third route pursues the application of a ceramic-particle-filled polymer provided by a commercial vendor. Short conductor piece lengths and spirals coated with this material from the commercial vendor yielded homogeneous dielectric properties at thicknesses of about 13 μm after heat treatment show promise to significantly increase packing density in coils (Figure 19).

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Pnictides

The recently discovered Fe-based superconductors (FBS) exhibit intrinsic properties that turn out to be potentially of interest for applications. In fact they have critical temperatures T_c up to 55 K, upper critical fields H_{c2} exceeding 100 T and low anisotropy. However, in order to determine the real FBS potentialities several requirements are necessary. From the material point of view, high critical current density, J_c , with weak field-dependence, irreversibility field as close as possible to H_{c2} and transparent grain boundaries are necessary. From the technological point of view, it is essential to develop round wire or low-cost tapes capable of obtaining the same performances found in single crystals and thin films. Unfortunately the FBS compounds with largest T_c , the REAsFeO_{1-x}F_x (RE=La,Sm,Nd,...) or RE-1111, have

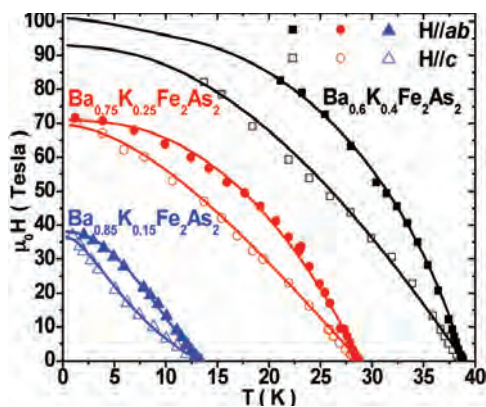


FIGURE 20. H_{c2} of three $\text{Ba}_{1-x}\text{K}_x\text{Fe}_2\text{As}_2$ single crystals at different doping levels with magnetic field parallel to c and ab measured at NHMFL¹⁴.

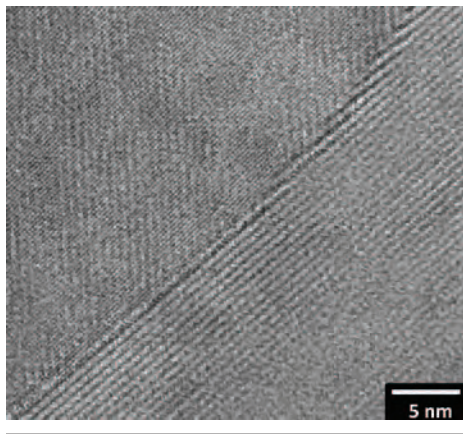


FIGURE 21. High resolution TEM image of a typical K-doped Ba122 grain boundary. There is no indication of a wetting impurity phase.¹⁵

shown granular behavior with a global J_c 2-3 orders of magnitude lower than the local J_c ¹². The reason of this suppression was found in secondary phases (FeAs and RE_2O_3) that wet the grain boundary and act as current-blockers. As a consequence the interest moved to the cobalt and potassium doped BaFe_2As_2 (Ba122) that, despite the lower T_c (~25–38 K), have weaker grain boundary problems. In the case of Co-doping Ba122, we demonstrated the high tunability of the pinning properties thanks to the introduction of a high density of non-superconducting nanorods that strongly decrease the J_c field-dependence and the J_c anisotropy¹³. In the case of K-doping Ba122, we studied the doping dependence of H_{c2} (Figure 20) showing that at the optimal doping H_{c2} reaches 100 T with anisotropy close to 1¹⁴. Moreover a new low temperature synthesis technique has been developed in our laboratory in order to obtain high quality polycrystals with clean grain boundaries and high global current. Figure 21 shows a TEM image of a typical K-doped Ba122 grain boundary revealing absence of wetting phases. The same material was powdered and used to prepare a powder-in-tube (PIT) round wire. The obtained transport J_c exceeds 0.1 MA/cm² at self-field and flattens at 10 kA/cm² at about 10 T (Figure 22)¹⁵. Those values are more than 10 times better than any other FBS material in randomly oriented form.

These preliminary results on the Ba122 phase are promising, even if further optimizations (like the possibility to introduce nanometric defects, overdoping or multicore wiring) have to be considered in order to improve the in-field behavior and the grain boundary properties.

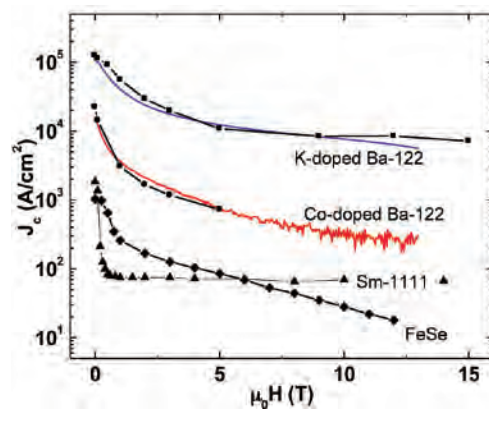


FIGURE 22. Transport J_c in different FBS round wires. Ba122 wire shows a strong improvement in respect to the others.¹⁵

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FIGURE 23. The CICC model coil after reaction heat treatment and epoxy impregnation. The flanges have been removed and a machining device is installed for removal of the coil mandrel.

LTS Magnets & Materials

CICC Magnets

Several milestones have been reached in the continuing construction of the two Series-Connected Hybrid magnet projects including: the cable-in-conduit conductor (CICC) fabrication, coil winding, joint development, cryogenic system delivery, protection and controls system design, and the model coil fabrication. These magnets will consist of a large Nb₃Sn/Cu CICC outer coil and a set of Florida-Bitter plate resistive inner coils and will provide unique capabilities with dramatic power savings compared to all-resistive magnets. One of the SCH magnets will be located at the Magnet Lab in Tallahassee and provide 36 T in a 40 mm bore with 1 ppm uniformity. The other SCH will be installed at the Helmholtz Zentrum Berlin (HZB) for neutron scattering experiments at 25 T.

The model coil was built in order to help develop fabrication techniques, components, and quality controls, as well as to train personnel and to have an instrument for demonstrating the heat treatment and epoxy facilities. Early in 2011

the winding of the model coil was completed. Some of the most important developments that came from the experience are the impedance measurements, which are used to check for electrical shorts, and how to build critical components such as lead anchors, ramps, and fillers. Other milestones completed with the model coil include the heat treatment and epoxy impregnation of the coil. A view of the model coil after its epoxy impregnation is shown in **Figure 23**. Valuable information on the temperature distribution through the coil and improvements in the procedures were obtained which will be used to tune the heat-treatment process for the production coils.

A major milestone was reached this summer with the successful completion of the CICC fabrication for the superconducting outsert coils. The CICC consists of high J_c Nb₃Sn/Cu wires fabricated by the Rod-Restack-Process (RRP) and then twisted into a multi-stage cable and compacted inside of a stainless steel conduit. This type of conductor has two primary advantages over other superconducting

cables: strength and stability. The stainless steel jacket is the main structural component of the coil that contains the electro-magnetic loads, which approaches 80 kN (18,000 lb) on one turn of conductor. Inside the steel jacket, the void space inside the cable represents about 30% of the internal volume. This will be filled with supercritical helium at 4.5 K during magnet operation. Having helium in direct contact with the superconducting strands provides a very stable superconducting environment. Heat generated through AC losses or friction can be efficiently swept away allowing for fast ramping of the coil and thus conducive to series connection to resistive coils.

The jacketing and compaction of the superconducting cables with the steel tubes was an international collaborative effort. The activities were conducted at a new CICC fabrication facility setup by part of the Italian Consortium for Applied Superconductivity (ICAS) group, with technical support by the NHMFL and HZB. Five piece lengths of CICC totaling about 2 km were fabricated for each coil; the longest single length is 590 m.

Coil fabrication has commenced with the winding of the HZB outsert coil. Seven of 18 layers have now been wound. All of the large high-field CICC have been wound into the first three layers and all of the mid-field CICC have been wound into the fourth through sixth layers of the coil. The ends of adjacent pieces of conductor have been spliced via a unique feature referred to as a splice-tie which results in a stronger coil-pack than traditional technology. Winding of the coil is shown in **Figure 24**. Following the winding of the HZB coil will be the winding of the NHMFL coil. The coil-reaction heat-treatment and vacuum-pressure epoxy impregnation will occur in the coil-processing facility at the NHMFL, recently put to test using the model coil. The ability to wind and process large Nb₃Sn CICC coils is not commonplace throughout the world. The MagLab's capabilities have brought interest in potential coil construction for future CICC magnet projects at the High Field Magnet Lab (HFML) in Nijmegen, the Netherlands and ENEA in Italy.

In joint development, an important



FIGURE 24. Winding of the HZB superconducting outsert coil.

milestone was crossed by completing the final joint tests. To demonstrate reliability in joint fabrication, four Nb₃Sn to Nb₃Sn joints were built in series and tested simultaneously. The joint resistance of 0.2 nΩ was an order of magnitude better than the target value of 2 nΩ and gives data and confidence that they can be made to high quality, repeatedly. Improvements in the NbTi bus bar joint were shown in another joint test. The NbTi joint-technology utilized compression contact only (for Nb₃Sn joints the strands are sintered together during the coil reaction heat treatment). The process has been improved by applying solder to the outside of the cable using induction heating prior to and after compaction into its copper jacket which serves as a terminal post in the joint. The application



FIGURE 25. Installation of the helium liquefier in cell 16 of the Magnet Lab.

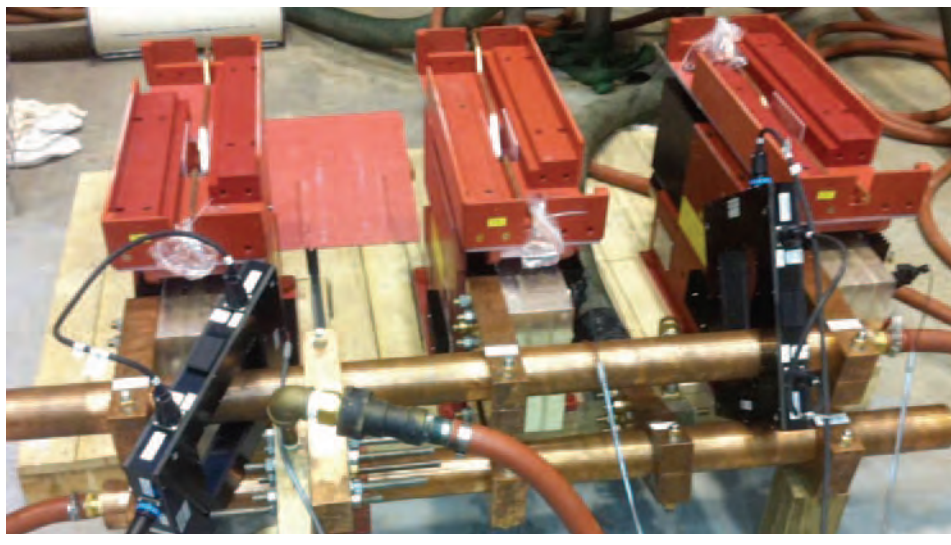


FIGURE 26. Protection & control system circuit breakers during testing at the NHMFL.

of solder on the outer surface of the cable has lowered the resistance threefold. The perimeter soldering using induction heating techniques still allows helium to flow freely through the joint box.

The HTS leads are at a critical stage as they are now set-up for prototype testing of one 4 kA element. Following this test, a full cost estimate for their construction will be prepared and evaluated against HTS leads that are presently available in industry.

The helium refrigerator was tested in the vendor's factory in January, 2011 and showed that it has a maximum capacity of 880 W plus a liquefaction of 25 liters per hour. This capacity is almost 30% more than what was required. It has since been delivered, installed and commissioned (**Figure 25**) and it has been in operation quite frequently to produce liquid helium for the users at the MagLab. Other major cryogenic components have been installed including the main compressors, oil removal system, and several transfer lines. The final major component, the central distribution box (CDB), has had good progress in its manufacture with the large heads being completed. Delivery of this component is expected early in the second quarter of 2012. Following that, connection of the remaining transfer lines and 45 T magnet to the new refrigerator and CDB will commence.

Procurement of the major items requiring long lead times for the protection and control system has also

been completed in 2011 (**Figure 26**). This includes items such as the dump resistor, diodes, high current switches, and circuit breakers, to name a few. Installation of the platform and many of these items will start in the first quarter of 2012.

Nb₃Sn for Cable-In-Conduit Conductors

Nb₃Sn was the first high field superconductor and is still the primary choice for coils developing magnetic fields above 11 T and up to 23 T; it is also an essential technology for high field NMR and the Series-Connected-Hybrid magnets being developed by the Magnet Lab. Nb₃Sn strand is produced on a large commercial scale in a variety of designs for different applications; two such types, "Bronze" strand and a "High-J_c" strand are shown in the comparative field/current plot in **Figure 27**. The performance of the "Bronze" strand in **Figure 27** is typical of strands with low hysteresis loss designed for cyclic field loading as in the ITER tokamak reactor being constructed as an international collaboration in Cadarache, France. The MagLab is heavily involved in ITER, providing essential data on strand and conductor performance. The "High-J_c" strand is typical of strands designed for maximum critical current density, such as the MagLab's SCHs, high-field particle accelerator magnets and compact cyclotrons; these strands are the focus

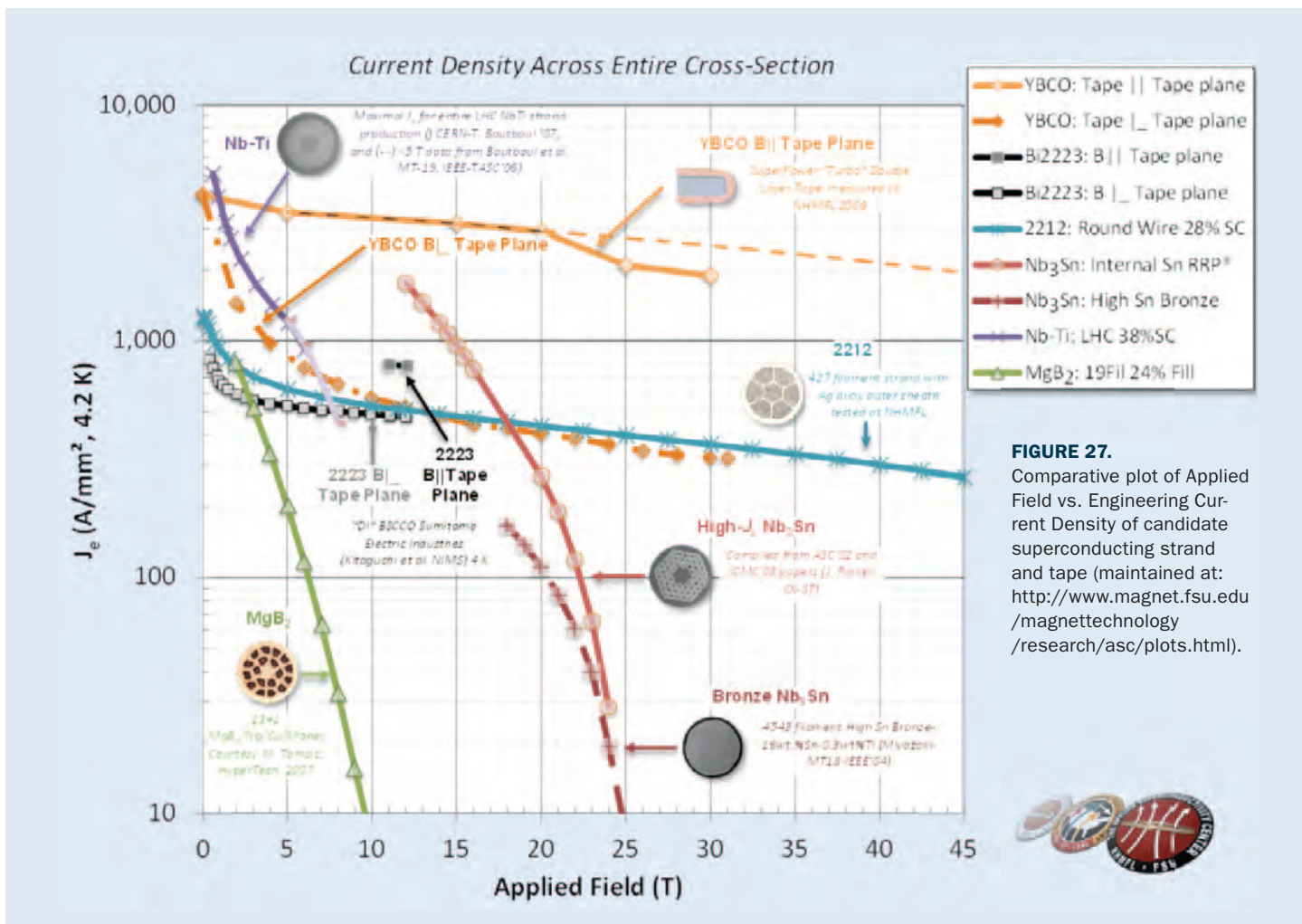


FIGURE 27. Comparative plot of Applied Field vs. Engineering Current Density of candidate superconducting strand and tape (maintained at: <http://www.magnet.fsu.edu/magnettechnology/research/asc/plots.html>).

of DOE-HEP sponsored research at the NVMFL.

A major drawback of Nb₃Sn is that it is extremely brittle and cannot withstand significant bending; this means that for most applications the coils are wound with strand that contains the components that are needed to react to produce Nb₃Sn and then a multistage heat-treatment is applied to the coil to produce the superconducting phase. Fortunately all the reacted Nb₃Sn filaments are embedded in a Cu(Sn) matrix which has a greater thermal contraction than the Nb₃Sn, which means that after cooling down each Nb₃Sn filament is surrounded by a protective compressive jacket. Sufficient bending, however, can move the Nb₃Sn strain state into the tensile regime where cracking can more easily occur. In cable-in-conduit conductors (CICC), used for such applications as the SCH and ITER, the cabled strands are able move

to some extent. In **Figure 28** we show a cross-section from a prototype CICC for the ITER Toroidal Field (TF) coils (each Toroidal Field coil is 14 m high and 9 m wide) that has been image processed so that the Nb₃Sn and Cu strands have been shaded by adjacent feature count, revealing the increased separation of the strands. This illustrates the movement of the strands under the Lorentz force generated by the magnetic field and also the reductions in strand-to-strand mechanical support as the strands move further apart.

In addition to cable cross-sections, the individual strands are examined for their response to mechanical strain. A variety of ITER strands were subjected to extended cyclic tensile loading¹⁶ designed to simulate the long-term uniaxial tensile cyclic loading (30,000 cycles) of the ITER Central Solenoid (CS) coils expected during the lifetime of ITER.

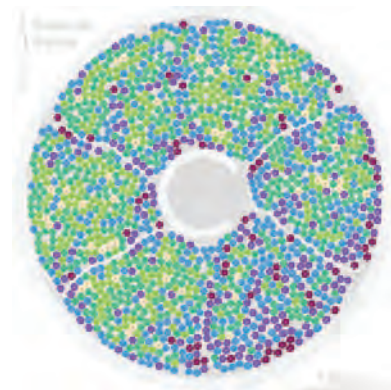


FIGURE 28. Transverse cross section of an ITER TF CICC after testing in the high field zone of the SULTAN test facility. The strands have been separated by 1 pixel using image processing and then colored according to adjacent feature count (an adjacent features is one connected by a single pixel-wide four-connected line). The count ranges from a maximum of 5 (light) to 0 (dark). This image processing reveals that the strands in the lower right hand corner have moved apart under the Lorentz force which is in the bottom-to-top direction in this image.

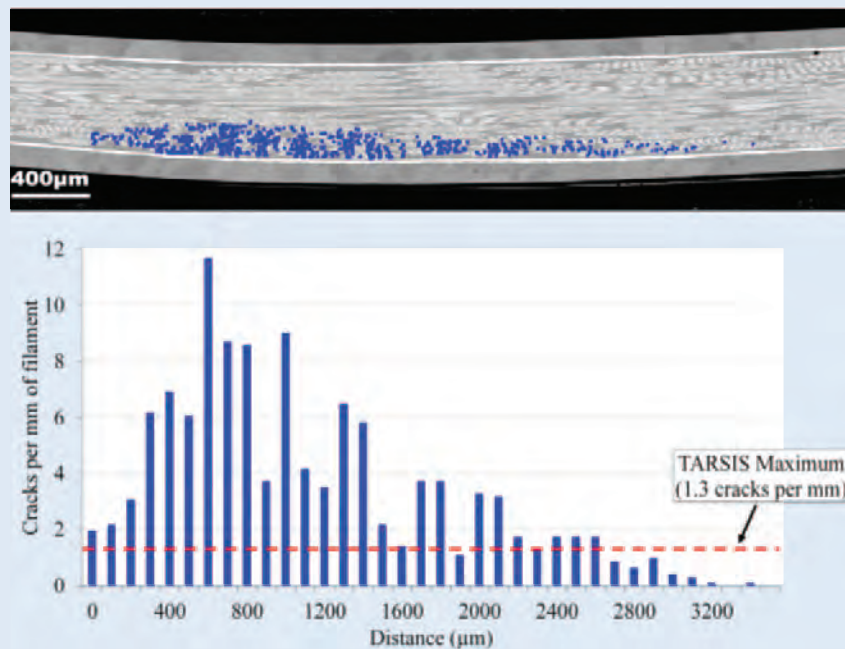


FIGURE 29. Filament cracks (marked in blue) in a strand extracted from the high field zone cable shown in Figure 27. The crack distribution strongly suggests that they are the result of bending strain with the lower surface being the tensile side of the bend. The red dotted line represents the maximum crack concentration that was seen in strands tested under controlled bend conditions (TARSIS) at the University of Twente (collaboration with the group of Arend Nijhuis).

It was found that strands needed to be loaded close to their tensile fracture strain before significant filament fracture occurred¹⁷. As we have not observed strand breakage in any CICC but we have observed extensive localized filament fracture it is clear that the culprit is not uniaxial tensile strain. In **Figure 29** we show a longitudinal cross-section of strand extracted from the CICC shown in **Figure 28**, in which filament cracks have been marked in blue. The crack distribution and geometry of the strand is consistent with the fracture being due to bending strain (with the lower surface of the strand being the tensile bend surface) rather than uniaxial tension¹⁸.

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Strand-Level Nb₃Sn Optimization

The central issue that complicates optimization of any Nb₃Sn conductor is that actually the composition varies from about 18-25at.%Sn and that ALL practical conductor forms include all compositions

within the filament cross-section. A major difference between the low-hysteresis loss ITER-type strands and the "high- J_c " strands is that the geometries required to maintain filament separation for low coupling loss also result in lower and more inhomogeneous Sn contents in the Nb₃Sn. Thus the present status of Nb₃Sn strand is one based on compromise rather than complete optimization. There is still potential to significantly improve the performance of the strand if the variables influencing the properties can be fully understood. Since the T_c varies from 6-18 K with similarly large range of J_c and H_{c2} and filaments are as small as 3 μm in diameter, the actual extraction of this superconducting property distribution has seldom been performed on production strand. Characterization of superconducting properties by specific heat (C_p) provides information about the critical temperature distribution in superconducting samples. C_p is a bulk measurement sensitive to the whole sample property distribution on the scale of the coherence length, $\xi \sim 5$ nm, unlike magnetic measurements where, because of screening effects on a scale of $\lambda \sim 250$ nm, internal regions of filaments with lower T_c are screened from view while regions smaller than the penetration depth give weak or no magnetic response. We are characterizing several Nb₃Sn wires from different manufacturers covering a wide range of production strands, from low hysteresis loss ITER-type strands to high J_c HEP strands. An example of the data that we can get from measuring the specific heat, a rather uncommon capability, especially when performed in fields up to 16 T as we can, is shown in **Figures 30 and 31**. A small sample of the whole conductor (which contains stabilizing Cu, diffusion barriers, residual bronze etc.) is measured and from this we subtract the phonon and electron contributions of the normal Cu, Cu-Sn etc. to extract only the electronic C_p of the superconducting phases, the Nb₃Sn filaments and any Nb or Ta in the diffusion barriers too. **Figure 30** compares the specific heat for the baseline LARP OST-RRP® strand heat treated over a range of final temperatures by Arup Ghosh and colleagues at BNL.

The RRP® wires show an enhanced homogeneity and the heat treatment differences affect the jump amplitude of the Nb₃Sn and Nb transitions. Increasing the reaction temperature used to form the A15 phase (Nb₃Sn), the Nb jump becomes smaller and smaller, whereas the Nb₃Sn transition become sharper with a more intense peak.

The deconvolution of the calorimetric data provides more quantitative information and the T_c-distribution can be determined. F(T) is the integral from 0 to T of the T_c-distribution f(T) and, thus, represents the volume fraction of sample with T_c ≤ T given by the relation:

$$\int_0^T f(T_c) dT_c \equiv F(T) = \frac{nS_e(T) - C_e(T)}{(n-1)\gamma T}$$

where C_e and S_e are the electronic specific heat and entropy at temperature T, γ is the Sommerfeld constant and n is a parameter defined in the Gorter-Casimir model. **Figure 31** reports the F(T) curves (obtained for the data in **Figure 32**) and their derivatives f(T), are plotted in the inset.

The effects of the heat treatments reported in **Figure 32** for the high-J_c RRP® wires indicate that the transition broadening is similar for A15 reactions between 650° C and 680° C with only a small change in the residual Nb (it decreases from 6.6 to 4.1%). However, a more drastic change is observed at 695° C and 750° C that produce much sharper A15 phase transitions with a larger fraction of high-T_c A15. ΔT_c decreases from 3-3.9 K for the samples annealed at 650–680 but falls even more down to 2.3 K for the 695–750° C annealing. However the residual Nb in the diffusion barrier falls to 3.7 and 1.6% of residual Nb. This is generally associated with Nb barriers that are too thin to protect the desired high RRR in the stabilizing Cu, a degradation that both affects the low field stability of the magnet and the ability to safely protect magnets during quench.

All of these measurements are designed to explain the boundaries of Nb₃Sn in pursuit of a strand that has both high current and low hysteresis loss. The uniform and well-separated 3 to 6 μm diameter Nb₃Sn filaments covered in the previous section are being produced in multifilamentary strand on a vast

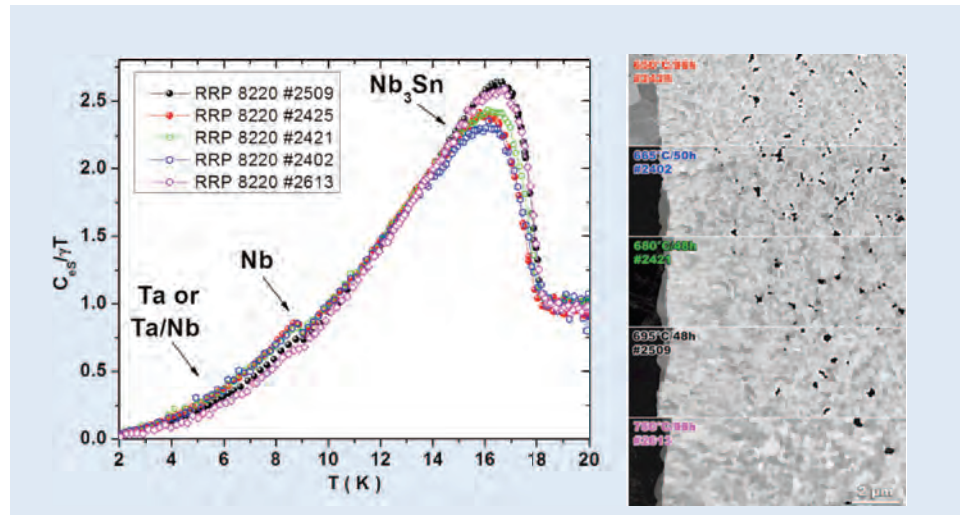


FIGURE 30. Normalized electronic contribution to the superconducting part of baseline LARP strands heat treated and J_c tested at BNL. The Nb or Ta/Nb signals come from the diffusion barriers. Clear differences in the sharpness of the T_c transition are clear. The microstructure of grains in a typical filament is indicated at right, together with the applied HT. Higher temperature reactions produce a sharper T_c which raises the H_{c2} distribution, but also grows larger grains that produce lower vortex pinning. Optimizing J_c plays off these two variables in a so far largely unknown way.

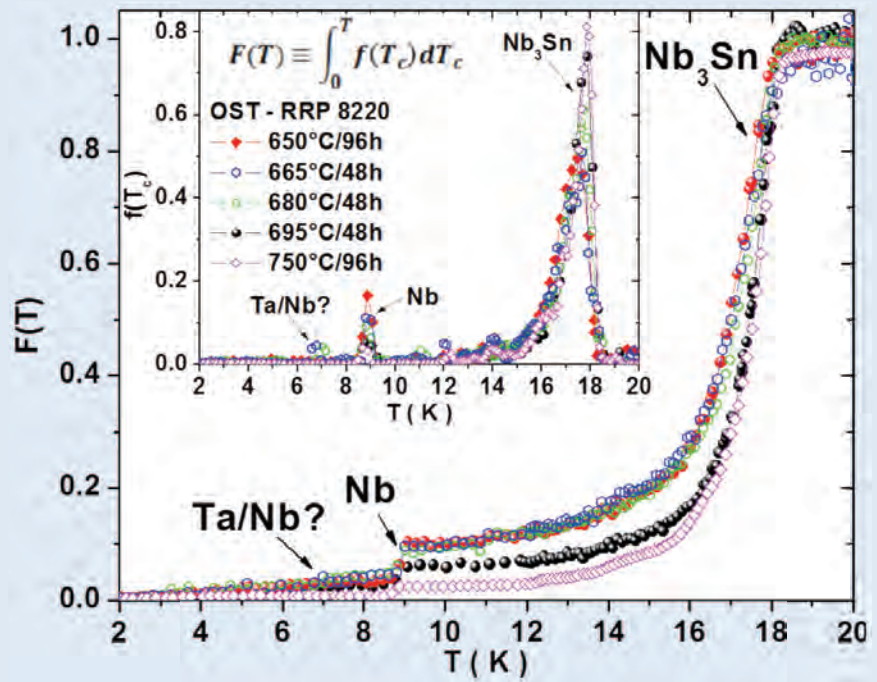


FIGURE 31. Integral of the T_c-distributions and T_c-distributions obtained by the analysis of the specific heat curves shown in Error! Reference source not found.

production scale for the ITER project but the quality of the Nb₃Sn is much poorer than in HEP strands (as shown in **Table I**), resulting in a remarkable 67% loss in J_c (layer). We believe that

the secret to whether it is possible lies in understanding the correlations that our combined BNL, ITER and ASC characterizations allow.

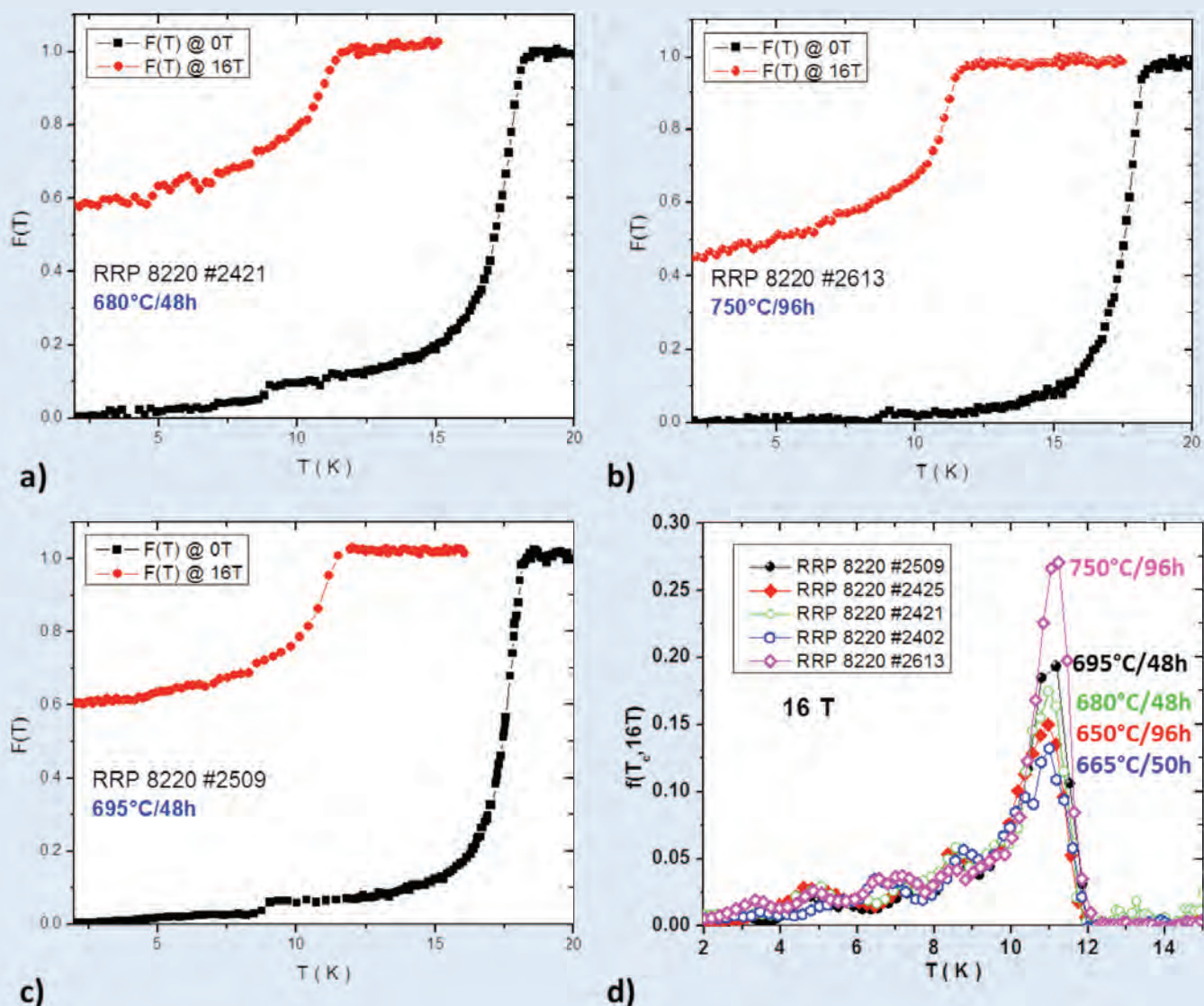


FIGURE 32. In-field behavior for RRP samples: **a.**, **b.** and **c.** At low temperature and in-field the superfluid density is significantly enhanced in the 750° C-annealed sample but almost constant in all the other samples. **d.** At 16 T there is a close relation between annealing temperature and amplitude of the peak but also the annealing time as some effects (compare red and blue curves).

Intrinsic Nb₃Sn Optimization

Because any conductor microstructure contains all A15 compositions, it is not possible to extract direct relationships between composition and superconducting properties, so we have been making high homogeneity binary, ternary and quaternary Nb₃Sn bulk samples using powder samples reacted very homogeneously in our 2000° C hot isostatic press. We believe that they have made the highest homogeneity

Nb₃Sn that has yet been achieved. In work published in an *Applied Physics Letters* this year¹⁹, we showed surprising H_{c2} data on binary samples that exhibit identical upper critical field $H_{c2}(0.3\text{ K}) = 29 \pm 0.2\text{ T}$ with or without undergoing the cubic-to-tetragonal transition, a result in strong contrast to widely used multiple-source data compilations that show a strong depression of $H_{c2}(0\text{ K})$ from 29 T to 21.4 T in the tetragonal state. As improvements in HEP strand produce more Nb₃Sn that

is close to stoichiometry it is important to understand what effects composition variations will have on the optimization of strand performance. Zhou's PhD work shows that the upper critical field falls well below 10 T for the Sn-poor compositions of the A15 phase²⁰.

ITER Wires

Data from Specific Heat

	Jastec	Hitachi	Kiswire
T_c onset K	17.9	17.9	18.1
T_c peak K	16.8	17.0	17.0
ΔT_c , K FWHM of $f(T_c)$ peak	1.7	0.9	1.2
ΔT_c , K 10-90% of $1-F(T_{c, Nb/Nb-Ta})$	4.0	3.5	3.3
$f(T_{c \text{ peak}})$	0.40	0.53	0.57
%Nb	7.2%	13.1%	0%
Volume superfluid at 16T, 2K	40%	34%	45%

OST RRP Samples

Data from Specific Heat

	2425 RRP-8220-4	2402 RRP-8220-4	2421 RRP-8220-4	2509 RRP-8220-1	2613 RRP-8220-1
T_c onset K	<18.2	18.4	18.4	18.3	18.4
T_c peak K	17.5	17.7	17.7	17.9	17.9
ΔT_c , K FWHM of $f(T_c)$ peak	1.5	1.3	1.2	1.0	0.8
ΔT_c , K 10-90% of $1-F(T_{c, Nb/Nb-Ta})$	3.0	3.9	3.3	2.3	2.3
$f(T_{c \text{ peak}})$	0.50	0.51	0.61	0.74	0.81
%Nb	6.6%	4.9%	4.1%	3.7%	1.6%
Volume superfluid at 16T, 2K	40%	37%	42%	40%	54%

OST RRP Samples

BNL Data

	2425 RRP-8220-4	2402 RRP-8220-4	2421 RRP-8220-4	2509 RRP-8220-1	2613 RRP-8220-1	
210°C/ 48h+400°C/ 48h	Temp °C	650	665	680	695	750
	h	96	50	48	48	96
$J_c(12T)$ A/mm ²	3072	2987	3060	3114	2371	
RRR	233	171	109	56	15	
H_k T	23.5	23.8	25.1	26.4	27.3	
T_c K	16.92	16.92	17.10	17.32	17.24	
ΔT_c K	0.85	0.85	1.13	1.00	1.35	
F_p/max GN/m ³	67.3	64.3	61.0	57.2	40.6	
%Barrier Reacted	38%	41%	34%	35%	68%	

TABLE 1. Comparison between Fusion and HEP (Arup Ghosh-BNL) Nb₃Sn strands.

REFERENCES

- J. Zhou, Y. Jo, Z.-H. Sung, H. Zhou, P.J. Lee and D.C. Larbalestier, Evidence that the upper critical field of Nb₃Sn is independent of whether it is cubic or tetragonal, *Appl. Phys. Lett.*, **99**, 122507 (2011).
- J. Zhou, The effects of variable tin content on the properties of A15 superconducting Nb₃Sn, PhD Thesis, Florida State University (2011).

CHAPTER 5

User Collaboration Grants Program

The National Science Foundation charged the National High Magnetic Field Laboratory with developing an internal grants program that utilizes the laboratory's facilities to carry out high quality research at the forefront of science and engineering and advances the facilities and their scientific and technical capabilities. The User Collaboration Grants Program (UCGP), established in 1996, stimulates magnet and facility development and provides intellectual leadership for research in magnetic materials and phenomena.

The UCGP seeks to achieve these objectives by funding research projects of normally one- to two-year duration in the following categories:

- small, seeded collaborations between internal and/or external investigators that utilize their complementary expertise;
- bold but risky efforts that hold significant potential to extend the range and type of experiments; and
- initial seed support for new faculty and research staff, targeted to magnet laboratory enhancements.

The Program strongly encourages collaboration between NHMFL scientists and external users of NHMFL facilities. Projects are also encouraged to drive new or unique research, i.e., serve as seed money to develop initial data leading to external funding of a larger program. In accord with NSF policies, the Magnet Lab cannot fund clinical studies.

Sixteen (16) UCGP solicitations have now been completed with a total of 474 pre-proposals being submitted for review. Of the 474 proposals, 243 were selected to advance to the second phase of review, and 107 were funded (22.58% of the total number of submitted proposals).

2011 Solicitation and Awards

The NHMFL UCGP has been highly successful as a mechanism for supporting outstanding projects in the various areas of research pursued at the laboratory. Since 2001, the proposal submission and two-stage proposal review process has been handled by means of a web-based system.

Of the 19 pre-proposals received, the committee recommended that 12 pre-

proposals be moved to the full proposal state. Of the 12 full proposals, 7 grants were awarded. A breakdown of the review results is presented in **Tables 1 and 2**.

2012 Solicitation

The 2012 Solicitation Announcement should be released on about May 19, 2012. Awards will be announced by the end of the year.

Results Reporting

To assess the success of the UCGP, reports were requested in February 2012, on grants issued from the solicitations held in the years 2006 through 2010, which had start dates respectively near the beginnings of years 2007 through 2011. At the

TABLE 1

UCGP Proposal Solicitation Results

for 2011

Research Area	Pre-Proposals Submitted	Pre-Proposals Proceeding to Full Proposal	Projects Funded
Condensed Matter Science	14	8	5
Biological & Chemical Sciences	3	2	2
Magnet & Magnet Materials Technology	2	2	0
TOTAL	19	12	7

TABLE 2

UCGP Funded Projects from 2011 Solicitation

Principal Investigator	NHMFL Institution	Project Title	Funding
Thomas Mareci	UF	Unique MR Probe for <i>in vivo</i> Studies of Rats and Mice in a 17.6 T, 89 mm Vertical Magnet	\$195,933
Naresh Dalal	FSU	A Versatile Variable Temperature Probe for the Ultra Wide Bore 21.2 T (900UWB MHz) Spectrometer for High Resolution NMR of Solids	\$199,608
Clifford Bowers	UF	Optical NMR Probes for High Field Optically Pumped NMR Spectroscopy in Semiconductor Quantum Structures	\$199,418
Jason Cooley	LANL	Magnetic Field Dependence of the Latent Heat, Melting and Freezing Points During Solidification	\$200,000
Marcelo Jaime	LANL	Optical Fiber Bragg Grating-based Magnetostriction in Pulsed Magnets	\$190,000
Vivien Zapf	LANL	Phase Transitions in Quenched Magnetic Fields: Emergence of Topological Defects	\$196,000
Eun Sang Choi	FSU	Development of Low Temperature DC Magnetometry	\$159,094

TABLE 3

Facility Enhancements Reported from 2006-2010 UCGP Solicitations

Enhancement and available date	Users *
Silicon micromechanical Faraday balance for absolute magnetization measurements, 1/06	3
OPO laser for IR spectroscopy in conjunction with ICR, 1/07	3
Temperature control of 3He rotator probe for superconductor measurements, 12/06	8
Time-resolved reflection, photoluminescence and Kerr effect spectroscopy, in 17 T and 31 T magnets, 10/07	6
Time domain spectroscopy 200 GHz - 1 THz, 5/09	2
Photoluminescence probe with fiber-free light retrieval, 1/09	1
AFM cantilever tip as the active element in a dilatometer, 9/09	2
Thermal conductivity and specific heat measurements for high fields, 1/05	16
Rotator to perform pulsed critical currents measurements at different temperatures, 4 /09	1
Low temperature HEMT based NMR preamp, for High B/T facility, 5/08	1
Mössbauer facility, 2/07	2
Probe and coils for <i>in vivo</i> NMR with 900 MHz and 600 MHz magnets, 1/09	3
900 MHz high B1 homogeneity dielectric resonator for NMR, 5/09	1
Triple resonance 600 MHz "low E" probe, 3/10	1
Double resonance low E magic angle spinning probe for 750 MHz biological solid state NMR, 12/08	2
High resolution visible spectrometer with LN ₂ -cooled CCD, 7/09	1
Microscope-based setup for room temperature Raman spectroscopy, 8/09	1

* Number of external users (PI's only) reported to have used the enhancements.

TABLE 4

Publications Reported 2006-2010 UCGP Solicitations

App. Phys. Lett.	4
Applied Supercond.	1
Biochemistry	1
Chem. Acta	1
Chem. Commun.	1
Chem. Int. Ed.	1
Chem. Sci.	1
Euro. Biophys. J.	1
Inorg. Biochem.	1
Inorg. Chem.	10
Inst. of Phys. Conf. Series	6
Int. J. Mass Spectrom.	2
J. App. Phys.	4
J. Cryst. Growth	1
J. Low Temp. Phys.	4
J. Membrane Sci.	1
J. of American Chemical Society	4
J. of Magnetic Resonance	4
J. of Physical Chemistry	2
J. Phys.	2
J. Phys. Chem. Lett.	2
J. Phys. Condens. Mat.	5
Langmuir	1
Magnetic Reson. Imaging	1
Magnetic Reson. Med.	1
Materials Science Forum	1
Nature	3
Nature Materials	2
Nature Struct. Mol. Bio.	1
Neuro Image	3
Neurology	1
Phys. Rev. B	21
Phys. Rev. Lett.	14
Physica B	1
Physica C	2
Rev. Sci. Instruments	1
Superconductor Sci. Technology	7
Ultrafast Phenomena	1

Publications (including accepted for publication) as of December 2011, reported from UCGP grants.

time of the reporting, some of these grants were in progress, and some had been completed. For this “retrospective” reporting, Principal investigators (PIs) were asked to include external grants, NHMFL facilities enhancements, and publications that were generated by the UCGP. Since UCGP grants are intended to seed new research through high risk initial study or facility enhancements, PIs were allowed and encouraged to report results that their UCGP grant had made possible, even if these were obtained after the term of the UCGP grant was complete.

Tables 3 and 4 summarize the results. The success of the program is evident from the wide-ranging enhancements produced and from the production of peer-reviewed publications, many in high impact journals. These include 3 articles in *Nature*, 14 in *Physical Review Letters*, and 4 in the *Journal of the American Chemical Society*. A significant positive impact on education is also evident from the reporting, since almost all grants were reported to have supported one or more students, at least partially or through supplies.

CHAPTER 6

Education

Introduction

The Center for Integrating Research & Learning (CIRL) currently runs up to 20 programs each year. Our mission to expand scientific literacy and to encourage interest in and the pursuit of scientific studies among educators and students of all ages has become more specifically targeted to encourage students to pursue STEM career paths. While this has always been a goal of CIRL programming, increasing the number of students entering the STEM pipeline has become a national imperative and one that is a mandate for informal science education. As such, CIRL has expanded programming to include partnerships that attract more students to the sciences. **Jose Sanchez**, assistant director, continues to form partnerships with minority serving institutions to ensure a diverse REU program; in addition, he works closely with Magnet Lab scientists to provide meaningful and productive research experiences for undergraduates, teachers, and high school students. **Carlos Villa**, outreach coordinator, works directly with students, teachers, and the general public to translate the research at the Magnet Lab through classroom outreach, school events, and regular science nights at local venues. **Roxanne Hughes**, postdoctoral associate, facilitates the popular *Science Cafés* as well as *SciGirls* for young women interested in science. In addition, she oversees research and assessment con-



ABOVE Physicist Harrison Prosper engages the crowd at Science Café.

ducted by CIRL.

Magnet Lab scientists who presented at *Science Cafés* in 2011 were **Albert Migliori** from Los Alamos, **Mike Davidson** from FSU, **Vincent Salters** and **Jeff Chanton** from Geochemistry at FSU, **Art Edison**, from the UF site, and **Greg Boebinger**, director of the Magnet Lab. Dedicated **mentorship** by Magnet Lab scientists with CIRL programs is essential to CIRL programming. In 2011, 16 scientists mentored REU students, 10 mentored RET participants, 8 mentored high school interns, and 12 scientists worked with middle school students. Graduate students and postdoctoral associates as well play a major part in the success of

CIRL programs by participating in after-hours activities, science fair judging, and community events, and by providing role models for elementary, middle, and high school students.

CIRL provides an added benefit to scientists who mentor and participate in the many outreach programs by creating opportunities through which they can meet the educational components and broader impacts criteria when submitting individual investigator grant proposals. The infrastructure currently in place encourages scientists to find a way to get involved that closely matches their research, background, and area of mentoring interest.



ABOVE Jose Sanchez “blowing up” peeps for Magnet Mystery Hour.

Research Experiences for Undergraduates

The REU 2011 class hosted 19 students from 14 different universities, including one student from the University of Puerto Rico Mayaguez (UPRM). 2011 marks the fifth year of the collaboration between the Magnet Lab and Dr. Marcelo Suarez, professor at UPRM’s Department of Engineering and Materials. Seventeen dedicated mentors worked with the 2011 REU program. Art Edison from UF worked closely with returning Claflin student Aaron Shepard on how to better understand the cold tolerance of fruit flies through genetic analysis. This is an example of an ongoing partnership between CIRL, scientists, and the Magnet Lab Diversity Program’s CO-WIN project.

The “Where Are They Now?” REU tracking project, headed by doctoral candidate **Brandon Nzekwe**, is currently updating the professional and academic accomplishments of past REU participants. Many of our REUs are pursuing and completing graduate degrees, and others are establishing themselves in the workforce. Through the use of our CIRL REU online social network, past participants are networking with one another as well as maintaining communication with CIRL. The REU tracking project

has expanded into an evaluative study that seeks to create a questionnaire that reliably measures constructs related to occupational role-identity development and attitudes toward science careers of prospective scientists/researchers. This questionnaire is being refined and tested across REU sites and with diverse sample populations of undergraduate science majors.

From 2007-2011, CIRL hosted 32 female and 61 male REU participants. Twenty-six publications were reported, 16 directly related to REU research; 41 former participants are pursuing undergraduate degrees, 11 pursuing Masters, and 19 are pursuing Ph.D.s in science and engineering.

Research Experiences for Teachers

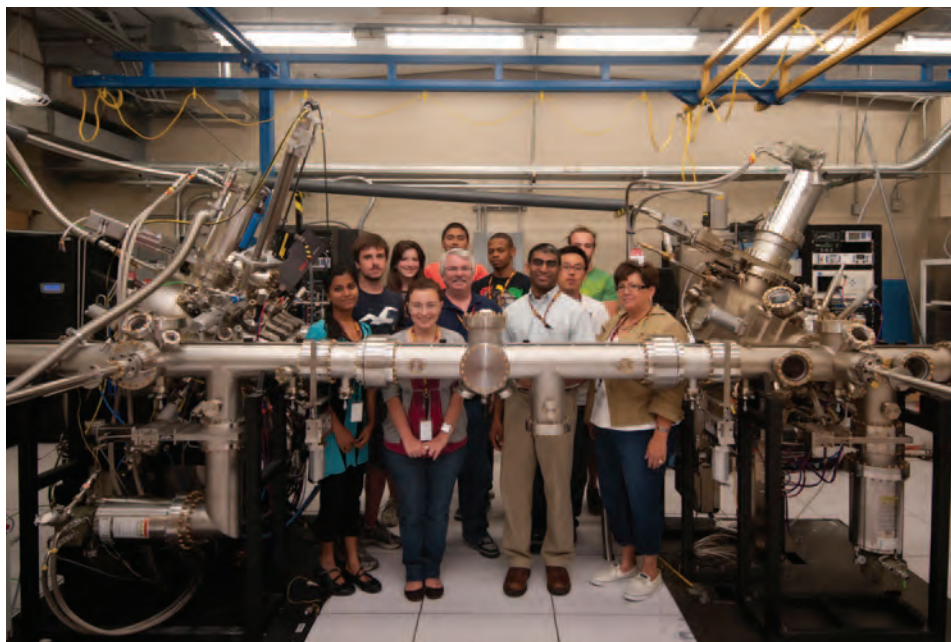
The 2011 RET program hosted 15 teachers, including two teachers from Santa Fe, New Mexico, who will serve as a conduit to expanding Magnet Lab outreach to the Los Alamos area. 2011 Marked the first year of a collaboration between the NHMFL, LANL and the Santa Fe Science Initiative. Two RET positions were created for teachers to become engaged in scientific inquiry. The partnership resulted in travel by **Jose Sanchez** to initiate content-rich professional develop-

ment and outreach in the Los Alamos area that focuses on materials science.

In the fall of 2011, Roxanne Hughes contacted past RETs from 1999-2011--a total of 146 teachers. Of that number eighty nine have working contact information. As of December 31, 2011, 51 of the 89 have responded to the CIRL survey with the following results: 89% are still teaching; 46% were teaching at Title I schools at the time of RET participation and 40% are still at Title I schools; 36% are elementary teachers; 29% middle school teachers; 36% high school teachers.

The teachers highlighted the increased confidence that the RET program gave them in a number of relevant areas, including: 86% feeling more confident about the science content they were teaching and trying new teaching activities; 84% credited the RET with motivating them to look for professional development and allow their students to explore more science topics; 93% said that the RET improved their understanding of science and increased their interest in science. 78% took on formal or informal leadership roles in their school or science education community.

It is estimated that in 2007-2011, 50 middle and high school teachers influenced a total of 125,000 students over the



ABOVE REU and RET mentor Maitri Warusawithana works with high school interns, REU and RET participants.

2011 Research Experiences for Undergraduates 19 Participants

REU Participant	School	Research Area	Mentor
Jason Allen	Florida A&M University	Power T/R Switch for NMR Application	Kiran Shetty
Esha Atolia	Massachusetts Institute of Technology	Management of Ultrahigh-Resolution FT-ICR Mass Spectrometry Crude Oil Data	Ryan Rodgers
Matthew Calkins	University of Florida	Construction and Operation of a Differential Hall Element Magnetometer	Mark Meisel
Daniel Escobedo	Florida State University	Analysis of Filament Fractures in Bronze Processed, Nb ₃ Sn Strands	Peter Lee
Jorge Gonzalez	University of Puerto Rico Mayaguez	Refurbishing and Optimizing a DTA to Analyze Iron-Pnictide	Eric Hellstrom
Jillian Harrison	Claflin University	Heat-Induced Stress Response of <i>Caenorhabditis elegans</i>	Art Edison
Graham Hawkes	University of North Carolina, Chapel Hill	Cavity Resonant Modes, On-chip and Off-chip Studies	Irinel Chiorescu
Ashley Huff	Florida State University	Rutherford Backscattering Calibration	Maitri Warusawithana
Kejing Jiang	Cornell University	Quantitative Analysis of Grain Boundary Dislocation Core Atomic Structures in High-Tc Superconductor YBCO	Yan Xin
Terrie Kweifio	Virginia Tech	The Combination of Direct Analysis in Real Time with Fourier Transform Ion Cyclotron Resonance Mass Spectrometry	Vlad Lobodin
Cody Lamarche	University of Vermont	Magnetic Circular Dichroism of Discotic Organic Semiconductor Crystalline Thin Films	Steve McGill
Eugene Milshteyn	University of Florida	Locating the Hard Plane of Fe ₃ using a 9/5/1 Superconducting Vector Magnet	Steve Hill
Justin Mincey	Bethune-Cookman University	Increasing Materials Strength of 350 Grade Maraging Steel by Cold Rolling and Aging for Higher Field Magnets	Yan Xin
Aaron Shepard	Claflin University	Protocol Development for a Metabolomics Approach to Understanding Cold Tolerance in <i>Drosophila Melanogaster</i>	Art Edison
Alesha Shorts	Garner-Webb University	Molecular Characterization of the Water-Soluble Species Extracted from the Deepwater Horizon Crude by Negative-Ion Electrospray Ionization FT-ICR Mass Spectrometry	Jackie Jarvis
Michelle Sokoll	Florida State University	SPIO Nanoparticle Labeling of Rat Microglia Cells Utilizing MR Microscopy	Sam Grant
Kedrick Vaughans	University of Alabama	Rutherford Backscattering Calibration	Maitri Warusawithana
Michael Wei	Duke University	Solid State Amorphization on the Properties of Materials	Ke Han
Andrew Wray	Florida State University	Digital Image Correlation for Measurement of In-Plane Deformation with Vic-2D in Air and Water	Robert Walsh

5 years; 25 elementary teachers influenced 12,500 students over 5 years. With an increase in confidence reported by RET participants, a significant number of students are being exposed to educators who are excited about science, are more apt to teach science, and who have an understanding of how science research is conducted in real-world situations.

High School Internships

The high school internship program was formalized in 2010 and has become an integral part of CIRL's programs that benefit, students, scientists, and the Magnet Lab as a whole. In 2011 the high school internship program hosted 10 students from 7 different schools. Eight mentors worked with the students throughout the academic

year exposing them to scientific research ranging from ICR to Geochemistry.

Outreach

In 2011, outreach efforts reached 11,442 K12 students, teachers, and members of the general public. CIRL increased its outreach to Title I and underserved schools including rural populations; 52%

2011 Research Experiences for Teachers 15 Participants

REU Participant	School	Research Area	Mentor
Kerry Adams	Shadeville Elementary School	Investigation of High Strength Materials for Achieving Higher Magnetic Fields	Yan Xin
Hakan Armagan	Burke High School	Creating Solid and Hollow Gold Nanoparticles for Use in Laser Spectroscopy	Ken Knappenberger
Barbara Barnard	Rock Lake Middle School	Cavity Resonant Modes, On-chip and Off-chip Studies	Irinel Chiorescu
Donna Barton	Cedar Hills Elementary	Ultra High Vacuum and Much Ado About Almost Nothing	Maitri Warusawithana
Steve Crandall	Inverness Middle School	Ultra High Vacuum and Much Ado About Almost Nothing	Maitri Warusawithana
Logan Crouch	Wakulla Middle School	Investigation of High Strength Materials for Achieving Higher Magnetic Fields	Yan Xin
Jianna Dalton	Rock Lake Middle School	Bi-2212: The Current Density Dynamo	Eric Hellstrom
Joel Falk	Acequia Madre Elementary	Solid State NMR Investigation of Toxic Particles Formed by the Alzheimer's Amyloid- β Protein	Anant Paravastu
Lisa Friend	Manatee Academy Middle	Electron Paramagnetic Resonance in a Holmium based Single Molecule Magnet	Chris Beedle
Carl Krings	Ortiz Middle School	Cavity Resonant Modes, On-chip and Off-chip Studies	Irinel Chiorescu
Matthew Lane	New River Middle School	Creating Solid and Hollow Gold Nanoparticles for Use in Laser Spectroscopy	Ken Knappenberger
Leonda Narramore	Lake Alfred Middle School	Investigation of Strain Within Niobium Grains	Bob Goddard
Jacqueline Norris	Lake City Middle School	Investigation of Strain Within Niobium Grains	Bob Goddard
Michele Van Voorst	Marathon Middle School	Bi-2212: The Current Density Dynamo	Eric Hellstrom
Robert Wallace	Wakulla High School	Solid State NMR Investigation of Toxic Particles Formed by the Alzheimer's Amyloid- β Protein	Anant Paravastu

of total outreach was to these targeted areas. Partnerships with Thomas University (in Thomasville, Georgia), the Big Bend Area Senior Center, 21st Century Learning Community after school programs, Chick-Fil-A, Barnes & Noble Bookstores, and other local community-based venues provide opportunities for Outreach Coordinator **Carlos Villa** and Magnet Lab faculty and staff to provide quality experiences for diverse audiences.

During the 2010-2011 school year, over 11,500 students in grades K-12 received outreach by CIRL staff. This is an increase from 9800 students in the previous school year. Over half of the outreach visits to public schools were to Title I schools (52%), also an increase from last year.

All of the teachers who responded to the survey (94) rated their outreach experience as good or better, with 88%

of these respondents rating the outreach as excellent. All of the teachers said that they would definitely participate in the program again.

Eighty-seven percent of respondents said that the outreach inspired them to incorporate more hands-on lessons in their teaching; 91% believed that the content was relevant to their instructional needs; 92% said that the materials were developmentally appropriate for their students; and 88% believed that the outreach contributed to their professional growth by expanding their instructional repertoire.

Last year's goal for outreach was to reach more Title I schools and expand outreach audiences. Both of these were achieved. All of the teachers surveyed claimed that they would recommend this program to their colleagues and gave the overall program a rating of good or better.



Middle School Mentorship

In addition to classroom outreach and on-site outreach and tours, middle school mentorship has been a part of CIRL programming for 15 years. In spring 2011, 13 students worked alongside scientists and engineers from the lab, researching the conductivity of foods, the collapse of a bridge, and isolated metallic isotopes



ABOVE Scientist Randall Hughes works with SciGirls II at the FSU Marine Lab.

in water samples from their school and communities. In partnership with a local charter school, participants spend one morning each week for a semester with their mentors culminating in a public presentation of their research.

Summer Camps

SciGirls I and II summer camps completed their sixth year in 2011 with 36 middle and high school girls participating in the 2-week experience. *SciGirls* is a partnership between the Magnet Lab and WFSU, the local public television station, to engage young women in STEM activities with role models. More than 166 young women have gone through the program and exhibit an interest in continuing engagement with both the program and with STEM courses. With support from public television, the Magnet Lab, local and international engineering firms, and engaged individuals, *SciGirls* provides a rigorous science-based experience through which young women learn about diverse science careers.

As part of the ongoing assessment of the program, CIRL staff is in the process of contacting participants who have graduated from high school and are entering college. Fifteen young women have been interviewed, all of whom are interested in science; 50% of them are majoring in a STEM field in college. Pre and post program surveys demonstrate that the camp has positive and significant improvements on participants' perceptions of scientists and science careers. Based on the post survey responses, the majority of the participants felt that the camp had increased their interest in science (80%) and science careers (81%). Thirty of the girls (88%) also said that the camp gave them

new positive perceptions of scientists and engineers.

Maglab Summer Science Camp was launched in 2011. Sixteen students spent one week at the lab in hands-on enrichment activities where the focus was engineering and physics. Campers worked collaboratively on engineering projects, participated in field trips, and interacted with lab engineers.

Partnerships

Maintaining and nurturing partnerships provides numerous opportunities for CIRL to expand programming, create new programs, and to take advantage of the greater academic community. Creating new partnerships through which CIRL conducts educational activities expands the base for research and assessment and for providing even more opportunities for K12 students and teachers. In 2011, CIRL's continuing partnership with WFSU provided media coverage for a wide variety of programs including the Magnet Lab's annual Open House. The original *SciGirls* grant was provided by public television and WFSU has provided CIRL with many opportunities to introduce hands-on science to young children and their families. The Panhandle Area Educational Consortium (PAEC) has con-

sistently looked to CIRL for educational resources for teacher professional development. In 2011 and 2012, CIRL Assistant Director **Jose Sanchez** is overseeing the development of activities to translate the complex concepts relative to nanotechnology for high school students and teachers.

CIRL is facilitating educational outreach for the *Deep-C Project*, which is part of a nine institution consortium funded by BP to study the effects of the Deepwater Horizon oil spill on coastal ecosystems. The Engineering Research Center FREEDM partnership with the FAMU-FSU College of Engineering, the Center for Advanced Power Systems, and North Carolina State University has allowed CIRL to offer a camp for middle school students, as well as paid internships for high school Young Scholars and for teachers to participate in an RET program related to renewable energy.

Thomas University faculty and students have been trained by CIRL educators to better serve K12 students in South Georgia. The partnership has resulted in science outreach to all Thomas County and City of Thomasville K12 students. CIRL will continue its involvement by participating in large outreach events. In addition, **Roxanne Hughes** assisted Thomas University faculty in establishing



ABOVE ERC FREEDM Young Scholars explore the power plant.



ABOVE Maglab Science Camp participants explore the interaction of Mentos with assorted carbonated sodas.

a *Science Café* for the Thomasville, Georgia, area. Events have been well attended with Magnet Lab Director **Greg Boebinger** giving the first talk that attracted a large and diverse audience.

Research

CIRL's research agenda is overseen by Post Doctoral Associate **Roxanne Hughes**, who was primary author on three publications:

- Hughes, R., Molyneaux, K., and Dixon, P. (2011) The Role of Scientist Mentors on Teachers' Perceptions of the Community of Science during a Summer Research Experience. *Research in Science Education*, (DOI) 10.1007/s11165-011-9231-8.
- Hughes, R. (2010). Keeping women in STEM fields. *International Journal of Gender, Science and Technology*, 2(3), 417-436.
- Hughes, R. (November 2011). Are the predictors of women's persistence in STEM painting the full picture? A series

of comparative case studies. *International Journal of Gender, Science and Technology*, 3 (3) 547-50.

In addition to the publications, presentations were made at the American Educational Research Association, the Association for Research in Science Teaching, and the Research on Women and Education conference.

CIRL conducts assessment on all programs as well as longitudinal research on *SciGirls*, REU and RET; comparative educational research is being conducted on all summer camps. Continuing engagement with the broader informal science education community is important to CIRL's national collaborations.

CHAPTER 7

Industrial Partners & Collaborations

Magnet Lab researchers and staff develop partnerships and collaborations with the private sector, federal agencies, and institutions and international organizations, resulting in a wide variety of magnet-related technologies and advancing other projects that bring technologies closer to the marketplace. Engaging in such research and development activities is part of the National Science Foundation's charge to the Magnet Lab.

Magnets, Magnet Technologies and Materials for Magnets

Advanced Conductor Technologies, Boulder, CO

The Applied Superconductivity Center and the Magnet Science and Technology division of the Magnet Lab are collaborating with Advanced Conductor Technologies on the development and testing of Coated Conductor Stranded Cable (CCSC), using multi-layer spiraling tapes around a core, for magnet applications. Danko van der Laan, director of the company and associated with NIST/University of Colorado Boulder is developing compact cables based on REBCO coated conductors, a High Temperature Superconductor. The ongoing collaboration resulted in the first measurements ever of HTS cables at low temperature and high magnetic field (4 K and 20 T in Cell 4).

(Magnet Lab contact: Huub Weijers, MS&T)

Advanced Magnet Lab, Inc., Palm Bay, FL

Engineers from the NHMFL are collaborating with Advanced Magnet Lab, Inc. to produce the innovative field-correction shims required to decrease spatial and temporal field disturbances in the Series-Connected Hybrid (SCH). Advanced Magnet Lab has provided the precision fabrication processes required to produce these innovative shims for the first-of-a-kind SCH magnet system that will produce 1 ppm field homogeneity at 36 T.

(Magnet Lab contact: Tom Painter, MS&T)

Criotec Impianti, Chivasso, Italy; ENEA, Rome, Italy

The Magnet Lab has collaborated with Criotec Impianti, an Italian cryogenic systems manufacturing company, and ENEA, an Italian Fusion Energy Research Organization, to jacket the cable-in-conduit superconductor for the outsert coils of the series-connected hybrid magnets. This work includes the welding and inspection of the stainless steel conduit, insertion of the cabled superconductor strands into the conduit, and compaction of the assembled conductor to a rectangular cross-section.

(Magnet Lab contact: Iain Dixon, MS&T)

Danfoss Turbocor Inc., Tallahassee, FL

Danfoss Turbocor Inc. is a company specializing in compressors, particularly the totally oil-free compressors. The compressors are specifically designed for the heating, ventilation, air conditioning and refrigeration (HVACR) industry and need high performance soft and hard magnet materials. The company and the laboratory started a joint research project on selection, characterization and development of permanent magnet materials for high performance and environmental friendly compressors.

(Magnet Lab contact: Ke Han, MS&T)

Faculty of Material Science and Engineering, Kunming University of Science and Technology, China

The collaboration between the Kunming University and the Magnet Lab is related to the magnetic field impact on phase transformation in steels. A professor from Kunming University will come to the Magnet Lab as a visiting scientist for one year to do the research.

(Magnet Lab contact: Ke Han, MS&T)

High Performance Magnetics (HPM), Tallahassee, FL

This start-up company is a spin-off from the Magnet Lab's Magnet Science & Technology Division and is involved in the US-DOE ITER program. The Cable-in-Conduit-Conductor (CICC) technology used successfully in the NHMFL High Field DC Hy-

brid magnets) is being advanced at HPM with the development of a state-of-the-art CICC jacketing production line. The jacketing process requires advance weld techniques that alter critical mechanical properties of the conduit. HPM has contracted with the Magnet Lab to additionally process the welds and to perform 4 K qualification tests.

(Magnet Lab contact: Bob Walsh, MS&T)

HZB, Berlin, Germany

In March 2007, HZB (formerly the Hahn-Meitner Institute) signed an agreement with Florida State University Magnet Research and Development to develop a Series-Connected Hybrid magnet suitable for neutron scattering experiments and to install it at HZB. The magnet is intended to provide 25 T on-axis using 4.4 megawatts of DC power and have upstream and downstream scattering angles of 30 degrees. Four external design reviews have been held with an international committee of reviewers. Fabrication of the magnet is underway: The superconducting strand has been delivered and cabled and jacketed, the cryostat has been ordered and is well into fabrication, winding of the superconducting coil is about halfway through, and design of the resistive insert coils is underway.

(Magnet Lab contact: Mark D. Bird, MS&T)

Industrial Research Limited, Lower Hutt, New Zealand

The Applied Superconductivity Center and the Magnet Science and Technology division of the Magnet Lab are collaborating with researchers at New Zealand's Industrial Research Limited on the testing of Roebel-style cables based on REBCO coated conductors, a high temperature superconductor. Testing of a 15-strand cable with transposed 5 mm wide strands is in preparation. Roebel-style cables represent one of three viable concepts for REBCO coated conductor cables suitable for high field magnets.

(Magnet Lab contact: Huub Weijers, MS&T)

Institute of Metal Research, Chinese Academy of Sciences, Shenyang, China

The collaboration between the Institute of Metal Research and the Magnet Lab is related to the characterization of stainless steels and other structural materials for high field magnets. The materials are mainly stainless steel 316LN and maraging steels with high mechanical strength.

(Magnet Lab contact: Ke Han, MS&T)

International Thermonuclear Experimental Reactor (ITER), US-ITER Project Office, Oak Ridge, TN

The United States is part of an international collaboration to construct and operate ITER, a full-scale experimental device designed to demonstrate the feasibility of the production of fusion energy. The Magnet Lab's Magnet Science and Technology division is assisting in the research and development of large superconducting magnets and components for the enormous Fusion Reactor Tokamak. Engineers in MS&T are collaborating on magnet design topics such as stress analysis, component tests, and materials characterization.

(Magnet Lab contact: Bob Walsh, MS&T)

Lawrence Berkeley Laboratory, Accelerator and Fusion Research, Berkeley, CA

The Applied Superconductivity Center and the Magnet Science and Technology division of the Magnet Lab are collaborating with researchers at the Berkeley National Laboratory on the testing of Roebel-style cables based on REBCO coated conductors, a high temperature superconductor. Testing of a 10-strand cable with transposed 2 mm wide strands is in preparation. Roebel-style cables represent one of three viable concepts for REBCO coated conductor cables suitable for high field magnets.

(Magnet Lab contact: Huub Weijers, MS&T)

Scientific Magnetics, Abingdon, England

Scientific Magnetics is a designer and manufacturer of superconducting magnets and cryogenic equipment. The Maglab is collaborating with Scientific Magnetics for the design and manufacturing of the Central Distribution Box of the cryogenic system. The CDB will be used for the cooling of the Series Connected Hybrid and also the 45 T Hybrid magnet.

(Magnet Lab contact: Hongyu Bai, MS&T)

Technique Materials Inc., Lincoln, RI

Technique Materials Inc. is a company specializing in fabrication of materials via glazing, plating, and coating. The company and the laboratory have undertaken a joint research project on fabrication of high strength conductors for next generation magnets. Because of the high efficiency of the fabrication approach, nanostructured conductors can be fabricated in a reasonable time.

(Magnet Lab contact: Ke Han, MS&T)

University of Science and Technology Beijing, Department of Materials Science and Engineering, Beijing, China

The collaboration between the University of Science and Technology Beijing and the Magnet Lab is related to the thermodynamic calculations of the multi-elements and multiphase systems. Currently, efforts are focused on understanding interstitial elements impact on the precipitation in steels for high field magnets.

(Magnet Lab contact: Ke Han, MS&T)

Ion Cyclotron Resonance

Falk Center for Molecular Therapeutics, Northwestern University, Evanston, IL

Joseph R. Moskal and Roger A. Kroes are collaborating with the FT-ICR group on the inhibition of invasion of glioblastoma brain tumors through gene therapy. Drs. Moskal and Kroes bring their unique glyco-gene array technology and expertise in the field of glycomics to the collaboration, which permits a systems biology approach (proteomics, lipidomics, glycomics, transcriptomics and phenotypic response) to the search for therapeutic targets for treatment of glioblastoma brain tumors.

(Magnet Lab contact: Alan Marshall, ICR)

General Electric Global Research, Niskayuna, NY

In the continuing effort to explore the utility of heavy oils, the FT-ICR MS facility has joined a collaborative research project with GE to provide a detailed inventory of heavy petroleum species. Of specific interest are metal-containing species (porphyrins) that are corrosive upon combustion. The project resulted in the first direct determination of metal (Ni and V) porphyrin species in unfractionated heavy crude oil.
(Magnet Lab contact: Ryan Rodgers, ICR)

M.D. Anderson Cancer Center, Houston, TX

This collaboration with Charles A. Conrad, M.D., associate professor of neurooncology and medical director of the Anne C. Brooks Neuro Center, involves the study of a protein (galectin-1) as a therapeutic target in the progression of glioblastoma multiforme brain tumors. The galectin target was discovered in previous collaborations between Conrad, Carol L. Nilsson (then of Goteborg University), and Mark R. Emmett of the FT-ICR program. The initial collaboration was primarily funded by a Swedish STINT grant. Recently, Mike Davidson, director of the Magnet Lab's Optical Microscopy group, joined the collaboration to provide high-resolution fluorescent photomicroscopy of the live glioblastoma cell lines.
(Magnet Lab contacts: Alan Marshall, ICR, and Mike Davidson, Optical Microscopy)

Nalco, Sugarland, TX

Deposits formed in petroleum production equipment pose major obstacles to safe, economical production of heavy oils in both terrestrial and deep off shore production environments. With the help of Nalco, the FT-ICR group has provided detailed compositional analysis for emerging production deposits for new and late production oil reserves all over the globe. The compositional information is vital to the design of the next generation of chemical dispersants and inhibitors to reduce deposition in the transport of heavy petroleum reserves. Another concern is that many species in oil that are soluble under reservoir conditions (high temperature and pressure) become unstable when oil production starts. Their precipitation poses significant problems. The FT-ICR facility has begun the compositional analysis of pressure-induced and temperature-induced precipitants from live oil samples in collaboration with Chevron. The results show that specific classes (chemical functionality) preferably precipitate when either the temperature or pressure is dropped from reservoir conditions.
(Magnet Lab contact: Ryan Rodgers, ICR)

Penn State University, University Park, PA

In collaboration with Jonathan Matthews at Penn State University, ICR scientists recently provided detailed compositional analysis of pyridine soluble coal species to aide in the construction of a detailed model of coal behavior. The Penn State model contains tens of thousands of individual molecules and is the most detailed model constructed to date. The FT-ICR MS data was used to validate the model through comparison with compositional data afforded by the FT-ICR Mass Spectrometers in the NSF-funded High Field FT-ICR MS facility.
(Magnet Lab contact: Ryan Rodgers, ICR)

Pfizer, Andover, MA

This collaboration is with Jason C. Rouse, who directs mass spectrometry research and development at Pfizer Andover. Current research focuses on identifying and locating the sites of post-translational chemical modifications of antibodies by top-down proteomics (i.e., direct analysis of intact gas-phase antibody molecules).

(Magnet Lab contact: Alan Marshall, ICR)

Scripps Research Institute

Current collaborations include principal investigators at Scripps La Jolla (Paul Schimmel, Xiang-Lei Yang) and Scripps Florida (Ming Guo). The common thread is structural characterization of transfer RNA synthetases functioning in roles other than protein synthesis. Those functions result from complexation of a given synthetase with one or more other proteins. Synthetase mutations lead to various diseases. Scripps provides the mutants, and we use hydrogen/deuterium exchange monitored by FT-ICR mass spectrometry to map the protein: protein contact surfaces in the complexes to establish structure: function relationships.

(Magnet Lab contact: Alan Marshall, ICR)

Sierra Analytics, Modesto, CA

The lab's ICR research team maintains a licensing agreement with Sierra, a company that provides mass spectrometry software to petroleum companies. The software contains high level algorithms for identification of thousands of compounds in petroleum mass spectra, obtained through the lab's pioneering Fourier transform ICR technique development. Lab researchers and Sierra Analytics continue to share updated information, enabling both to stay atop the petroleomics field.

(Magnet Lab contact: Chris Hendrickson, ICR)

Woods Hole Oceanographic Institute

As part of FSU's Gulf Research Initiative Consortium, the Magnet Lab collaborates with Christopher Reddy and Robert Nelson at WHOI in characterization of petroleum oil spills at the molecular level, by gas chromatography/gas chromatography and FT-ICR mass analysis. Characterization of the 2010 Macondo wellhead oil has been completed, and current research focuses on subsequent physical, chemical, and biological changes as the spill propagates into the environment.

(Magnet Lab contact: Ryan Rodgers, ICR)

Nuclear Magnetic Resonance**Agilent Technologies, Life Sciences/
Chemical Analysis Division, Santa Clara, CA**

Investigators from Magnet Lab facilities at UF and FSU collaborate with technical staff at Agilent on an NIH-funded project to develop improved superconductive cryogenic probes for solution NMR.

(Magnet Lab contacts: William Brey, NMR and Art Edison, AMRIS)

Bruker Biospin Corp., Billerica, MA

The Magnet Lab's NMR instrumentation program and Bruker Biospin collaborate on the development of Low-E probes for solid-state NMR in heat sensitive biological samples, such as proteins. Bruker Biospin manufactures a line of Efree probes based on the Low-E design developed at our lab.

(Magnet Lab contact: Peter Gor'kov, NMR)

Revolution NMR, Fort Collins, CO

The Magnet Lab's NMR instrumentation program and Revolution NMR collaborate on the development of stators for magic angle spinning NMR and on sample chambers for static solid-state NMR.

(Magnet Lab contact: Peter Gor'kov, NMR)

Université des Sciences et Technologies de Lille, Lille, France

The Magnet Lab accepted a contract to develop a Low-E RF probe for solid-state NMR of aligned proteins. The instrument will be used by the research group of Professor Jean-Paul Amoureux.

(Magnet Lab contact: Peter Gor'kov, NMR)

University of Oxford, Oxford, England

The Magnet Lab completed a contract to develop a Low-E RF probe for solid-state NMR of aligned proteins. The instrument is used by the research group of Professor Anthony Watts.

(Magnet Lab contact: Peter Gor'kov, NMR)

Education

Columbia University, Stanford University, University of California Santa Barbara, University of Rhode Island

The Center for Integrating Research & Learning continues its collaboration with other institutions that conduct educational outreach with teachers. Through the Research Experiences for Teachers (RET) Network, the Center maintains a national presence among other laboratories, centers, and universities that conduct RET and other teacher enhancement programs. Current projects include expansion of the current RET Network website to include input from additional sites and an interactive component to share best practices. In addition, the RET Network will be a comprehensive site that compiles lists of RET programs across the country.

(Magnet Lab contact: Pat Dixon, Educational Programs)

Leon County Schools, Tallahassee, FL

The Center for Integrating Research & Learning facilitates science workshops and summer institutes for Leon County Schools. With high stakes testing in science now part of school accountability, the Center has responded to the call of teachers and schools to provide quality professional development. The Center currently maintains formal partnerships with two elementary schools, three middle schools, and two high schools.

(Magnet Lab contact: Pat Dixon, Educational Programs)

North Carolina State University, Raleigh, NC

In partnership with the Center for Advanced Power Systems and the FAMU-FSU College of Engineering, the Center for Integrating Research & Learning supports ERC FREEDM educational and assessment activities. Working with The Science House and the ERC FREEDM Center at North Carolina State University, CIRL facilitates the pre-college education program through summer camps, Young Scholars high school internship programs, and Research Experiences for Teachers. In addition, one full-time graduate student coordinates assessment at all locations participating in the FREEDM grant.

(Magnet Lab Contact: Pat Dixon, Educational Programs)

Wakulla County Schools, Crawfordville, FL

After-school workshops are conducted by the Center for Integrating Research and Learning staff each month. Located at Riversink Elementary School in Crawfordville, FL, teachers from the entire district are invited to attend workshops. The school district facilitates workshop registration and coordinates the ongoing partnership.

(Magnet Lab contact: Jose Sanchez, Educational Programs)

WFSU-TV, Tallahassee, FL

The Center for Integrating Research & Learning partners with WFSU-TV, the area's public television station, to administer SciGirls. The program is a 2-week camp for middle and high-school girls with an interest in science. The collaboration between the Magnet Lab and WFSU-TV has resulted in a successful 6-year camp that has engaged the larger community. In addition, WFSU-TV and the Center partner to provide summer physics experiences for students entering high school.

(Magnet Lab contact: Pat Dixon, Educational Programs)

Optical Microscopy

89 North, Burlington, VT

Scientists at the Magnet Lab are working with applications specialists at 89 North to develop light-emitting diode technology for fluorescence microscopy. This collaboration involves testing the power output and usability of new high-power LED technology in the emission region between 490 and 590 nanometers, a spectral region that is central to microscopy investigations.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Agilent Technologies, Santa Clara, CA

Agilent Technologies is entering the imaging arena with a new "Monolithic" laser combiner featuring acousto-optic-tunable filter (AOTF) control. The Magnet Lab is collaborating with Agilent to prototype the laser system for use in super-resolution imaging.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Allele Biotech, San Diego, CA

Allele is a manufacturer and distributor of fluorescent protein constructs made by Robert Campbell and Nathan Shaner. The

Magnet Lab is collaborating with Allele to develop fusion vectors of selected fluorescent proteins.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Andor-Tech, Belfast, Northern Ireland

Andor-Tech is an imaging specialist involved with development of CCD camera systems designed to produce images at extremely low light levels. The Magnet Lab is collaborating with Andor-Tech to produce interactive tutorials describing electron multiplying CCD (EMCCD) technology and will work with the company to test new camera products in live-cell imaging.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

B&B Microscopes, Pittsburgh, PA

Scientists in the Optical Microscopy facility at the Magnet Lab are working with B&B engineers to develop new live-cell imaging techniques using the wide array of products offered by the company. Eventually, an educational website is planned.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Bioptechs, Butler, PA

The Magnet Lab is involved with Bioptechs of Pennsylvania to develop live-cell imaging techniques using the company's advanced culture chambers. The collaboration involves time-lapse imaging of living cells over periods of 36-72 hours using techniques such as differential interference contrast, fluorescence, and phase contrast.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Chroma, Rockingham, VT

A major supplier of Interference filters for fluorescence microscopy and spectroscopy applications, Chroma is collaborating with the Magnet Lab to build educational tutorials targeted at fluorescence microscopy. Working in conjunction with Nikon, engineers from Chroma and scientists from the Magnet Lab are examining the characteristics of a variety of filter combinations.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

The Cooke Corp., Romulus, MI

Scientists at the Magnet Lab are working with applications specialists at Cooke to field test the company's cooled and electron-multiplied scientific CCD camera systems. Demanding applications in quantitative image analysis and high-resolution images are being explored, as well as time-lapse fluorescence microscopy and resonance energy transfer imaging.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

CoolLed Ltd., Andover, Hampshire, United Kingdom

Scientists at the Magnet Lab are working with applications specialists at CoolLed to develop light-emitting diode technology for fluorescence microscopy. This collaboration involves testing the power output and usability of new LED technology in the emission region between 490 and 590 nanometers, a spectral region that is central to microscopy investigations.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Covance Research Products, Berkeley, CA

Covance is a biopharmaceutical company involved with research and diagnostic antibody production. Magnet Lab scientists are working with Covance researchers to examine immunofluorescence staining patterns in rat and mouse brain thin and thick sections using a wide spectrum of antibodies.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Diagnostic Instruments, Sterling Heights, MI

Scientists at the Magnet Lab are working with applications specialists at Diagnostics to field test the company's new line of cooled scientific CCD systems. Demanding applications in quantitative image analysis and high-resolution images are being explored, as well as time-lapse fluorescence microscopy and resonance energy transfer imaging.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Evrogen, Moscow, Russia

Evrogen is a manufacturer and distributor of fluorescent protein constructs made by Dmitriy Chudakov and Vladislav Verkhusha. The Magnet Lab is collaborating with Evrogen to develop fusion vectors of selected fluorescent proteins.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

EXFO, Mississauga, Ontario, Canada

The Magnet Lab is collaborating with EXFO to examine the spectra and output power of various illumination sources for microscopy including metal halide lamps, light engines, LEDs, and the LiFi illumination system.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Hamamatsu Photonics, Bridgewater, NJ

Scientists at the Magnet Lab are working with applications specialists at Hamamatsu to field test the company's cooled and electron-multiplied scientific CCD camera systems. Demanding applications in quantitative image analysis and high-resolution images are being explored, as well as time-lapse fluorescence microscopy and resonance energy transfer imaging.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Linkam, Surrey, United Kingdom

Scientists at the Magnet Lab collaborate with Linkam engineers to design heating and cooling stages for observation of liquid-crystalline phase transitions in the optical microscope. In addition, microscopists are assisting Linkam in introducing a new heating stage for livecell imaging in fluorescence microscopy.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Lumencor Inc., Beaverton, OR

The Magnet Lab is collaborating with Lumencor to examine the spectra and output power of various illumination sources for microscopy including metal halide lamps, light engines, LEDs, and the LiFi illumination system.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

MBL International, Woburn, MA

Scientists at the Magnet Lab are collaborating with MBL to develop new fluorescent proteins for live-cell imaging applications. These include both optical highlighters and fluorescence resonance energy transfer (FRET) biosensors.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Media Cybernetics, Silver Spring, MD

Programmers at the Magnet Lab are collaborating with Media Cybernetics to develop imaging software for timelapse optical microscopy. In addition, the Optical Microscopy group is working to add new interactive tutorials dealing with fundamental aspects of image processing and analysis of data obtained with the microscope.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Molecular Probes/Invitrogen, Eugene, OR

A major supplier of fluorophores for confocal and wide-field microscopy, Molecular Probes is collaborating with the Magnet Lab to develop educational tutorials on the use of fluorescent probes in optical microscopy.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Nikon USA, Melville, NY

The Magnet Lab maintains close ties with Nikon on the development of an educational and technical support microscopy website, including the latest innovations in digital-imaging technology. As part of the collaboration, the Magnet Lab is field-testing new Nikon equipment and developing new methods of fluorescence microscopy.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Olympus America, Melville, NY

The Magnet Lab is developing an education/technical website centered on Olympus products and will be collaborating with the firm on the development of a new tissue culture facility at the Magnet Lab in Tallahassee. This activity will involve biologists at the Magnet Lab and will feature Total Internal Reflection Fluorescence microscopy.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Olympus Corp., Tokyo, Japan

Investigators at the Magnet Lab have been involved in a collaboration with engineers at Olympus to develop and test new optical microscopy systems for education and research. In addition to pacing the microscope prototypes through basic protocols, the Optical Microscopy group is developing technical support and educational websites as part of the partnership.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Omega Optical, Brattleboro, VT

The Magnet Lab is involved in a collaboration with Omega to develop interactive tutorials targeted at education in fluorescence filter combinations for optical microscopy. Engineers at Omega work with Magnet Lab microscopists to write review articles about interference filter fabrication and the interrelationships

between various filter characteristics and fluorophore excitation and emission.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Photometrics (Roper Scientific Inc.), Tucson, AZ

The microscopy research team at the Magnet Lab is exploring single molecule fluorescence microscopy using electronmultiplying CCD camera systems developed by Photometrics. In addition, the team is conducting routine fixed-cell imaging with multiple fluorophores to gauge camera performance.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Prior Scientific Inc., Rockland, MA

Prior is a major manufacturer of illumination sources and filter wheels for fluorescence microscopy. The Magnet Lab team is collaborating with Prior to develop new illumination sources and mechanical stages for all forms of microscopy.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Qimaging, Burnaby, British Columbia, Canada

High-resolution optical imaging is the focus of the Magnet Lab collaboration with Qimaging, a Canadian corporation that specializes in CCD digital cameras for applications in quantitative image analysis and high-resolution images for publication. Target applications are interactive tutorials and image galleries that will be displayed on the Internet.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Semrock, Rochester, NY

The Magnet Lab Optical Microscopy group is collaborating with Semrock to develop interactive tutorials targeted at education in fluorescence filter combinations for optical microscopy. Engineers and support personnel at Semrock work with Magnet Lab microscopists to write review articles about interference filter fabrication and the interrelationships between various filter characteristics and fluorophore excitation and emission. In addition, Magnet Lab scientists produce images of living cells with Semrock filter combinations.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Sutter Instrument, Novato, CA

The Magnet Lab is collaborating with Sutter to examine the spectra and output power of various illumination sources for microscopy including metal halide lamps and the LiFi illumination system.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

Zeiss Micro Imaging, Thornwood, NY

The Optical Microscopy group at the Magnet Lab is negotiating a contract with Zeiss on the development of an educational and technical support microscopy website, including the latest innovations in digital imaging technology. As part of the collaboration, microscopists are field-testing new Zeiss equipment and developing new methods of fluorescence microscopy.

(Magnet Lab contact: Mike Davidson, Optical Microscopy)

CHAPTER 8

Conferences and Workshops

National Science Foundation Large Facilities Workshop

April 19-21, 2011

Tallahassee, Florida – Augustus B. Turnbull III Florida State Conference Center

Event Organizer: Brian Fairhurst

Attended by over 80 participants, the purpose of this annual meeting was to bring together NSF staff and personnel from the NSF-funded large facilities. The workshop provided a strategic forum for discussing best practices, sharing lessons learned, making new contacts, and fostering close interactions between facilities. Themes and topics included: Stewardship, management, and the business of large facilities; user programs: selection and time allocation; challenges for NSF large facilities; role and impact of large facilities in outreach and public education; and miscellaneous topics relevant to large facilities operations. The event was preceded by a Pre-Conference Large Facilities Working Session.

8th North American FT MS Conference

May 1-5, 2011

Key West, Florida – Key West Marriott Beachside Hotel

Event Organizer: Alan Marshall

The 8th Biennial North American FT MS Conference was held May 1-5, 2011 in Key West, Florida. Attended by 79 researchers, the conference began with a welcome mixer in the evening, and ended Wednesday evening with a banquet dinner. The FT MS Conference is held every two years and is the premier meeting of its kind in the field of Fourier Transform Mass Spectrometry and its applications. Presentations ranged from instrumentation to technique development in the biological/biomedical sciences; from pharmaceutical metabolism to proteomics; and environmental analysis and petroleomics, with special emphasis on new developments. Partial support was provided to several graduate students and postdocs who contributed posters.

Magnet Lab User Summer School

May 16-20, 2011

Tallahassee, Florida – Magnet Lab

Event Organizer: Albert Migliori

The third annual weeklong summer school featured tutorials on measurement techniques, practical exercises and plenary talks from experts in the field of condensed matter physics. This year's Summer School was attended by 25 advanced graduate students, postdoctoral associates and early career investigators looking to gain practical measurement experience.

The next User Summer School will be held May 14-18, 2012.



ABOVE Students gather inside a Magnet cell to learn about instrumentation from Jan Jaroszynski (left) as part of 2011's User Summer School program.



ABOVE Attendees of the Electronic Properties of Two Dimensional Electron Systems / Modulated Semiconductor Structures Conference share research posters with other scientists.

The 19th International Conference on Electronic Properties of Two-Dimensional Electron Systems and the 15th Conference on Modulated Semiconductor Structures

July 25-29, 2011

Tallahassee, Florida – Augustus B. Turnbull III Florida State Conference Center

Event Organizer: Lloyd Engel

EP2DS emphasizes the fundamental physics, including transport and optical properties of electronic states in low dimensional systems, which now include graphene, nanotubes and dielectric interfaces. MSS addresses the synthesis, processing and applications of modulated materials, as well as novel systems, the broader range of carbon based, hybrid, modulated organic, spintronic, and biologically based modulated structures. EP2DS/MSS was attended by 385 participants from 28 countries.

New Frontiers in High Field Condensed Matter NMR

October 14-15, 2011

Tallahassee, Florida – Magnet Lab

Event organizer: Arneil Reyes

This workshop was organized in conjunction with NHMFL's Annual User Committee Meeting. The purpose of this workshop was to bring together experts in the field, users, and prospective users of the Magnet Lab facilities to share views, science, and identify problems and solutions related to performing NMR

spectroscopy in high magnetic fields from the point of view of condensed matter systems. In particular, the Magnet Lab is building the new 36/41 T Series Connected Hybrid, which is scheduled to be commissioned in mid-2014. One particular feature of this magnet (compared to the 45 T Hybrid) is its higher homogeneity and power stability suitable for higher resolution (40 mm bore, 1 ppm/10 mmDSV) NMR due to large outsert inductance. Another is its very low power usage, which would allow running experiments over extended periods. The event included a panel discussion with active audience participation on ideas where this magnet can be used to its full potential. The workshop welcomed around 40 participants.

New Frontiers in the Physics of Two Dimensional Electron Systems (ICAM)

November 23-25, 2011

Buenos Aires, Argentina

The Magnet Lab was a partial sponsor of the 2011 ICAM gathering, and the laboratory's Dragana Popovic and Maitri Warusawithana were invited speakers. This year's topics included LAO/STO and oxide interfaces: 2DEG, photoemission, electrostatic doping, DMFT approaches, transport, multiferroic films, etc. Other 2DEGs: graphene and MOSFETs. Correlation effects in 2DEGs, Wigner crystallization, spin liquids. Other directions: Memristors and resistive switching, holographic duality and the Quantum Hall Effect, 2D atomic crystals.

CHAPTER 9

Management & Administration



ABOVE Group shot of personnel from the Magnet Lab's Tallahassee headquarters.

The Florida State University, the University of Florida and Los Alamos National Laboratory jointly operate the National High Magnetic Field Laboratory for the National Science Foundation under a cooperative agreement that establishes the laboratory's goals and objectives. Florida State University is responsible for establishing and maintaining administrative and financial oversight of the lab, and for ensuring that operations are in line with the objectives outlined in the cooperative agreement.

Management

The NHMFL Organizational Chart (**Figure 1**) shows the detailed interfaces between internal and external organizations.

Gregory Boebinger serves as director and principal investigator of the Magnet

Lab. He oversees the seven user facilities, magnet science and technology, the activities of the Applied Superconductivity Center, the associate lab director, health and safety, and public affairs.

Brian Fairhurst serves as associate lab director and he has the primary responsibility for Management and Administration. He oversees budgeting and finance, human resources and facilities.

The Magnet Lab has five co-principal investigators on the NSF grant. They are:

- Tim Cross (FSU), Nuclear Magnetic Resonance facility director
- Arthur Edison (UF), Chem/Bio director
- Alan Marshall (FSU), Ion Cyclotron Resonance facility director
- Charles Mielke (LANL), Pulsed Magnet facility director
- Neil Sullivan (UF), High B/T facility director.

The lab's scientific direction is overseen by the **Science Council**, a multidisciplinary group of distinguished faculty from all three sites that serves as a think tank to consider and help guide the lab's scientific mission. Members are: Albert Migliori (co-chair), Art Edison (co-chair), Gail Fanucci, Zhehong Gan, Lev Gor'kov, Stephen Hill, Jurek Krzystek, David Larbalestier, Dragana Popovic, Ryan Rodgers, Theo Siegrist, Glenn Walter, and Huub Weijers.

Two external committees meet regularly to provide critical advice on important issues. Reflecting the broad range of scientists who conduct research at the lab, the **Users Committee** provides guidance on the development and use of facilities and services in support of the work of those scientists. The **External Advisory Committee**, made up of representatives from academia, government and industry,



FIGURE 1. **NHMFL Organizational Chart**
 Governing & Advisory Committees, User Program, Magnet & Conductor Science and Technology, Affiliated Science Programs, Administration and Education

offers advice on matters critical to the successful management of the laboratory.

Personnel and Staffing

Six hundred thirty-four people worked for or were affiliated with the

Magnet Lab at its three sites in 2011. Of that number, senior personnel represent the largest group at 31 percent, followed by graduate students at 23 percent and support staff technical/managerial at 15 percent. The total distribution by NSF classification appears in **Figure 2**.

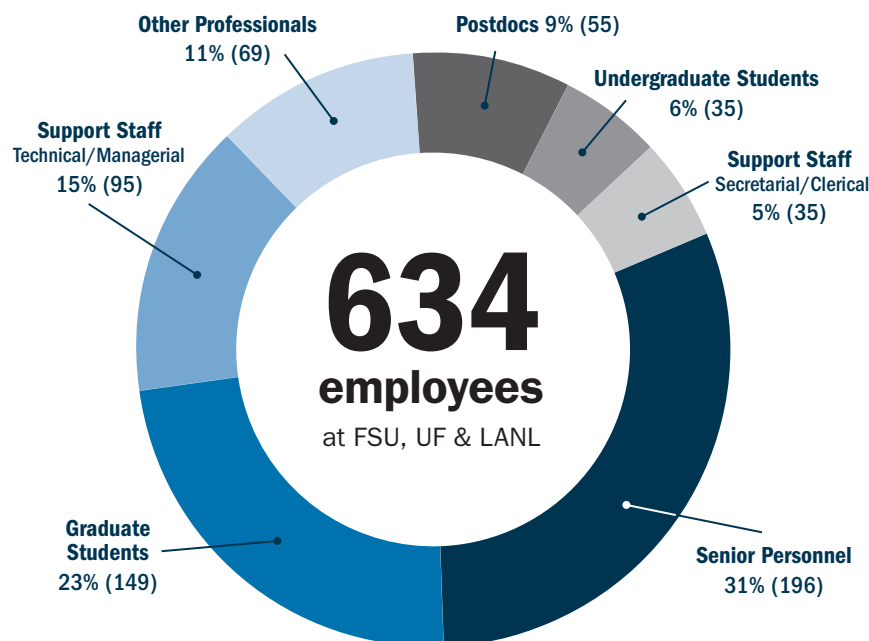
Diversity

Since the adoption of the formal diversity plan in 2004, the Magnet Lab has launched activities and efforts to increase the participation of underrepresented groups in science, engineering and mathematics.

The Magnet Lab aspires to become a

FIGURE 2.

MagLab Staffing



Includes NHMFL Employees paid by the NSF Core Grant or State of Florida funding, plus all Affiliated Professors, Postdoctoral Researchers and Graduate Students. Distribution by NSF Classification as of Jan. 4, 2012.

nationally recognized leader in the diversity of its scientific, technical and engineering staff, much the same way it is already recognized for its education and outreach programs. With this goal in mind, the lab in 2011 conducted the following activities:

- It continued its recruiting policies of including at least one member of the Magnet Lab Diversity Committee on each search committee for scientific and technical faculty, and advertised job openings in venues that target women and minorities. There were eight faculty job openings, all at the rank of Assistant Scholar/Scientist. One position was subsequently cancelled and will not be filled. Two positions are in the recruitment process. One of five scientists hired was from an underrepresented group. Additionally, a Visiting Assistant Scholar/Scientist was hired that did not require formal advertising.
- In collaboration with “The Alliance for the Advancement of Florida’s Academic Women in Chemistry and Engineering” (AAFAWCE), an NSF ADVANCE-PAID

grant, the Diversity Committee organized a workshop on “Faculty Recruitment for Excellence and Diversity” (FRED) designed to present methods for recruiting to promote excellence and diversity in the workplace. Two training sessions were held in May and the presenter was AAFWCE-FSU PI Prof. Penny Gilmer. A total of 41 faculty members attended. Starting in 2012, FRED attendance will be required for any scientist to serve on a scientific search committee.

- The Dependent Care Travel Grant Program (DCTGP), which seeks to assist and advance the careers of underrepresented groups including women by providing grants for travel-related expenses for dependents, gave four awards to women, one of whom was a new user scientist.
- Dragana Popović, Director of the Magnet Lab’s Diversity Program, became the co-PI on the FSU part of the AAFWCE grant, a collaboration of five Florida universities to increase the role of women in STEM fields. She is also co-PI on a recently submitted ADVANCE-IT proposal

“Collaborative Research: Advance-IT, Florida!” a collaboration of the same five Florida institutions (FSU, UF, FAMU, USE, FIU) that seeks to institutionalize the initial successes of the original ADVANCE-PAID program.

The lab continued its efforts to develop and cultivate individually crafted early career opportunities for members of underrepresented groups at the undergraduate level and above. Such efforts in 2011 included the following:

- A continuation of the successful “College Outreach – Workforce Initiative Program” (CO-WIN), where Magnet Lab scientists, engineers, and members of CIRL regularly travel to publicize NHMFL science and recruit REU students from women’s colleges, historically black and minority-serving colleges and universities. A list of past trips and lectures, which is available at <http://www.magnet.fsu.edu/about/howwework/diversity/outreach.aspx>, includes trips to the Joint Annual Conference of the National Society of Black Physicists and the National Society of Hispanic Physicists, and to the American Indian Science and Engineering Society conference.
- As an ongoing relationship with Claflin University initiated by a 2009 CO-WIN lecture, Art Edison provided NMR training (lectures, laboratory workshop, and seminar) to Claflin faculty and students on their new 700 MHz spectrometer. A Claflin undergraduate Aaron Shepard worked as a REU student with Edison for the second year. Art Edison had two more minority Claflin students working in his lab for the summer. Claflin will be one of the partners in Edison’s new NIH proposal. As part of another collaboration initiated by a 2007 CO-WIN lecture, Edison was working to establish a medical student summer exchange project with Universidad Peruana Cayetano Heredia (UPCH) in Lima, Peru with the expected start date in summer 2012.
- The Pulsed Field Facility established a summer undergraduate student program on high strength magnet conductors. The program explicitly recruited from multiple Native American student programs at several universities in the New Mexico, Colorado, Arizona, and Utah area. A to-

tal of 4 students were accepted, including one female and one Native American.

- Partial support was provided to four year-round undergraduate researchers: Kristen Collar (FSU), Lauren Riner (TCC), Kellie Borg (FSU), and Ashley Bernheisel (FSU).
- Partial support was provided to three graduate students: Luis Colon Perez (UF), Sherman Benjamin (FSU), and Parastou Foroutan (FSU).
- Matching funds were awarded to three postdoctoral research associates: Rongmei Niu (MS&T); Natanette Craig (ASC), and Ping Lin (DC Field CMS).
- Funds were provided to FAMU researchers to support 30 hours of time on the FSU Chemistry Dept. NMR facility; 5 hours were used in 2011.
- A PREM proposal was submitted to NSF to establish a partnership between the FAMU Physics Department, FAMU-FSU College of Engineering, and the NHMFL. The PIs are Charles Weatherford (FAMU) and Greg Boebinger (FSU).
- Theo Siegrist (NHMFL and College of Engineering) submitted an NSF proposal in collaboration with Montclair State University (MSU) in New Jersey. MSU has a majority female student population and about 30% minorities.

One of the lab's goals is to aim educational outreach for K-12 and the general public to broad and diverse groups. Educational outreach is primarily accomplished through the formal and informal programs of the MagLab's Center for Integrating Research and Learning (CIRL), in concert with various efforts by laboratory scientists and staff. In 2011, those efforts included the following:

- CIRL continued outreach activities at Title I and underserved schools. According to assessment of outreach programs, 52% of all school outreach is conducted at Title I schools.
- SciGirls camp hosted 36 young women in a two-week camp.
- The Magnet Lab Physics Camp had 7 out of 16 students registered as minority/underrepresented.
- The Magnet Lab hosted two female high school interns in the summer and one in the fall semester.
- Pulsed Field Facility scientists visited a

local high school serving predominantly Native American students and gave a lecture on pulsed magnets. They also conducted a tour of LANL for students from the same school.

- CIRL supported the ERC FREEDM grant by providing opportunities for 16 middle school students from Title I schools, 2 minority teachers from a Title I high school, and 6 Young Scholars from Title I schools.
- 2011 RET program hosted 2 teachers from New Mexico, who teach at schools with a majority of Hispanic and/or

Native American elementary students; in addition, 6 teachers taught at Title I schools.

- 2011 REU program had 13 of 19 participants categorized as minority or underrepresented.
- The Magnet Lab continued presentations to general public in local establishments, including Barnes & Noble bookstore, and the popular Science Café.
- The Public Affairs Office handled posting flyers and community outreach to draw in visitors for the annual Open House.

TABLE 1

NHMFL NSF 5-Year Budget

with indirect cost distributed to programs and facilities

Division / Program / User Facility	2008-2012 5-Year NSF Summary	% of Budget
Director's Office	6,012,871	3.96%
Associate Director/Management & Administration	11,950,521	7.88%
DC Field Facility	17,182,127	11.32%
Magnet Science & Technology	19,812,903	13.06%
Condensed Matter Science	7,209,844	4.75%
CIMAR - NMR	4,898,153	3.23%
CIMAR - ICR	7,320,824	4.83%
CIMAR - EMR	2,184,060	1.44%
CIRL & REU	1,695,550	1.12%
ASC	7,599,416	5.01%
Electricity & Gases	25,795,385	17.00%
LANL	28,618,765	18.86%
UF - High B/T	1,903,359	1.25%
UF- AMRIS	4,103,177	2.70%
Diversity	474,617	0.31%
User Collaboration Grants Program ⁶	4,963,428	3.27%
TOTAL NSF COOPERATIVE AGREEMENT ^{1,2,3,4,5}	\$151,725,000	100.00%

¹ FY 2008 included award of \$26,500,000 plus supplement of \$1,250,000 for a total award of \$27,750,000.

² FY 2009 included award of \$22,525,000 plus August 2010 supplement of \$3,975,000 for a total award of \$26,500,000. Supplement ARRA funding of \$5,000,000 is not included in the financial data reported in this budget section.

³ FY 2010 included award of \$26,500,000 plus supplement of \$6,500,000 for a total award of \$33,000,000.

⁴ FY 2011 included award of \$26,675,000 plus an advance of \$5,000,000 received in Sept 2010 for a total award of \$31,675,000.

⁵ The National Science Foundation (National Science Board) approved funding of up to \$162,000,000 for 2008-2012.

⁶ UCGP (User Collaboration Grants Program) for FSU/NHMFL, LANL and UF reported as one line item.

TABLE 2

NHMFL – NSF Budget by Program/User Facility with indirect cost separate from programs

Division / Program / User Facility	2008 ¹	2009 ²	2010 ³	2011 ⁴	2012	Total Budget ⁵
Director's Office	578,614	-453,866	2,051,017	1,342,496	1,344,050	4,862,311
Associate Director/ Management & Administration	1,554,740	1,676,171	1,688,772	1,592,194	1,688,637	8,200,514
DC Field Facility	2,286,768	2,168,960	2,180,666	2,417,219	2,567,123	11,620,736
Magnet Science & Technology	2,340,153	2,250,915	2,653,109	2,732,504	3,576,072	13,552,753
Condensed Matter Science	500,894	953,785	974,190	1,094,806	1,219,643	4,743,318
CIMAR - NMR	587,040	623,469	650,256	659,574	856,037	3,376,376
CIMAR - ICR	961,673	1,053,252	1,119,366	989,849	1,039,409	5,163,549
CIMAR - EMR	131,519	133,475	998,930	222,401	261,871	1,748,196
CIRL & REU	187,807	216,087	258,735	288,607	333,137	1,284,373
ASC	447,101	490,014	1,233,965	1,257,050	1,805,425	5,233,555
Electricity & Gases	5,791,897	4,779,676	4,918,789	3,834,130	3,830,735	23,155,227
LANL	2,895,534	3,065,568	3,218,243	6,213,942	5,000,000	20,393,287
UF - High B/T	212,483	273,940	272,036	447,372	387,372	1,593,203
UF - AMRIS	500,159	562,705	556,443	1,038,689	838,689	3,496,685
Diversity	64,073	64,001	64,642	62,997	67,669	323,382
User Collaboration Grants Program ⁶	897,225	911,400	1,208,143	1,296,660	650,000	4,963,428
Indirect Cost	7,812,320	7,730,448	8,952,698	6,184,510	7,334,131	38,014,107
TOTAL	\$27,750,000	\$26,500,000	\$33,000,000	\$31,675,000	\$32,800,000	\$151,725,000

¹ 2008 included award of \$26,500,000 plus supplement of \$1,250,000 for a total award of \$27,750,000.

² FY 2009 included award of \$22,525,000 plus supplement of \$3,975,000 for a total award of \$26,500,000.

Supplement ARRA funding of \$5,000,000 is not included in the financial data reported in this budget section.

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⁴ FY 2011 included award of \$26,675,000 plus an advance of \$5,000,000 received in Sept 2010 for a total award of \$31,675,000.

⁵ The National Science Foundation (National Science Board) approved funding of up to \$162,000,000 for 2008-2012.

⁶ UCGP (User Collaboration Grants Program) for FSU/NHMFL, LANL and UF reported as one line item.

- NHMFL/FSU staff attended the Career Fair at a local high school serving mostly minority students encouraging them to pursue an education in one of the STEM programs.
- CIRL Assistant Director recruited for REU at Morehouse College resulting in increased applications from that institution. Two spots are allocated for summer 2012.
- CIRL facilitated the Undergraduate Recruitment Symposium in collaboration with the Physics Department and Florida Georgia Louis Stokes Alliance for Minority Participation.

NHMFL continues to publicize

among staff and user facilities that diversity matters, via labwide meetings, the NHMFL diversity website, and the dissemination of NHMFL and national statistics on diversity. Diversity presentations and discussions are regular agenda items at meetings of the NHMFL Executive Committee, External Advisory Committee, User Committee and NSF Site Visits. The annual meeting of the Diversity Advisory Committee was held in December. Jan Musfeldt served as Chair of the Users Executive Committee. Alexandra Stetson was elected to the ICR User Advisory Committee and will begin her term in 2012. The Diversity Action Plan was updated.

Budget

The National High Magnetic Field Laboratory operates with funding provided by federal, state, institutional, and industry sources. In addition, the Magnet Lab faculty and staff have been very successful in securing individual research funding for specific areas of research from a variety of sources, including federal and private sectors. Although the lab receives funding from numerous sources, the National Science Foundation (NSF) is its primary funding source for operations.

NSF Facilities Budget

The National Science Foundation Division/Directorate approved the National

High Magnetic Field Laboratory's facilities renewal award on December 12, 2007 with an effective date of January 1, 2008. **Table 1** provides a view of the current 5-Year award.

Table 2 presents the annual NSF budgets for the 5-Year award period. **Table 3** summarizes the Magnet Lab's budget position as of December 31, 2011. The budget balance represents deferred capital and expense items, such as resistive magnets maintenance and upgrade and other miscellaneous equipment purchases.

Matching Commitment

The NSF award includes a matching commitment by the State of Florida through Florida State University that is 10% of the annual award. In addition, the State of Florida also provides institutional funds to the laboratory above the NSF matching requirement. The Magnet Lab utilizes these additional state resources as cost-sharing funds for other funding opportunities, as well as supporting other NSF activities. **Table 4** presents the State of Florida matching requirements and contribution provided through FSU.

American Recovery and Reinvestment Act (ARRA) Funding

In 2009, the laboratory received a \$5,000,000 ARRA award from the NSF which was used to upgrade systems, magnets and purchase upgrades for imaging and spectroscopy consoles.

ARRA funds were used during 2009, 2010 and 2011 to mitigate prior budget reductions. Cumulative underfunding of the 5-Year NSF award led to the deferment of equipment replacement, preventive maintenance, projects and a reduction in DC magnet operations. The receipt of ARRA funds provided the National High Magnetic Field Laboratory (NHMFL) the ability to reinstate many of the deferred items.

A helium liquefier system has been purchased and installed to replace unreliable equipment that is 18-22 years old. This system will enable the lab to maintain a state-of-the-art facility for users. The Florida State University has provided supplementary funds in the amount of \$1.9 million dollars to support this enhancement.

TABLE 3

NSF Budget & Expenses

for Fiscal Year 2011

Expense Classification	Budget	Spent and Encumbered	Balance 12/31/2011
Salaries and Fringe	8,474,858	8,414,966	59,892
Subawards	7,805,003	7,392,871	412,132
Capital Equipment	1,724,876	1,558,432	166,444
Other Direct Cost	7,485,753	5,595,828	1,889,925
SUBTOTAL	25,490,490	22,962,097	2,528,393
Indirect Cost	6,184,510	5,999,725	184,785
TOTAL Before Indirect on Encumbrances	31,675,000	28,961,822	2,713,178
Program Income	0	0	0

TABLE 4

Fiscal Year 2011/2012 State of Florida Matching and Contribution

	State Matching	State Contribution	Total State Funding
State of Florida Recurring Funds Cost-Sharing	3,167,500	5,854,151	9,021,651
Indirect Costs (52%)	1,647,100	3,044,159	4,691,259
TOTAL	\$4,814,600	\$8,898,310	\$13,712,910

The system components include a liquefier which is being used to recover helium gas via a lab-wide recovery system, purify and liquefy helium for re-use as coolant for superconducting magnets and for use with samples during scientific experiments. The liquefier is now in regular operation.

A Central Helium Distribution Box (CDB), comprising valves, heat exchangers, and helium sub coolers, has been purchased to supply liquid helium for the 45 tesla hybrid magnet system and for the cryogenic shields. This is an interface between the output of the 750 W turbine helium liquefier and the current cooling system of the 45 tesla magnet. The system

is also designed for future expansion and the next generation of hybrid magnets. The CDB is scheduled for delivery in 2012.

Vacuum jacketed transfer lines are a necessity for coupling the Central Distribution Box to the 45 tesla hybrid. These transfer lines enable the cost-effective (and environmentally friendly) transfer of liquid helium.

The NHMFL committed \$475,270 from other non-federal funding sources to support the purchase of a new Magnet Cooling Pump System. The total cost of the project is \$575,270 which includes \$350,000 for a pump. ARRA funds in the amount of \$100,000 were applied to the purchase of this pump. The magnet

cooling pump provides increased cooling efficiency and the ability to operate longer magnet “run times” during users’ research projects.

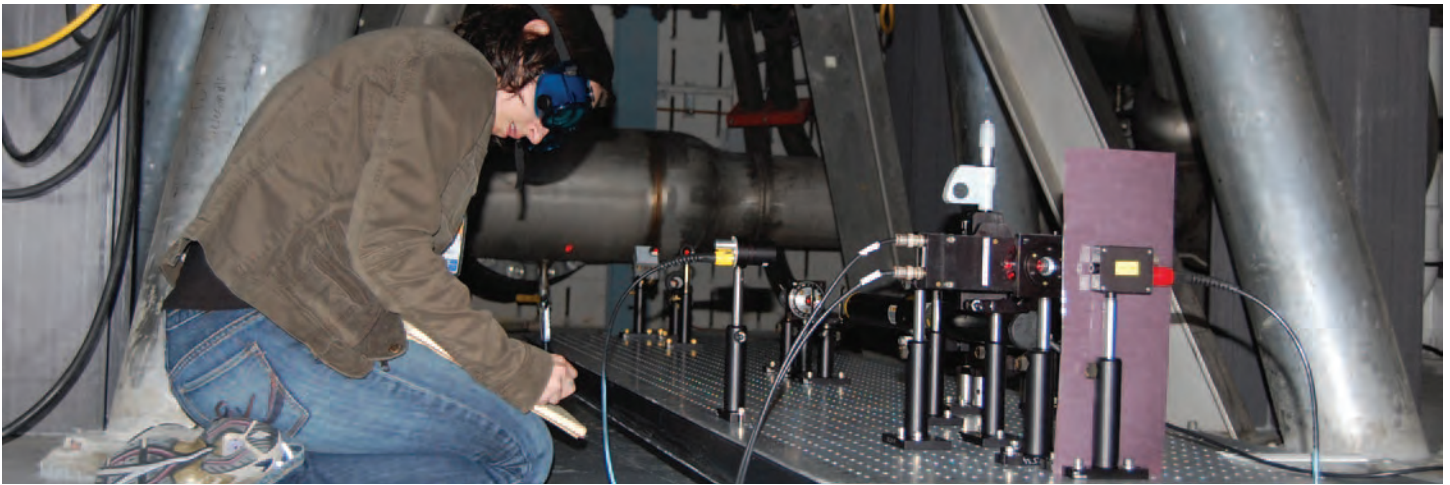
Equipment purchases at the Los Alamos National Laboratory (LANL), via a sub-award, include \$639,000 to purchase emergency replacement parts for the 60T and 100T Long Pulse Magnet Systems. Without these replacement parts, any magnet failure will require immediate suspension of the respective Pulsed Magnet User Facility. These magnet projects are 65% complete; however, more than 90% of the components have been purchased.

Also, a cryostat has been purchased, installed and is now operational at LANL — at a cost of \$71,013. Low loss cryostats decrease the consumption of liquid helium for magnet systems that are used in the user facility. The improved efficiency is required to offset the increasing costs of liquid helium.

Equipment purchases for the Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) Facility at the University of Florida, via a sub-award, include \$200,000 to purchase upgrades for imaging and spectroscopy consoles. Four of the current consoles are over ten years old and nearing the end of their useful lives. Frequent component breakdowns are negatively impacting the NHMFL user operations. However, commercial NMR instrument manufacturers have made great strides in digital technology over the last decade and modernizing the AMRIS consoles yields gains in sensitivity, dynamic range, and pulse sequence programming that further leverages the already impressive performance of our high magnetic fields and radiofrequency coils. These upgrades were necessary to support cutting-edge imaging and *in vivo* spectroscopy experiments that are required by NHMFL external users.

CHAPTER 10

Science & Research Productivity



The laboratory continued its strong record of publishing, giving presentations at conferences, and advising and training students who earn Master degrees and Ph.D.s. **Table 1** summarizes these activities, and the listings follow. For additional information, refer to the Magnet Lab's Web site: www.magnet.fsu.edu (/search/publications/search.aspx), where you can search the publications database and link to many articles online. Grant information, received from Florida State University and the University of Florida's respective offices of sponsored research, is also presented in this chapter, beginning on page 161.

Of the publications reported by Magnet Lab users and faculty in 2011, 203 (60%) appeared in some of the most prominent science and major disciplinary journals (**Table 2**).

TABLE 1

2011 MagLab Activities Summary

	Number Reported	Page Number for Listings
Publications in Peer-Reviewed Journals	341	128
Presentations, Posters & Other Publications	337	141
Books, Book Chapters, Other One-time Publications	8	155
Internet Disseminations	8	155
Patents and Other Products	6	156
Awards	17	156
Dissertations, Ph.D.	69	157
Theses, Master	19	160

TABLE 1

2011 Prominent Journal Articles

Journal	Number of Articles
Accounts of Chemical Research	1
Analytical Chemistry	9
Angewandte Chemie International Edition	3
Applied Physics Letters	7
Biochemical and Biophysical Research Communications	1
Biochimica et Biophysica Acta	2
Biophysical Journal	3
Chemistry of Materials	1
Energy & Fuels	3
Environmental Science & Technology	1
IEEE Transactions on Applied Superconductivity	10
Inorganic Chemistry	6
International Journal of Mass Spectrometry	6
Journal of Applied Physics	6
Journal of Biological Chemistry	1
Journal of Biomolecular NMR	1
Journal of Magnetic Resonance	6
Journal of Mass Spectrometry	1
Journal of Medicinal Chemistry	1
Journal of Molecular Biology	1
Journal of Physics-Condensed Matter	6
Journal of Proteome Research	1
Journal of the American Chemical Society	10
Journal of the American Society for Mass Spectrometry	2
Macromolecules	1
Magnetic Resonance in Medicine	1
Nano Letters	3
Nature	2
Nature Chemistry	1
Nature Physics	6
Nature Structural & Molecular Biology	1
NeuroImage	2
Physical Review B	42
Physical Review B Rapid Communications	11
Physical Review Letters	25
Proceedings of the National Academy of Sciences of the United States of America	7
Protein Science	1
Science	1
Superconductor Science and Technology	10
TOTAL	203

Peer-Reviewed Publications

This section lists over 340 articles that appeared in print in referred journals and conference proceedings in 2011. Journal titles appearing in **red boldface** are regarded by the laboratory as prominent or major disciplinary publications.

To read a publication noted as [\[read online\]](#), go the “pubs database”: <http://www.magnet.fsu.edu/search/publications/search.aspx>

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Presentations, Posters & Abstracts

This section lists invited and contributed talks and papers at conferences; papers in conference proceedings that were not peer-reviewed; posters; abstracts; and presentations at universities and public forums in 2011. More than 330 activities were reported this year.

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Balicas, L., *Anisotropic Hysteretic Hall Effect and Magnetic Control of Chiral Domains in the Chiral Spin States of Pr₂Ir₂O₇ (contributed)*, *Novel Phenomena in Frustrated Systems*, Santa Fe, NM, May 23-27 (2011)

Balicas, L., *Brief overview of the National High Magnetic Field Laboratory*, Leon High School, Tallahassee, FL, November (2011)

Balicas, L., *Field-induced magneto-chiral domains in the frustrated metallic pyrochlore Pr₂Ir₂O₇ (contributed)*, SCES 2011, Cambridge, UK, August 29-September 3 (2011)

Balicas, L., *High Magnetic Fields as a Probe to Unveil the Physical Properties of the Newly Discovered Fe Oxypnictide Superconductors and Related Compounds (invited)*, DOE-BES-Experimental Condensed Matter Physics Principal Investigators Meeting, Rockville, MD, August 9-12 (2011)

Balicas, L., *Metallic and insulating spin liquids: role of spin-chirality and fermionic-like spin excitations*, Penn State University, State College, PA, September 20 (2011)

Balicas, L., *Torque magnetometry in single layer oxypnictide single crystals*, University of Florida, Department of Physics, Gainesville, FL, March (2011)

Baxter, M.K.; McGavin, J.A.; Kraus, N.B.; De Angelis, A.A.; Seckute, J.; Burzynski, C.M.; Berke, D.M.; Smajic, N.; Nicholson, L.K.; Opella, S.J. and Cotten, M., *Bicelle-bound solid-state NMR Structural Studies and membrane-permeabilizing activities of piscidin 1 and piscidin 3: Implications for mode of antimicrobial action.*, 55th Annual Biophysical Society Meeting, Baltimore, MD, March (2011)

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Bird, M.D., *Development of Magnets for Spectroscopy at the NHMFL, Invited Lecture, Status and Perspectives on Neutron Research in High Magnetic Fields*, Potsdam, Germany, March 31 - April 1 (2011)

Bird, M.D., *Magnet Development at the NHMFL*, Invited Seminar, Grenoble High Magnetic Field Lab, Grenoble, France, September 20 (2011)

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- Dobrosavljevic, V., *Lecture 1: Dynamical mean-field theory of correlated electrons with disorder - exact solution in infinite dimensions*, invited lecture at the Asia-Pacific Center for Theoretical Physics, Pohang, Korea, November 8 (2011) [[read online](#)]
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- Hsu, C.S., *Future Fuels Institute and FT-ICRMS Accomplishments*, Shell Global Solutions, Houston, TX, April 25 (2011)
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- Hsu, C.S., *Future Fuels Institute for Biofuels*, Core University Liaison Meeting and Bioenergy Worksho, Oak Ridge National Laboratory, Oak Ridge, TN, May 11 (2011)
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- Hsu, C.S., *Opportunities in Fuel Research*, invited talk at Zhejiang University, Hanzhou, Zhejiang, China, November 9 (2011)
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- Jaime, M., *Magnetic Textures and Magnetostriction of SrCu₂(BO₃)₂*, Solidos 2011 (plenary speaker), Tucuman, Argentina, November 8-11 (2011)
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Atolia, E. (Eta), One of 40 national Finalists in 2011 Intel Science Talent Search (2011)

Bolotin, K. (Kirill), NSF Career Award (2011)

Dobrosavljevic, V. (Vlad), PAI Award for Excellence in Teaching and Research (2011)

Dorsey, A.T. (Alan), Chair, APS Lars Onsager Prize Selection Committee (2011)

Dorsey, A.T. (Alan), Fellow, SEC Academic Consortium Academic Leadership Development Program (2011)

Froelich, P. (Philip), Fellow, American Association for the Advancement of Science (AAAS) (2011)

Furis, M. (Madalina), NSF Career Award (2011)

Geerts, W. (Wilhelmus), Chair-Elect of the APS Topical Group on Instrument and Measurement Science (2011)

Hayes, S.E. (Sophia), Vice-Chair, Gordon Research Conference on Magnetic Resonance (2011)

Hendrickson, C. (Christopher), 2011 FSU Distinguished University Scholar Award (2011)

Jaime, M. (Marcelo), Fellow, American Physical Society (2011)

Paravastu, A.K. (Anant), NSF Faculty Early Career Development Award (CAREER) (2011)

Rodgers, R. (Ryan), ACS Division of Petroleum Chemistry Emerging Researcher Award (2011)

Song, L. (Likai), Full member, Sigma Xi (2011)

Song, L. (Likai), Young/Early Career Investigator Award, the Collaboration for AIDS Vaccine Discovery (2011)

Terletska, H. (Hanna), Dirac-Hellman Award in Theoretical Physics (awarded by FSU Physics Department) (2011)

Yang, K. (Kun), Fellow, American Physical Society (2011)

Ph.D. Dissertations

Sixty-eight (69) Ph.Ds were reported for 2011: 32 were awarded to users / students at FSU, UF, or FAMU; 37 were awarded to users at other academic institutions.

Ph.Ds. (32) awarded to users/ students at FSU, UF or FAMU:

- Astary, G. (Garrett), "MR-Guided Real-time Convection-enhanced Delivery", University of Florida, Biomedical Engineering, advisor: Mareci, T.H. (Thomas) (2011)
- Barrios, M. (Matt), "Material Characterization of Rigid Foam Insulation at Low Temperature", Florida State University, Mechanical Engineering, advisor: Van Sciver, S. (Steven) (2011)
- Bembridge, N.G. (Nicholas Gutzmore), "Innovative Severe Plastic Deformation of Niobium with Application to Superconducting Radio Frequency Cavities", Florida A&M University, Mechanical Engineering, advisor: Kalu, P.N. (Peter) (2011)
- Besara, T. (Tiglet), "NMR Near Ferroelectric, Magnetic, and Quantum Phase Transitions", Florida State University, Dept. Chemistry and Biochemistry; and Dept. of Physics, advisor: Dalal, N.S. (Naresh) (2011)
- Bou-Assaf, G.M., "Solution-phase Hydrogen/deuterium Exchange Monitored by FT-ICR Mass Spectrometry: Technique development & application to muscle biochemistry", Florida State University, Chemistry & Biochemistry, advisor: Marshall, A.G. (Alan) (2011)
- Conner, B.S. (Benjamin), "Single Crystal Growth and Magnetic and Thermal Properties of $Pb_2V_3O_9$ ", Florida State University, Physics, advisors: Wiebe, C. (Christopher) and Balicas, L. (Luis) (2011)
- Costa, V.D. (Vincent), "Cognitive Regulation and Reversal of Fear: Reflex Physiology and Neural Activity", University of Florida, Psychology, advisor: Bradley, M.M. (Margaret) (2011)
- Dumont, M. (Matt), "Nanostructures of Metallophosphates and Cyanometallates for Applications and Physical Studies", University of Florida, Chemistry, advisor: Talham, D. (Daniel) (2011)
- Farver, R.S. (Suzanne), "Investigations of Lipid Dynamics and Polymorphisms in Lung Surfactant", University of Florida, Biochemistry & Molecular Biology, advisor: Long, J.R. (Joanna) (2011).
- Foroutan, P. (Parastou), "High Field Magnetic Resonance Assessments of Neurodegenerative Disease at 21.1 T", Florida State University, Chemical & Biomedical Engineering, advisor: Grant, S.C. (Samuel) (2011)
- Goswami, D., "Role of Defects in the Supersolid Phenomena", University of Florida, Physics, advisor: Dorsey, A.T. (Alan) (2011)
- Kim, S.S., "A Study of Nuclear Spin Relaxation in Isotopic Mixtures of Dilute ^3He in Solid ^4He using NMR", University of Florida, Physics, advisor: Sullivan, N.S. (Neil) (2011)
- Kim, Y.H. (Young Hak), "Phase Transitions, Thermodynamics, and Magnetism of the Low-Dimensional Antiferromagnets $\text{Cr}(\text{diethylenetriamine})(\text{O}_2)_2 \cdot \text{H}_2\text{O}$ and $(\text{CH}_3)_2\text{CHNH}_3\text{CuCl}_3$ ", University of Florida, Physics, advisor: Takano, Y. (Yasu) (2011)
- Koo, C. (Changhyun), "High Frequency Electron Paramagnetic Resonance Studies of the Anisotropy of Molecular Magnets and a Spin Dimer Compound", University of Florida, Physics, advisor: Hill, S. (Stephen) (2011)
- Li, J. (Junjie), "Femtosecond Electron Pulse as an Ultrafast Probe", Florida State University, Physics, advisor: Cao, J. (Jianming) (2011)
- Mallick, S., "Neodymium isotopic investigation of heterogeneities in the sub-ridge mantle", Florida State University, Earth, Ocean and Atmospheric Sciences, advisor: Salters, V. (Vincent) (2011)
- Masad, I.S., "Assessments of Skeletal Muscle Architecture and Energetics by Magnetic Resonance Diffusion Tensor Imaging and ^{31}P Spectroscopy", Florida State University, Department of Chemical and Biomedical Engineering, advisor: Grant, S.C. (Samuel) (2011)
- Ninios, K. (Konstantinos), "Micromechanical Force Magnetometers for Measuring Magnetization at High Magnetic Fields and Low Temperatures", University of Florida, Physics, advisor: Chan, H.-B. (Ho-Bun) (2011)
- Noble, K. (Kyle), "Physical Characterization of Intrinsically Disordered Proteins", Florida State University, Molecular Biophysics, advisor: Logan, T. (Timothy) (2011)
- Pati, M. (Mekhala), "Quantum Phase Transitions in New 3d1 Compounds", Florida State University, Chemistry and Biochemistry, advisor: Dalal, N. (Naresh) (2011)
- Pishko, G. (Gregory), "Magnetic Resonance Imaging-Based Computational Models of Solid Tumors", University of Florida, Mechanical and Aerospace Engineering, advisor: Sarntinoranont, M. (Malisa) (2011)
- Podgorski, D.C. (David), "Novel Ionization Methods for Characterization of Natural Organic Matter by Fourier Transform Ion Cyclotron Resonance Mass Spectrometry", Florida State University, Chemistry & Biochemistry, advisor: Cooper, W.T. (William) (2011)
- Priman, N.L. (Natasha), "A Multi-Frequency Electron Paramagnetic Resonance Spectroscopy Study of the Intrinsically Disordered Protein, IA3", University of Florida, Chemistry, advisor: Fanucci, G.E. (Gail) (2011)
- Ramachandran, V. (Vasanth), "Thermomagnetic, Dielectric and EPR Studies on Four New Multiferroics", Florida State University, Chemistry and Biochemistry, advisor: Dalal, N. (Naresh) (2011)
- Rosenberg, J. (Jens), "Intracellular MRI Contrast Agents for High Magnetic Fields", Florida State University, Chemical & Biomedical Engineering, advisor: Grant, S.C. (Samuel) (2011) [[read online](#)]
- Saha, A. (Ajoy), "Hydrothermal Synthesis of Near-Infrared Emitting Quantum Dots for Magnetic and Fluorescent Bimodal Imaging", University of Florida, Materials Science & Engi-

neering, advisor: Moudgil, B.M. (Brij) (2011)

Samantaray, R. (Raghavendra), " $M_{3x}(NH_4)_xCrO_8$ ($M = K, Rb, Cs$): A New family of $Cr(5+)$ -based Magnetic Ferroelectrics", Florida State University, Chemistry and Biochemistry, advisor: Dalal, N. (Naresh) (2011)

Selarka, S. (Aniket), "*A Study on Processing of Cellulose and Its Interaction with Supercritical Carbon Dioxide and Co-solvent*", University of Florida, Materials Science & Engineering, advisor: Baney, R. (Ronald) (2011)

Terletska, H. (Hanna), "*Unconventional Transport Around Metal-Insulator Transition*", Florida State University, Physics, advisor: Dobrosavljevic, V. (Vlad) (2011)

Tfaily, M.M. (Malak), "*Molecular Characterization of Dissolved Organic Matter (DOM) in Northern Peatlands: Identifying The Chemical Signatures of Climate Change*", Florida State University, Chemistry & Biochemistry, advisor: Cooper, W.T. (William) (2011)

Zhang, C. (Chunfu), "*Late Cenozoic C4 Expansion in the Central Inner Mongolia and Paleoenvironmental Evolution of the Qaidam Basin, China*", Florida State University, Earth, Ocean and Atmospheric Science, advisor: Wang, Y. (Yang) (2011)

Zhou, J. (Jian), "*The Effects of Variable Sn Content on the Properties of A15 Superconducting Nb_3Sn* ", Florida State University, FAMU-FSU College of Engineering (Mechanical), advisor: Larbalestier, D.C. (David) (2011)

Ph.Ds. (37) awarded by other academic institutions to external users/students:

Bao, W. (Wenzhong), "*Electrical and Mechanical Properties of Graphene*", University of California, Riverside, Physics, advisor: Lau, C.N. (Chun Ning) (2011)

Benjamin, D. (Daniel), "*Thermal Transport and Photo-induced Charge Transport in Graphene*", Georgia Institute of Technology, Physics, advisor: Jiang, Z. (Zhigang) (2011)

Buannic, L. (Lucienne), "*Solid State NMR Study of Protonic Conductors for Applications as Electrolyte Materials in Solid Oxide Fuel*

Cells", Stony Brook University, Chemistry, advisor: Grey, C.P. (Clare) (2011)

Chiang, H.-S. (Hung-Sheng), "*Nonlinear Transport in Two-Dimensional Electron Gas at Large Filling Factors*", University of Minnesota-Twin Cities, School of Physics and Astronomy, advisor: Zudov, M. (Michael) (2011)

Chu, J.-H. (Jian-Haw), "*Electronic Properties of Fe-pnictide Superconductors*", Stanford University, Applied Physics, advisor: Fisher, I. (Ian) (2011)

Dai, Y. (Yuanhua), "*Magnetotransport and Microwave Photoconductivity in Modulated Two-Dimensional Electron Systems*", Rice University, Physics and Astronomy, advisor: Du, R.-R. (Rui-Rui) (2011)

Diedrich, J. (Jolene), "*Harnessing Radical Chemistry for the Facile Identification of Post Translational Modification Sites in Proteins by Photodissociation Mass Spectrometry*", University of California, Riverside, Chemistry, advisor: Julian, R. (Ryan) (2011)

Drahus, M.D. (Michael), "*Mixed-conducting $Sr(Ti,Fe)O_3$ as Temperature-Independent Oxygen Sensors - Interplay between Defect Structure and Conductivity*", University of Freiburg, Chemistry, advisor: Eichel, R.-A. (Ruediger) & Smyth, D.M. (Donald) (2011)

Eruenel, E. (Ebru), "*Novel Lead-Free Piezoceramics - Impact of Aliovalent Doping on Defect Structure and Materials Properties*", University of Freiburg, Chemistry, advisor: Eichel, R.-A. (Ruediger) (2011)

Ferentinos, E. (Eleftherios), "*Structural, Spectroscopic and Magnetic Properties of Transition Metal (Mn, Fe, Co, Ni, Cu, Zn) Complexes, Containing Imidodiphosphinato Ligands*", University of Athens, Chemistry, advisor: Kyritsis, P. (Panayotis) (2011)

Guenster, C. (Christoph), "*Research on Magnetically Driven Grain Boundary Migration and Grain Growth in Zinc*", RWTH Aachen University, Institute of Physical Metallurgy and Metal Physics, advisor: Molodov, D. (Dmitri) (2011)

Hamidane, H.B. (Hisham Ben), "*Peptide Structure and Radical Chemistry in the Gas Phase Revealed by Product Ion Abundance Analysis*

in Electron Capture and Transfer Dissociation Mass Spectrometry", Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland, Institute of Chemical Sciences and Engineering, advisor: Tsybin, Y.O. (Yury) (2011)

Hatke, A.T., "*Nonequilibrium Transport in Semiconductor Quantum Structures*", University of Minnesota - Twin Cities, School of Physics & Astronomy, advisor: Zudov, M. (Michael) (2011)

Hidalgo, A.G.A. (Ana G. Arevalo), "*Nanoporous Materials for Carbon Dioxide Adsorption at Low Concentration*", University of Puerto Rico at Mayaguez, Chemical Engineering, advisor: Hernandez, A. (Arturo) (2011)

Jalan, B. (Bharat), "*Hybrid Molecular Beam Epitaxy for High Quality $SrTiO_3$ Films*", University of California, Santa Barbara, Materials, advisor: Stemmer, S. (Susanne) (2011)

Jang, T.-H. (Tae-Hwan), "*Studies on Magnetic Properties and Critical Phenomena in Multiferroic Materials*", Pohang University of Science and Technology (POSTECH), Physics, advisor: Jeong, Y.-H. (Yoon Hee) (2011)

Keith, B. (Brian), "*Experimental Studies of Low-Dimensional Heisenberg Antiferromagnets*", Clark University, Physics, advisor: Landee, C. (Christopher) (2011)

Kim, S. (Seyoung), "*Electron Transport in Independently Contacted Graphene Double Layers*", University of Texas at Austin, Electrical and Computer Engineering, advisor: Banerjee, S. (Sanjay) & Tutuc, E. (Emanuel) (2011)

Kühne, H. (Hannes), "*A NMR Study of the Spin Chain Systems Copper Pyrazine Dinitrate and Bisphenazinium Copper Tetrachloride*", Technische Universität Dresden, Physics, advisor: Klauss, H.-H. (Henning) (2011)

Lo, C.C. (Cheuk Chi), "*Electrical Detection of Spin-dependent Transport in Silicon*", University of California at Berkeley, Electrical Engineering and Computer Sciences, advisor: Bokor, J. (Jeffrey) (2011)

Lu, T.-M. (Tzu-Ming), "*High-Mobility Two-Dimensional Electrons in Si/SiGe Heterostructures: Realization and Transport Properties*", Princeton University, Electrical Engineering, advisor: Tsui, D.C. (Daniel) (2011)

Martin, J. (Jesse), "Magnetic Field Dependent Charge Transport Studies in Organic Semiconductors", The Ohio State University, Physics, advisor: Epstein, A.J. (Arthur) (2011)

Misiti, T. (Teresa), "Fate, Toxicity and Biotransformation of Naphthenic Acids in Biological Treatment Systems", Georgia Institute of Technology, Civil and Environmental Engineering, advisor: Pavlostathis, S.G. (Spyros) (2011)

Ostapenko, T.B., "Magneto-Optical and Imaging Studies of Chromonic and Thermotropic Liquid Crystals", Kent State University, Physics, advisor: Gleeson, J.T. (2011)

Ozerov, M. (Mike), "High-field ESR of Low-dimensional Quantum Systems", Technical University Dresden, Germany, advisor: Zvyagin, S. (Sergei) & Wosnitza, J. (2011)

Qu, D-X. (Dong-Xia), "Transport Study on the Surface States of Topological Insulators", Princeton University, Electrical Engineering, advisor: Ong, N.P. (N. Phuan) (2011)

Rall, J. (James), "Nanosize Effects in the Magnetic Properties of the Two Layered Hydroxides of Nickel", West Virginia University, Physics, advisor: Seehra, M.S. (Mohindar) (2011)

Rangaraju, N. (Nikhil), "Investigation of III-V Magnetic Semiconductor Thin Films and Heterojunction Devices", Northwestern University, Materials Science and Engineering, advisor: Wessels, B. (Bruce) (2011)

Searles, T.A. (Thomas), "Optical Spectroscopy of Single-Walled Carbon Nanotubes", Rice University, Applied Physics/Electrical & Computer Engineering, advisor: Kono, J. (Junichiro) (2011)

Shafaat, H. (Hannah), "Spectroscopy and Dynamics of Amino Acid Radical Intermediates in Electron Transfer Processes", University of California, San Diego, Chemistry & Biochemistry, advisor: Kim, J. (Judy) (2011)

Shane, D.T. (David), "NMR Studies of Hydrogen Storage Systems", Washington University, St. Louis, Physics, advisor: Conradi, M. (Mark) (2011)

Shayib, R.M. (Ramzy), "Molecular Compositions, Structures, and Acid Properties of Silica-Alumina, Silicate, and Aluminosilicate Catalysts and Supports", University of California at Santa Barbara, Chemical Engineering, advisor: Chmelka, B.F. (Bradley) (2011)

Sorte, E.G. (Eric), "Investigations of a New Model of Dipolar-coupled Nuclear Spin Relaxation and Applications of Dynamic Nuclear Polarization", University of Utah, Physics and Astronomy, advisor: Saam, B. (Brian) (2011)

Vorobyev, A. (Aleksey), "Dehydrated Peptide and Protein Radical Ion Chemistry and Conformations", Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland, Institute of Chemical Sciences and Engineering, advisor: Tsybin, Y.O. (Yury) (2011)

Wright, J. (Jeffrey), "Research on Zeeman Effects on Nodal Superconductors Using NMR Methods, including the Confirmation of Inhomogeneous Superconductivity in κ -(BEDT-TTF)₂Cu(NCS)₂", University of California at Los Angeles, Physics and Astronomy, advisor: Brown, S. (Stuart) (2011)

Xiao, F. (Fan), "Magnetic Properties of Copper Pyrazine-Bridged Quasi Two-Dimensional Quantum Heisenberg Antiferromagnetic (QHAF) Compounds", Clark University, Physics, advisor: Landee, C. (Christopher) (2011)

Yin, W. (Wenjing), "Dilute Magnetic Ge_{1-x}Mn_x for Nanostructure Devices", University of Virginia, Materials Science and Engineering, advisor: Wolf, S. (Stuart) (2011)

Master Theses

Capley, E.N. (Erin), "Structural Characterization of Suwannee River Fulvic Acid With High Resolution Mass Spectrometry", University of South Alabama, Environmental Toxicology, advisor: Stenson, A.C. (Alexandra) (2011)

Chen, Y.-J. (Yen-jung), "Research on Far-infrared Optical Properties of Topological Insulators in High Magnetic Fields (thesis not required)", Georgia Institute of Technology, Physics, advisor: Jiang, Z. (Zhigang) (2011)

Elumalai, M. (Malathy), "Birdcage Coils for MRI- In Vivo Imaging of 35-Chlorine and 1-Hydrogen Nuclei", Florida A&M University, FAMU-FSU College of Engineering, Electrical Engineering, advisor: Foo, S. (Simon) (2011)

Iyama, A. (Ayato), "Magnetodielectric Effects in Rare-earth Manganites Showing the A-type Antiferromagnetic Order", Osaka University, Materials Physics, Graduate School of Engineering Science, advisor: Kimura, T. (Tsuyoshi) (2011)

Kanungo, R. (Rohit), "Pulsed Field Gradient NMR Study of Sorbate Transport in Carbon Molecular Sieves and SBA-16 Materials", University of Florida, Chemical Engineering, advisor: Vasenkov, S. (Sergey) (2011)

Katihar, A. (Aakanksha), "Diffusion of Light Gases in Nanostructured Sorbents", University of Florida, Chemical Engineering, advisor: Vasenkov, S. (Sergey) (2011)

Kihara, T. (Takumi), "Development of a Probe for the Measurements of the Magneto-caloric Effects in Pulsed-fields", University of Tokyo, Institute for Solid State Physics, advisor: Tokunaga, M. (Masashi) (2011)

Lang, D. (David), "New Materials Grown from Ca/Li Flux", Florida State University, Chemistry, advisor: Latturmer, S. (Susan) (2011)

Lee, K. (Kayoung), "Electron Transport in Dual-gated Graphene A-B Bilayers", University of Texas at Austin, Electrical and Computer Engineering, advisor: Tutuc, E. (Emanuel) (2011)

Masik, B.K. (Brady), "Separation and Analysis of Liquid Crystalline Material from Heavy Petroleum", University of Alberta, Chemical and Materials Engineering, advisor: Shaw, J.M. (John) (2011)

Noe, G.T. II (Gary Timothy), "Ultrafast and Magneto-optical Spectroscopy of Semiconductor Heterostructures", Rice University, Applied Physics/Electrical & Computer Engineering, advisor: Kono, J. (Junichiro) (2011)

Odezulu, C. (Christopher), "Stable Hydrogen and Oxygen Isotopic Variations in Natural Waters in North Florida: Implications for hydrological and paleoclimatic studies", Florida State University, Earth, Ocean and Atmospheric Science, advisor: Wang, Y. (Yang) (2011)

Ramaswamy, V. (Vijaykumar), "Design of High Sensitivity Probes for NMR Spectroscopy", University of Florida, Biomedical Engineering, advisor: Edison, A.S. (Arthur) (2011)

Seshadhri, M. (Madhumitha), "A 'Proton-Free' Coil for Magnetic Resonance Imaging of Porous Media", Florida State University, Electrical and Computer Engineering, advisor: Foo, S.F. (Simon) (2011)

Sheth, M. (Manan), "Fatigue Behavior of Nb₃Sn Composite Strands Used for ITER Magnets", Florida State University, FAMU-FSU College of Engineering (Mechanical), advisor: Larbaestier, D.C. (David) (2011)

Takada, K. (Kohsuke), "Low-temperature physical properties of organic triangular spin systems of TNN · CH₃CN and TIM · CH₃CN", Osaka Prefecture University, Graduate School of Science, Department of Physical Science, advisor: Hosokoshi, Y. (Yuko) (2011)

Valleau, T. (Tom), "A Spin-1/2 Magnetic Rectangle and a Ferromagnetic Copper Compound", Clark University, Physics, advisor: Landee, C. (Christopher) (2011)

Vemaraju, S. (Satish), "Improved NMR Field Mapping in Powered Magnets", Florida A&M University, FAMU-FSU College of Engineering, Electrical Engineering, advisor: Andrej, P. (Petru) (2011)

Wolf, M.S. (Michael), "Infrared and Optical Studies of Topological Insulators Bi₂Te₃, Bi₂Se₃ and Sb₂Te₃", University of Akron, Physics, advisor: Dordevic, S.V. (Sasa) (2011)

Grants Awarded to NHMFL-Affiliated Faculty at Florida State University

As reported by the FSU Office of Sponsored Research for calendar year 2011

Note: Individual investigator grants awarded to faculty is a measure of scientific productivity, similar to publications, presentations, and patents. The information below is presented in this context. Because individual awards are administered differently (by different agencies; under different terms), this information should not be aggregated.

PI: Alamo, Rufina G.

Grant Title: EH Branching Microstructure

Agency: Exxon Chemical Company

Project Dates: 10/1/06 - 12/31/13

Award: \$237,025

PI: Alamo, Rufina G.

Grant Title: Kinetic Control of Crystalline Order in Olefin-Based...

Agency: National Science Foundation

Project Dates: 6/1/11 - 5/31/15

Award: \$115,000

PI: Balicas, Luis Molinuevo

Grant Title: SISGR - High Magnetic Fields as a Probe to Unveil the...

Agency: U.S. Department of Energy

Project Dates: 9/15/09 - 9/14/12

Award: \$150,000

PI: Balicas, Luis Molinuevo

Grant Title: Atomic Layers of Nitrides, Oxides and Sulfides (ALNOS)

Agency: Rice University

Project Dates: 9/1/11 - 3/31/12

Award: \$44,625

PI: Boebinger, Gregory S.

Grant Title: National High Magnetic Field Laboratory Renewal Proposal

Agency: National Science Foundation

Project Dates: 1/1/08 - 12/31/12

Award: \$13,500,000

PI: Boebinger, Gregory S.

Grant Title: National High Magnetic Field Laboratory Renewal Proposal

Agency: National Science Foundation

Project Dates: 1/1/08 - 12/31/12

Award: \$10,000,000

PI: Boebinger, Gregory S.

Grant Title: National High Magnetic Field

Laboratory Renewal Proposal

Agency: National Science Foundation

Project Dates: 1/1/08 - 12/31/12

Award: \$3,175,000

PI: Boebinger, Gregory S.

Grant Title: National High Magnetic Field Laboratory Renewal Proposal

Agency: National Science Foundation

Project Dates: 1/1/08 - 12/31/12

Award: \$13,500,000

PI: Boebinger, Gregory S.

Grant Title: National High Magnetic Field Laboratory Renewal Proposal

Agency: National Science Foundation

Project Dates: 1/1/08 - 12/31/12

Award: \$6,000,000

PI: Bonesteel, Nicholas E.

Grant Title: Correlated Electrons in Reduced Dimensions

Agency: U.S. Department of Energy

Project Dates: 6/1/97 - 7/31/12

Award: \$70,000

PI: Brey, William W.

Grant Title: Improved NMR Technology for Natural Products and Metabolic...

Agency: University of Florida

Project Dates: 8/1/09 - 6/30/12

Award: \$159,710

PI: Brey, William W.

Grant Title: Design and Testing of Coil Set for 5MM Triple Resonance...

Agency: Agilent Technologies Inc

Project Dates: 1/3/11 - 1/2/12

Award: \$26,000

PI: Brooks, James S.

Grant Title: Electronic, Magnetic, and Spectroscopic Properties of...

Agency: National Science Foundation

Project Dates: 9/1/10 - 8/31/13

Award: \$140,000

PI: Bruschweiler, Rafael

Grant Title: Covariance-Based NMR of Proteins and Complex Metabolite...

Agency: National Institute of General Medicine

Project Dates: 5/1/09 - 4/30/12

Award: \$253,046

PI: Chanton, Jeffrey

Grant Title: Environmental Controls on the Dynamics of Nursery Habitat

Agency: University of Florida

Project Dates: 2/1/10 - 1/31/13

Award: \$86,490

PI: Chanton, Jeffrey

Grant Title: Genes, Isotopes, and Ecosystem Biogeochemistry

Agency: University of Arizona

Project Dates: 7/1/10 - 6/30/12

Award: \$98,218

PI: Chanton, Jeffrey

Grant Title: Genes, Isotopes, and Ecosystem Biogeochemistry

Agency: University of Arizona

Project Dates: 7/1/10 - 6/30/12

Award: \$98,087

PI: Chanton, Jeffrey

Grant Title: Development and Application of a Tracer Gas Correlation

Agency: Environmental Research and Education Foundation

Project Dates: 2/2/11 - 2/1/12

Award: \$30,588

PI: Chanton, Jeffrey

Grant Title: Impact of Crude Oil on Coastal and Ocean Environments

Agency: Mississippi State University
Project Dates: 7/15/10 - 12/31/12
Award: \$105,913

PI: Chanton, Jeffrey

Grant Title: Field-Deployable Gas Analyzer for Methane Isotopes

Agency: Los Gatos Research, Inc.
Project Dates: 3/15/11 - 2/14/12
Award: \$52,037

PI: Cross, Timothy A.

Grant Title: Four Mtb Membrane Proteins: Structure and Function

Agency: National Institute of Allergy
Project Dates: 12/1/07 - 11/30/12
Award: \$36,726

PI: Cross, Timothy A.

Grant Title: Four Mtb Membrane Proteins: Structure and Function

Agency: National Institute of Allergy
Project Dates: 12/1/07 - 11/30/12
Award: \$363,122

PI: Cross, Timothy A.

Grant Title: M Tuberculosis Membrane Protein Pharmaceutical Targets

Agency: National Institute of Allergy
Project Dates: 8/20/09 - 7/31/12
Award: \$1,737,687

PI: Cross, Timothy A.

Grant Title: M Tuberculosis Membrane Protein Pharmaceutical Targets

Agency: National Institute of Allergy
Project Dates: 8/20/09 - 7/31/12
Award: \$1,737,687

PI: Cross, Timothy A.

Grant Title: Correlations: Structure-Dynamics-Function in Channels

Agency: National Institute of Allergy
Project Dates: 8/1/11 - 7/31/12
Award: \$481,610

PI: Davidson, Michael W.

Grant Title: Construction of Interactive Tutorials

Agency: Various DNPO
Project Dates: 4/1/00 - 12/31/15
Award: \$50,000

PI: Dixon, Patricia

Grant Title: QuarkNet

Agency: University of Notre Dame

Project Dates: 9/1/08 - 8/31/11
Award: \$10,400

PI: Dobrosavljevic, Vladimir

Grant Title: Complex Behavior Near the Metal-Insulator Transition

Agency: National Science Foundation
Project Dates: 9/15/10 - 8/31/13
Award: \$115,000

PI: Engel, Lloyd W.

Grant Title: Microwave/Rf Spectroscopy of 2D Solids/Stripes

Agency: U.S. Department of Energy
Project Dates: 7/1/05 - 6/30/12
Award: \$135,000

PI: Fairhurst, Brian P.

Grant Title: 2011 Large Facilities Workshop

Agency: National Science Foundation
Project Dates: 6/15/11 - 11/30/11
Award: \$14,899

PI: Gaffney, Betty

Grant Title: Reactive Intermediates in Lipoxygenase Pathways

Agency: National Institute of General
Project Dates: 1/1/09 - 12/31/12
Award: \$18,138

PI: Hellstrom, Eric E.

Grant Title: Investigation of Phase Relations and Reaction Pathways

Agency: National Science Foundation
Project Dates: 7/1/10 - 6/30/13
Award: \$245,371

PI: Hill, Stephen Olof

Grant Title: International Collaboration in Chemistry: EPR Characteri...

Agency: National Science Foundation
Project Dates: 9/1/09 - 8/31/12
Award: \$50,000

PI: Hill, Stephen Olof

Grant Title: Applications of Terahertz-to-Infrared Probes in Molecular...

Agency: National Science Foundation
Project Dates: 5/15/11 - 4/30/12
Award: \$49,995

PI: Hsu, Chang S.

Grant Title: Future Fuels Institute Membership Agreement

Agency: Various DNPO
Project Dates: 7/1/11 - 6/30/15

Award: \$125,000

PI: Hsu, Chang S.

Grant Title: Future Fuels Institute Membership Agreement

Agency: Various DNPO
Project Dates: 7/1/11 - 6/30/15
Award: \$125,000

PI: Humayun, Munir

Grant Title: Elemental Abundances in the Solar Wind

Agency: National Aeronautics & Space A
Project Dates: 2/15/09 - 2/14/13
Award: \$43,648

PI: Humayun, Munir

Grant Title: Elemental Abundances in the Solar Wind

Agency: National Aeronautics & Space A
Project Dates: 2/15/09 - 2/14/13
Award: \$50,000

PI: Humayun, Munir

Grant Title: Siderophile Element Constraints on Solar System Process

Agency: NASA
Project Dates: 8/1/10 - 7/31/13
Award: \$115,000

PI: Kim, Jeong-Su

Grant Title: Skeletal Muscle Research

Agency: SAEKWANG FRP Inc
Project Dates: 4/1/11 - 3/31/13
Award: \$8,000

PI: Knappenberger, J.R.; Kenneth L.

Grant Title: Magnetoplasmonic Nanomaterials: A Route to Predictive...

Agency: Air Force Office of Scientific Research
Project Dates: 6/15/10 - 6/14/13
Award: \$119,666

PI: Knappenberger, J.R.; Kenneth L.

Grant Title: Fundamental Antenna-Receiver Interactions In Metal-Based...

Agency: American Chemical Society
Project Dates: 9/1/11 - 8/31/13
Award: \$100,000

PI: Landing, William M.

Grant Title: Atmospheric Deposition of Mercury and Trace Metals

Agency: University of West Florida
Project Dates: 1/1/08 - 12/31/11
Award: \$26,593

PI: Landing, William M.

Grant Title: Atmospheric Deposition of Mercury and Trace Metals

Agency: University of West Florida

Project Dates: 1/1/08 - 12/31/11

Award: \$114,861

PI: Landing, William M.

Grant Title: Acquisition of a Sector Magnet ICPMS

Agency: National Science Foundation

Project Dates: 4/1/11 - 3/31/13

Award: \$250,000

PI: Landing, William M.

Grant Title: GEOTRACES Atlantic Section: Aerosol and Rainfall Collection

Agency: National Science Foundation

Project Dates: 8/1/11 - 7/31/12

Award: \$27,091

PI: Larbalestier, David C.

Grant Title: High Field Superconductor Development and Understanding

Agency: U.S. Department of Energy

Project Dates: 4/1/07 - 3/31/12

Award: \$610,000

PI: Larbalestier, David C.

Grant Title: Electro-Mechanical Characterization and Understanding of ...

Agency: Fermi National Accelerator Lab

Project Dates: 9/1/09 - 3/31/12

Award: \$170,000

PI: Lee, Peter

Grant Title: Understanding & Development of High Field SCS for Fusion...

Agency: U.S. Department of Energy

Project Dates: 7/1/06 - 6/30/12

Award: \$90,000

PI: Lee, Peter

Grant Title: Investigate and Gain and Understanding of the Origins of...

Agency: Fermi National Accelerator Lab

Project Dates: 2/2/10 - 12/31/12

Award: \$125,000

PI: Liang, Zhiyong

Grant Title: Carbon Nanotube Buckypaper/ Thermoplastic Composites...

Agency: Office of Naval Research

Project Dates: 11/22/10 - 12/31/13

Award: \$25,000

PI: Liang, Zhiyong

Grant Title: Carbon Nanotube Buckypaper/ Thermoplastic Composites...

Agency: Office of Naval Research

Project Dates: 11/22/10 - 12/31/13

Award: \$100,000

PI: Liang, Zhiyong

Grant Title: Electrical Conductivity Improvement of Carbon Nanotube

Agency: Henkel Corporation Bridgewater

Project Dates: 1/10/11 - 1/10/12

Award: \$95,001

PI: Liang, Zhiyong

Grant Title: Through-Thickness Mechanical and Thermal Property Enhancement

Agency: KAI LLC

Project Dates: 9/30/11 - 6/30/12

Award: \$45,000

PI: Lu, Jun

Grant Title: Superconducting Wire Critical Current Test

Agency: Western Superconducting

Technologies Co.

Project Dates: 8/1/11 - 6/30/12

Award: \$47,190.16

PI: Oates, William

Grant Title: Development and Implementation of Piezoelectric Microjet

Agency: U.S. Army Research Office

Project Dates: 5/1/08 - 4/30/11

Award: \$24,419

PI: Oates, William

Grant Title: CAREER: Materials Driven by Light: Nonlinear Photomechanical...

Agency: National Science Foundation

Project Dates: 2/15/11 - 1/31/16

Award: \$400,000

PI: Pamidi, Sastry

Grant Title: Magnetic Shielding with High Temperature Superconductors

Agency: Office of Naval Research

Project Dates: 1/15/08 - 9/30/13

Award: \$93,750

PI: Pamidi, Sastry

Grant Title: Magnetic Shielding with High Temperature Superconductors

Agency: Office of Naval Research

Project Dates: 1/15/08 - 9/30/13

Award: \$65,000

PI: Pamidi, Sastry

Grant Title: STTR: Fabrication of Higher Temperature Semiconductors

Agency: Tai Yang Research Corp

Project Dates: 6/1/10 - 5/4/13

Award: \$149,995

PI: Pamidi, Sastry

Grant Title: STTR: Fabrication of Higher Temperature Semiconductors

Agency: Tai Yang Research Corp

Project Dates: 6/1/10 - 5/4/13

Award: \$9,000

PI: Paravastu, Anant K.

Grant Title: CAREER: Solid State NMR Characterization of Molecular...

Agency: National Science Foundation

Project Dates: 1/15/11 - 12/31/15

Award: \$76,512

PI: Rikvold, Per A.

Grant Title: Computational Studies of Nonequilibrium Processes...

Agency: National Science Foundation

Project Dates: 9/1/11 - 8/31/14

Award: \$200,000

PI: Rikvold, Per A.

Grant Title: Molecular Dynamics Simulations...

Agency: Mississippi State University

Project Dates: 4/6/11 - 10/30/11

Award: \$13,515

PI: Rodgers, Ryan P.

Grant Title: Examination of Crude Oils

Agency: Nalco Company

Project Dates: 4/1/09 - 12/31/11

Award: \$125,000

PI: Rodgers, Ryan P.

Grant Title: Performed Complex Organic Molecules from the Matrix of...

Agency: Search for Extra Terrestrial Intelligence

Project Dates: 6/1/11 - 9/30/12

Award: \$7,750

PI: Rodgers, Ryan P.

Grant Title: Performed Complex Organic Molecules from the Matrix of...

Agency: Search for Extra Terrestrial Intelligence

Project Dates: 6/1/11 - 9/30/12

Award: \$17,250

PI: Sanchez, Jose Antonio

Grant Title: FloridaLearns STEM Scholars

Agency: Panhandle Area Educational Consortium

Project Dates: 9/13/11 - 6/30/12

Award: \$28,449.58

PI: Shatruk, Mykhailo

Grant Title: CAREER: Magnetostructural Correlations in Rare Earth...

Agency: National Science Foundation

Project Dates: 5/1/10 - 4/30/15

Award: \$100,000

PI: Siegrist, Theo Max

Grant Title: Characterized Uncoated Magnetite Powder

Agency: Pulse Therapeutics

Project Dates: 5/19/11 - 8/31/12

Award: \$3,410

PI: Siegrist, Theo Max

Grant Title: Characterized Uncoated Magnetite Powder

Agency: Pulse Therapeutics

Project Dates: 5/19/11 - 8/31/12

Award: \$6,200

PI: Siegrist, Theo Max

Grant Title: Characterized Uncoated Magnetite Powder

Agency: Pulse Therapeutics

Project Dates: 5/19/11 - 8/31/12

Award: \$2,900

PI: Smirnov, Dmitry

Grant Title: Infrared Optical Study of Graphene in High Magnetic Fields

Agency: U.S. Department of Energy

Project Dates: 8/15/07 - 11/30/12

Award: \$140,000

PI: Smirnov, Dmitry

Grant Title: Infrared Optical Study of Graphene in High Magnetic Fields

Agency: U.S. Department of Energy

Project Dates: 8/15/07 - 11/30/12

Award: \$140,000

PI: Song, Likai

Grant Title: Eliciting B Cells to Produce Anti-HIV gp41 MPER...

Agency: Dana-Farber Cancer Institute

Project Dates: 9/1/10 - 8/31/11

Award: \$9,679

PI: Song, Likai

Grant Title: Structural Approaches to HIV-1 Immunogen Design for BNab...

Agency: Dana-Farber Cancer Institute

Project Dates: 9/1/10 - 8/31/12

Award: \$9,679

PI: Song, Likai

Grant Title: Structural Approaches to HIV-1 Immunogen Design for BNab...

Agency: Dana-Farber Cancer Institute

Project Dates: 9/1/10 - 8/31/12

Award: \$12,906

PI: Song, Likai

Grant Title: Eliciting Broadly Neutralizing Antibodies against Clade...

Agency: Dana-Farber Cancer Institute

Project Dates: 9/1/10 - 8/31/11

Award: \$6,376

PI: Song, Likai

Grant Title: Eliciting B Cells to Produce Anti-HIV gp41 MPER...

Agency: Dana-Farber Cancer Institute

Project Dates: 9/1/11 - 8/31/12

Award: \$9,679

PI: Song, Likai

Grant Title: Eliciting Broadly Neutralizing Antibodies against Clade...

Agency: Dana-Farber Cancer Institute

Project Dates: 9/1/11 - 8/31/12

Award: \$6,376

PI: Tozer, Stanley

Grant Title: Electron Interactions in Actinides and Related Systems

Agency: U.S. Department of Energy

Project Dates: 1/11/10 - 1/10/13

Award: \$470,000

PI: Vafek, Oskar

Grant Title: CAREER: Theoretical Approach to Dirac and Related Critical...

Agency: National Science Foundation

Project Dates: 7/1/10 - 6/30/15

Award: \$84,000

PI: Van Sciver, Steven W.

Grant Title: Liquid Helium Fluid Dynamics Studies

Agency: U.S. Department of Energy

Project Dates: 1/1/96 - 4/30/12

Award: \$225,000

PI: Van Sciver, Steven W.

Grant Title: Liquid Helium Fluid Dynamics Studies

Agency: U.S. Department of Energy

Project Dates: 1/1/96 - 4/30/12

Award: \$155,000

PI: Van Sciver, Steven W.

Grant Title: Conduct Superfluid Helium Research in Support of...

Agency: Fermi National Accelerator Lab

Project Dates: 6/4/09 - 3/31/12

Award: \$50,000

PI: Walsh, Robert P.

Grant Title: Material Characterization CS & TF R&D

Agency: UT-Battelle LLC

Project Dates: 1/18/11 - 9/30/12

Award: \$33,713

PI: Walsh, Robert P.

Grant Title: Material Characterization CS & TF R&D

Agency: UT-Battelle LLC

Project Dates: 1/18/11 - 9/30/12

Award: \$734,526

PI: Walsh, Robert P.

Grant Title: Superconducting Wire Critical Current Test

Agency: High Performance Magnetics

Project Dates: 10/1/11 - 9/30/12

Award: \$4,404

PI: Yang, Kun

Grant Title: Design Principles for Quantum Hall States

Agency: Princeton University

Project Dates: 9/1/09 - 8/31/12

Award: \$59,764

PI: Yang, Kun

Grant Title: Unconventional Phases and Phase Transitions in Electronic...

Agency: National Science Foundation

Project Dates: 10/1/10 - 9/30/13

Award: \$90,000

PI: Zhou, Huan-Xiang

Grant Title: Theory of Protein-Protein Association

Agency: National Institute of General Medicine

Project Dates: 4/1/08 - 3/31/12

Award: \$226,742

PI: Zhou, Huan-Xiang

Grant Title: Theory of Protein-Protein Association

Agency: National Institute of General Medicine

Project Dates: 4/1/08 - 3/31/12

Award: \$22,674

PI: Zhou, Huan-Xiang

Grant Title: Modeling Crowding & Confinement of Cellular Environments

Agency: National Institute of General Medicine

Project Dates: 8/1/10 - 7/31/12

Award: \$250,368

PI: Zhu, Lei

Grant Title: Development of Sensitive Fluorescent Probes

Agency: National Institute of General Medicine

Project Dates: 1/1/10 - 11/30/12

Award: \$236,803

PI: Zhu, Lei

Grant Title: Development of Sensitive Fluorescent Probes

Agency: National Institute of General Medicine

Project Dates: 1/1/10 - 11/30/12

Award: \$236,803

PI: Zhu, Lei

Grant Title: Development of Sensitive Fluorescent Probes

Agency: National Institute of General Medicine

Project Dates: 1/1/10 - 11/30/12

Award: \$23,680

PI: Zhu, Lei

Grant Title: Development of Sensitive Fluorescent Probes

Agency: National Institute of General Medicine

Project Dates: 1/1/10 - 11/30/12

Award: \$236,803

Grants Awarded to NHMFL-Affiliated Faculty at the University of Florida

As reported by the UF Office of Sponsored Research for calendar year 2011

Note: Individual investigator grants awarded to faculty is a measure of scientific productivity, similar to publications, presentations, and patents. The information below is presented in this context. Because individual awards are administered differently (by different agencies; under different terms), this information should not be aggregated.

PI: Abernathy, C.

Grant Title: A 21st Century Approach to Electronic Device Reliability

Agency: U.S. Air Force

Project Dates: 5/15/08 - 8/14/13

Award: \$64,836

PI: Andraka, B.

Grant Title: Investigation of Novel Strongly Correlated Electron States with the Emphasis on Pr-Based Systems

Agency: U.S. Department of Energy

Project Dates: 2/1/99 - 1/31/14

Award: \$109,345

PI: Angerhofer, A.

Grant Title: The Catalytic Mechanism of Oxalate Decarboxylase Studied By Advanced EPR Experiments

Agency: National Science Foundation

Project Dates: 7/1/08 - 6/30/12

Award: \$44,850

PI: Angerhofer, A.

Grant Title: Ex Vivo Analysis of Irradiated Finger/Toe Nails by EPR as a Biodosimeter

Agency: Dartmouth College

Project Dates: 8/1/11 - 7/31/12

Award: \$6,968

PI: Blackband, S.J.

Grant Title: MR Microscopy at the Cellular Level Using Microsurface Rf Coils

Agency: Florida State University

Project Dates: 2/1/10 - 1/31/12

Award: \$86,902

PI: Blackband, S.J.

Grant Title: Development of MR Microscopy at the Cellular Level

Agency: National Institutes of Health

Project Dates: 9/30/10 - 8/31/14

Award: \$521,420

PI: Bowers, C.R.

Grant Title: Inducing Molecular Single File Diffusion by Co-Adsorption in One Dimensional Channels for Gas Separations And Catalysis

Agency: National Science Foundation

Project Dates: 6/22/10 - 8/31/13

Award: \$168,147

PI: Cheng, H.P.

Grant Title: Understanding and Reducing

Thermal Noise via Atomistic Simulations

Agency: National Science Foundation

Project Dates: 9/1/11 - 8/31/14

Award: \$105,000

PI: Cheng, H.P.

Grant Title: A Computational Approach to Complex Junctions and Interfaces

Agency: U.S. Department Of Energy

Project Dates: 9/1/02 - 12/30/11

Award: \$220,000

PI: Christou, G.

Grant Title: Collaborative Research: Molecular Spintronics with Single-Molecule Magnets

Agency: National Science Foundation

Project Dates: 5/1/10 - 4/30/13

Award: \$66,782

PI: Christou, G.

Grant Title: Transition Metal Clusters as Single-Molecule Magnets

Agency: National Science Foundation

Project Dates: 9/1/09 - 8/31/12

Award: \$174,000

PI: Edison, A. S.

Grant Title: Comparative Behavioral Metabolomics in Nematodes

Agency: National Institutes of Health

Project Dates: 5/1/09 - 2/28/13

Award: \$265,370

PI: Edison, A. S.

Grant Title: National High Magnetic Field Laboratory (NHMFL) Project

Agency: Florida State University

Project Dates: 1/1/08 - 12/31/12

Award: \$419,345

PI: Edison, A. S.

Grant Title: Lit: Collaborative Research: Integrating Physiological and Genetic Mechanisms to Understand the Evolution of Cold...

Agency: National Science Foundation

Project Dates: 4/1/11 - 3/31/13

Award: \$22,986

PI: Edison, A.S.

Grant Title: Endogenous G-Protein Coupled Receptor Antagonists

Agency: University of Minnesota

Project Dates: 8/1/11 - 7/31/12

Award: \$19,587

PI: Edison, A.S.

Grant Title: Comparative Behavioral Metabolomics in Nematodes

Agency: National Institutes of Health

Project Dates: 5/1/09 - 2/28/13

Award: \$26,538

PI: Edison, A.S.

Grant Title: National High Magnetic Field Laboratory (NHMFL) Project

Agency: Florida State University

Project Dates: 1/1/08 - 12/31/12

Award: \$619,345

PI: Edison, A.S.

Grant Title: Improved NMR Technology for Natural Products and Metabolomics

Agency: National Institutes of Health

Project Dates: 8/1/09 - 6/30/13

Award: \$336,336

PI: Eyler, J.R.

Grant Title: Pire: A US-Dutch Mass Spectrometry Consortium for Advanced Modeling and Biological Structure and Imaging Applications

Agency: Wayne State University

Project Dates: 10/1/07 - 9/30/11

Award: \$74,142

PI: Eyler, J.R.

Grant Title: Pire: A US-Dutch Mass Spectrometry Consortium for Advanced Modeling and Biological Structure and Imaging Applications

Agency: Wayne State University

Project Dates: 10/1/07 - 9/30/12

Award: \$77,624

PI: Eyler, J.R.

Grant Title: Pire: A US-Dutch Mass Spectrometry Consortium for Advanced Modeling and Biological Structure and Imaging Applications

Agency: Wayne State University

Project Dates: 10/1/07 - 9/30/12

Award: \$2,278

PI: Fanucci, G.E.

Grant Title: Upgrade to E500 X- and Q-Band CW EPR Spectrometer for Biomedical Research

Agency: National Institutes of Health

Project Dates: 7/15/11 - 7/14/12

Award: \$523,030

PI: Fanucci, G.E.

Grant Title: Career: Site-Directed Spin Labeling EPR Applications in Intrinsically Unstructured Proteins

Agency: National Science Foundation

Project Dates: 8/1/08 - 7/31/12

Award: \$106,250

PI: Fanucci, G.E.

Grant Title: Career: Site-Directed Spin Labeling EPR Applications in Intrinsically Unstructured Proteins (Participant Support)

Agency: National Science Foundation

Project Dates: 8/1/08 - 7/31/12

Award: \$12,000

PI: Fanucci, G.E.

Grant Title: Ex Vivo Analysis of Irradiated Finger/Toe Nails by EPR as a Biodosimeter

Agency: Dartmouth College

Project Dates: 8/1/11 - 7/31/12

Award: \$6,846

PI: Hebard, A.F.

Grant Title: Physics of Proximate Metallic and Insulating Phases

Agency: National Science Foundation

Project Dates: 9/1/10 - 8/31/12

Award: \$130,000

PI: Hershfield, S.P.

Grant Title: REU Site: Materials Physics at the University of Florida (Participant Support)

Agency: National Science Foundation

Project Dates: 4/1/09 - 3/31/12

Award: \$101,475

PI: Hershfield, S.P.

Grant Title: REU Site: Materials Physics at the University Of Florida

Agency: National Science Foundation

Project Dates: 4/1/09 - 3/31/12

Award: \$18,525

PI: Hirschfeld, P.J.

Grant Title: Grains, Wires and Interfaces of Cuprate Superconductors

Agency: U.S. Department Of Energy

Project Dates: 9/1/05 - 8/31/14

Award: \$105,000

PI: Hirschfeld, P.J.

Grant Title: Disorder and Emergence of Inhomogeneous Phases in Strongly Correlated Electron Systems

Agency: National Science Foundation

Project Dates: 9/16/10 - 9/30/13

Award: \$90,000

PI: Ingersent, K.

Grant Title: Materials World Network - Collaborative Research: Symmetry, Local-Environment and Time-Dependent Effects In Nanoscale...

Agency: National Science Foundation

Project Dates: 9/15/11 - 8/31/12

Award: \$180,980

PI: Long, J.R.

Grant Title: Console Upgrade for Microimaging and Solid State NMR Spectroscopy at 600 MHz

Agency: National Institutes of Health

Project Dates: 3/15/11 - 3/14/13

Award: \$449,900

PI: Luesch, H.

Grant Title: Mitochondrial Oxidative Stress in the Retinal Pigment Epithelium as a Model for Atrophic Macular Degeneration

Agency: National Institutes of Health

Project Dates: 3/1/11 - 2/28/14

Award: \$51,150

PI: Mareci, T.H.

Grant Title: Computational Transport Models for Convection-Enhanced CNS Delivery

Agency: National Institutes of Health
Project Dates: 7/1/08 - 7/31/13
Award: \$103,011

PI: Mareci, T.H.

Grant Title: Correlating Disturbed Sleep and Damaged White Matter Tracts in the Brainstem in Traumatic Brain Injury Using Diffusion...

Agency: Florida Department of Health
Project Dates: 7/1/11 - 6/30/12
Award: \$67,882

PI: Mareci, T.H.

Grant Title: Neuroimage Processing for Rehabilitation Research for Neuroimaging Core

Agency: U.S. Department of Veterans Affairs
Project Dates: 9/12/11 - 9/11/12
Award: \$10,000

PI: Maslov, D.

Grant Title: Materials World Network: Control of the Electron Nuclear Interaction in Nanoelectronic Devices

Agency: National Science Foundation
Project Dates: 8/1/09 - 7/31/13
Award: \$85,000

PI: Pearton, S.J.

Grant Title: Fundamental Studies and Modeling of Radiation Effects in Gan-Based Heterostructures

Agency: U.S. Department of Defense
Project Dates: 4/27/11 - 5/1/14
Award: \$120,000

PI: Pearton, S.J.

Grant Title: Ain/Gan Hemt Device Life-Time and Reliability Testing

Agency: SVT Associates Inc
Project Dates: 3/3/09 - 7/2/11
Award: \$26,035

PI: Pearton, S.J.

Grant Title: A 21st Century Approach to Electronic Device Reliability

Agency: U.S. Department of the Air Force
Project Dates: 5/15/08 - 8/14/13
Award: \$66,731

PI: Pearton, S.J.

Grant Title: Low Cost, Scalable Manufacturing of Surface-Engineered Superhard (SESH) Substrates for Next Generation Electronic & Phot...

Agency: SINMAT
Project Dates: 2/1/11 - 1/20/12
Award: \$141,000

PI: Pearton, S.J.

Grant Title: Revenue for Alumni / Endowed Professorship

Agency: UF Foundation
Project Dates: 9/1/05 - 6/30/15
Award: \$17,994

PI: Richards, N.G.

Grant Title: Biochemical Studies of Oxalate Decarboxylase

Agency: National Institutes of Health
Project Dates: 4/15/10 - 6/30/14
Award: \$263,148

PI: Richards, N.G.

Grant Title: Landscapes in Catalytic Nucleic Acids

Agency: Foundation for Applied Molecular Evolution
Project Dates: 8/16/11 - 8/23/12
Award: \$40,883

PI: Rinzler, A.G.

Grant Title: SWNT Based Air Cathodes for Fuel Cells & Metal Air Batteries

Agency: nRadiance
Project Dates: 12/16/10 - 12/15/11
Award: \$41,000

PI: Rinzler, A.G.

Grant Title: Carbon Nanotube-Based Transparent Electrodes for Polymer Emittin, Electro...

Agency: nRadiance
Project Dates: 7/15/05 - 8/31/12
Award: \$123,151

PI: Rinzler, A.G.

Grant Title: Carbon Nanotube-Based Transparent Electrodes for Polymer Emittin, Electro...

Agency: nRadiance
Project Dates: 7/15/05 - 12/31/12
Award: \$328,010

PI: Stanton, C.J.

Grant Title: Carrier, Phonon and THz Dynamics in Narrow Gap and Carbon Based Nanostructures

Agency: National Science Foundation
Project Dates: 8/15/11 - 8/31/13
Award: \$100,000

PI: Stanton, C.J.

Grant Title: US-Japan Cooperative Research and Education on Terahertz Dynamics in Nanostructures

Agency: Rice University
Project Dates: 9/15/10 - 8/31/12

Award: \$64,603

PI: Stewart, G.R.

Grant Title: Fe Pnictide and F-Electron Novel Materials: Magnetism, Superconductivity, and Quantum Criticality

Agency: U.S. Department of Energy
Project Dates: 10/1/09 - 11/30/11
Award: \$150,000

PI: Stewart, G.R.

Grant Title: Fe Pnictide and F-Electron Novel Materials: Magnetism, Superconductivity, and Quantum Criticality

Agency: U.S. Department Of Energy
Project Dates: 10/1/09 - 11/30/12
Award: \$150,000

PI: Sullivan, N.S.

Grant Title: Revitalization of University of Florida Helium Liquefaction and Recovery System

Agency: National Science Foundation
Project Dates: 9/1/10 - 8/31/13
Award: \$1,683,544

PI: Sullivan, N.S.

Grant Title: National High Magnetic Field Laboratory--High B/T Facility

Agency: Florida State University
Project Dates: 1/1/08 - 12/31/12
Award: \$193,686

PI: Sullivan, N.S.

Grant Title: Revitalization of University of Florida Helium Liquefaction and Recovery System

Agency: National Science Foundation
Project Dates: 9/1/10 - 8/31/13
Award: \$37,022

PI: Sullivan, N.S.

Grant Title: National High Magnetic Field Laboratory--High B/T Facility

Agency: Florida State University
Project Dates: 1/1/08 - 12/31/12
Award: \$193,685

PI: Sullivan, N.S.

Grant Title: National High Magnetic Field Laboratory--High B/T Facility

Agency: Florida State University
Project Dates: 1/1/08 - 12/31/12
Award: \$60,000

PI: Sullivan, N.S.

Grant Title: Miscellaneous Donors

Agency: Miscellaneous Donors

Project Dates: 7/30/89 - 6/30/15

Award: \$12,810

PI: Sullivan, N.S.

Grant Title: Miscellaneous Donors

Agency: Miscellaneous Donors

Project Dates: 7/30/89 - 6/30/15

Award: \$13,260

PI: Takano, Y.

Grant Title: National High Magnetic Field Laboratory - User Collaboration Grants Program

Agency: Florida State University

Project Dates: 7/1/11 - 12/31/12

Award: \$100,964

PI: Talham, D. R.

Grant Title: ACS Hach Land Grant Scholarship

Agency: American Chemical Society

Project Dates: 5/18/11 - 5/17/12

Award: \$12,000

PI: Talham, D.R.

Grant Title: Magnetic and Photomagnetic Coordination Polymer Heterostructures

Agency: National Science Foundation

Project Dates: 7/1/10 - 6/30/13

Award: \$130,000

PI: Tanner, D.B.

Grant Title: Development of High Power Continuous Wave Lasers, Components and Optical Contamination Diagnostics for Future Ground-Base

Agency: National Science Foundation

Project Dates: 8/1/11 - 7/31/12

Award: \$85,000

PI: Tanner, D. B.

Grant Title: Time-Resolved Far-Infrared Experiments: Implications for Nanotechnology

Agency: U.S. Department of Energy

Project Dates: 5/15/02 - 5/14/12

Award: \$165,000

PI: Tanner, D. B.

Grant Title: Task N: Research in High Energy Physics (Experimental and Therotical) Together with Quarknet Educational Outreach

Agency: U.S. Department of Energy

Project Dates: 3/1/10 - 6/30/12

Award: \$112,212

PI: Tanner, D. B.

Grant Title: Task N: Research in High Energy Physics (Experimental and Therotical) Together with Quarknet Educational Outreach

Agency: U.S. Department of Energy

Project Dates: 3/1/10 - 6/30/12

Award: \$24,787

2011 USER FACILITY STATISTICS

DC Field Facility



Users, Requests & Operations

 January 17, 2011 - January 15, 2012

Note: A user is an individual or a member of a research group that is allocated magnet time. The user does not have to be “on site” for the experiment. A researcher who sends samples for analysis; a scientist who uses new lab technologies to conduct experiments remotely; or a PI who sends students to the Magnet Lab, are all considered users. All user numbers reflect distinct individuals, i.e. if a user has multiple proposals (different scientific thrusts) or is allocated magnet time more than once during the year, he/she is counted only once.

TABLE 1

DC Field Facility: User Demographics

	Users	Female	Minority ¹	Users Present ^{3,7}	Users Operating Remotely ^{4,7}	Users Sending Sample ^{5,7}	Off-Site Collaborators ^{6,7}
Senior Investigators, U.S.	161	15	7	109	0	0	52
Senior Investigators, non-U.S.	70	8	3	34	0	5	31
Postdocs, U.S.	46	8	2	43	0	0	3
Postdocs, non-U.S.	16	5	1	13	0	0	3
Students ² , U.S.	123	29	7	106	0	0	17
Students ² , non-U.S.	37	6	1	29	0	0	8
Technician, U.S.	0	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0	0
TOTAL	453	71	21	334	0	5	114

1 Minority status includes American Indian, Alaska Native, Black or African American, Hispanic, Native Hawaiian or other Pacific Islander. Minority status excludes Asian and White-Not of Hispanic Origin.

2 “Students” generally refers to graduate students, but may include a few undergraduate students.

3 “Users Present” includes users physically present in the MagLab user facility during the experiment AND any MagLab-Affiliated or Local users on the experiment.

4 “Users Operating Remotely” refers to users who operate the magnet system from a remote location. Remote operations are not currently available in all facilities.

5 “Users Sending Sample” refers to users who send the sample to the facility and the experiment is conducted by in-house user support personnel.

Users at UF, FSU, and LANL cannot be “sample senders” for facilities located on their campuses.

6 “Off-Site Collaborators” are scientific or technical participants on the experiment; who will not be present, sending sample, or operating the magnet system remotely; and who are not located on the campus of that facility (i.e., they are off-site).

7 The total of Users Present + Users Operating Remotely + Users Sending Sample + and Off-Site Collaborators will equal the total number of users.

TABLE 2

DC Field Facility: User Affiliations

	Users	NHMFL Affiliated Users ¹	Local Users ¹	University Users ^{2,4}	Industry Users ⁴	National Lab Users ^{3,4}
Senior Investigators, U.S.	161	54	7	125	2	34
Senior Investigators, non-U.S.	70	0	0	52	0	18
Postdocs, U.S.	46	11	8	36	0	10
Postdocs, non-U.S.	16	0	0	13	0	3
Students, U.S.	123	13	11	121	0	2
Students, non-U.S.	37	0	0	34	0	3
Technician, U.S.	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	453	78	26	381	2	70

1 NHMFL-affiliated users are defined as anyone in the lab’s personnel system [i.e. on our Web site/directory], even if they travel to another site. Local users are defined as any non-NHMFL-affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site. The sum of NHMFL-affiliated and Local users equals what was formerly referred to as “Internal Investigators”.

Note for Annual Reporting: Due to programming limitations and the dynamic nature of information in this system, Local Users may include a few NHMFL-affiliated users who left during the year and whose records have not yet been updated.

2 In addition to external users, all users with primary affiliations at FSU, UF, or FAMU are reported in this category, even if they are also NHMFL associates.

3 In addition to external users, users with primary affiliations at NHMFL/LANL are reported in this category.

4 The total of university, industry, and national lab users will equal the total number of users.

TABLE 3

DC Field Facility: Users by Discipline

	Users	Condensed Matter Physics	Chemistry, Geochemistry	Engineering	Magnets, Mats., Testing, Instruments	Biology, Biochemistry, Biophysics
Senior Investigators, U.S.	161	108	14	21	16	2
Senior Investigators, non-U.S.	70	62	1	3	3	1
Postdocs, U.S.	46	36	6	1	2	1
Postdocs, non-U.S.	16	14	0	2	0	0
Students, U.S.	123	98	10	12	3	0
Students, non-U.S.	37	34	0	2	1	0
Technician, U.S.	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	453	352	31	41	25	4

TABLE 4

DC Field Facility: Experimental Requests¹ for Magnet Time

Weeks Requested	Weeks Granted	Weeks Declined
344	289 (76.46%)	89 (23.54%)

¹ Due to operational differences, experimental requests for magnet time are measured differently among facilities. A request for NMR magnet time is measured in the number of days requested. A request for DC Field magnet time is measured in weeks. In the PFF, High B/T, EMR, and ICR facilities, the number of requests is equal to the number of experiments. For any given year, the time (or requests) granted and the time (or requests) declined may not equal the total number of requests. This is because (1) magnet time may be granted to experiments submitted in a prior year and/or (2) in NMR and DC Field facilities, the days or weeks granted may be more (as in the case of a user getting exceptional results) or less than what was requested due to operational limitations.

TABLE 5

DC Field Facility: Research Proposals¹ Profile with Magnet Time

	Number of Proposals
Condensed Matter Physics	127
Chemistry, Geochemistry	8
Engineering	3
Magnets, Materials, Testing, Instruments	15
Biology, Biochemistry, Biophysics	4
TOTAL	157
	Number of Proposals
Minority ²	2
Female ³	19

¹ A "proposal" may have associated with it a single experiment or a group of closely related experiments. A PI may have more than one proposal.

² The number of proposals satisfying one of the following two conditions: (a) the PI is a minority OR (b) the PI is a non-minority working at a minority-serving college or university AND the proposal includes minority participants.

³ The number of proposals satisfying one of the following two conditions: (a) the PI is a female OR (b) the PI is a male working at a college or university for women AND the proposal includes female participants.

TABLE 6

DC Field Facility: Operations Statistics Number of Magnet Days¹

	Resistive Magnets & Hybrid	Superconducting Magnets	Total Days Allocated /User Affiliated	Percentage Allocated /User Affiliated
NHMFL-Affiliated ²	115.17	113.00	228.17	14.89%
Local ²	18.84	118.00	136.84	8.93%
U.S. University	278.32	464.00	742.32	48.44%
U.S. Govt. Lab.	53.62	40.00	93.62	6.11%
U.S. Industry	0.00	0.00	0.00	0.00%
Non-U.S.	211.39	102.00	313.39	20.45%
Test, Calibration, Set-up, Maintenance	10.42	7.75	18.16	1.19%
TOTAL	687.76	844.75	1532.50	100.00%

1 User Units are defined as magnet days. For the DC Field Facility, one magnet day is defined as 7 hours in a water-cooled resistive or hybrid magnet.

Using this definition, a typical 24-hour day in the DC Field Facility contains three or four "magnet days." For experiments in the superconducting magnets, one "magnet day" is defined as 24 hours of use.

2 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 7

DC Field Facility: Operations by Discipline Number of Magnet Days¹

	Total Days ¹ Allocated /User Affil.	Condensed Matter Physics	Chemistry, Geochem.	Engineering	Magnets, Matls, Testing, Instruments	Biology, Biochemistry, Biophysics
NHMFL-Affiliated ²	228.17	202.05	7.99	4.25	13.89	0.00
Local ²	136.84	40.84	96.00	0.00	0.00	0.00
U.S. University	742.32	710.51	20.23	0.00	5.94	5.64
U.S. Govt. Lab.	93.62	87.32	0.00	0.00	6.30	0.00
U.S. Industry	0.00	0.00	0.00	0.00	0.00	0.00
Non-U.S.	313.39	293.67	0.00	15.09	4.62	0.00
Test, Calibration, Set-up, Maintenance	18.16	3.56	0.00	0.00	14.60	0.00
TOTAL	1532.50	1337.95	124.22	19.34	45.35	5.64

1 User Units are defined as magnet days. For the DC Field Facility, one magnet day is defined as 7 hours in a water-cooled resistive or hybrid magnet.

Using this definition, a typical 24-hour day in the DC Field Facility contains three or four "magnet days."

For experiments in the superconducting magnets, one "magnet day" is defined as 24 hours of use.

2 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 8

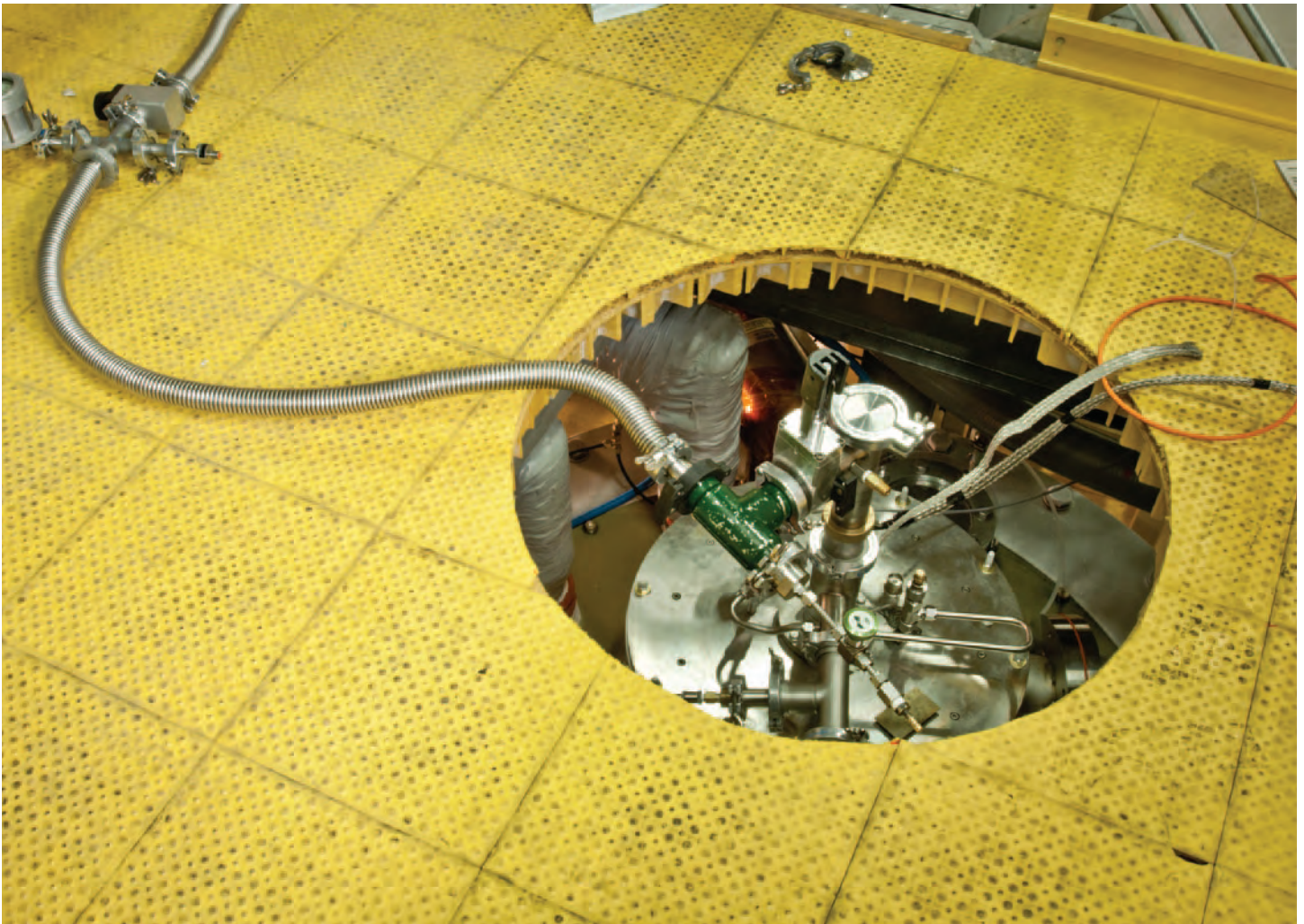
DC Field Facility: New User PIs¹ (25)

Name	Organization	Proposal	Year of Magnet Time
Grosche, Malte	University of Cambridge	P01620	2011
van der Laan, Danko	National Institute of Standards and Technology	P01693	2011
Howarth, Thomas	NAVSEA Division Newport	P01702	2011
Zhou, Xiaoling	Kunming University of Science and Technology	P01706	2011
Cao, Yunwei Charles	University of Florida	P01715	2011
Stoica, Vladimir	University of Michigan	P01718	2011
Kim, Jun Sung	POSTECH	P01719	2011
Zhang, Lin	NHMFL	P01721	2011
Greven, Martin	University of Minnesota	P01725	2011
Maesato, Mitsuhiro	Kyoto University	P01781	2011
Li, Lu	University of Michigan	P01822	2011
Andrei, Eva	Rutgers The State University of New Jersey	P01823	2011
Zhang, Chi	Peking University	P01824	2011
Graf, David	Florida State University	P01832	2012
Ignatchik, Oleg	Helmholtz-Zentrum Dresden-Rossendorf	P01834	2012
Yuan, Huiqiu	Zhejiang University	P01840	2011
Jarillo-Herrero, Pablo	MIT	P01842	2011
Haga, Yoshinori	Japan Atomic Energy Agency	P01845	2012
Searles, Thomas	Morehouse College	P01910	Scheduled 2012
Sarkar, Biprajit	Freie Universität Berlin	P01919	2011
Mallah, Talal	Université Paris Sud XI	P01924	Scheduled 2012
Wang, Hailin	University of Oregon	P01928	Scheduled 2012
Prozorov, Ruslan	Ames Laboratory-Iowa State University	P01930	2012
Hanisch, Jens	Leibniz Institute for Solid State and Materials Research IFD Dresden	P01938	2012
Armitage, N. Peter	The Johns Hopkins University	P01943	2012

¹ This table lists users serving as a principal investigator for the first time, and whose proposal was submitted during this year. It also shows the year in which magnet time was received. TBD stands for To Be Determined, indicating it has not yet been allotted magnet time.

2011 USER FACILITY STATISTICS

Pulsed Field Facility



Users, Requests & Operations

A user is an individual or a member of a research group that is allocated magnet time. The user does not have to be “on site” for the experiment. A researcher who sends samples for analysis; a scientist who uses new lab technologies to conduct experiments remotely; or a PI who sends students to the Magnet Lab, are all considered users. All user numbers reflect distinct individuals, i.e. if a user has multiple proposals (different scientific thrusts) or is allocated magnet time more than once during the year, he/she is counted only once.

TABLE 1

Pulsed Field Facility: User Demographics

	Users	Female	Minority ¹	Users Present ^{3,7}	Users Operating Remotely ^{4,7}	Users Sending Sample ^{5,7}	Off-Site Collaborators ^{6,7}
Senior Investigators, U.S.	74	3	5	49	0	11	14
Senior Investigators, non-U.S.	32	3	6	4	0	9	19
Postdocs, U.S.	26	5	2	22	0	4	0
Postdocs, non-U.S.	1	0	0	0	0	0	1
Students ² , U.S.	13	5	0	7	0	4	2
Students ² , non-U.S.	6	1	0	3	0	2	1
Technician, U.S.	0	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0	0
TOTAL	152	17	13	85	0	30	37

1 Minority status includes American Indian, Alaska Native, Black or African American, Hispanic, Native Hawaiian or other Pacific Islander.

Minority status excludes Asian and White-Not of Hispanic Origin.

2 "Students" generally refers to graduate students, but may include a few undergraduate students.

3 "Users Present" includes users physically present in the MagLab user facility during the experiment AND any MagLab-Affiliated or Local users on the experiment.

4 "Users Operating Remotely" refers to users who operate the magnet system from a remote location. Remote operations are not currently available in all facilities.

5 "Users Sending Sample" refers to users who send the sample to the facility and the experiment is conducted by in-house user support personnel. Users at UF, FSU, and LANL cannot be "sample senders" for facilities located on their campuses.

6 "Off-Site Collaborators" are scientific or technical participants on the experiment; who will not be present, sending sample, or operating the magnet system remotely; and who are not located on the campus of that facility (i.e., they are off-site).

7 The total of Users Present + Users Operating Remotely + Users Sending Sample + and Off-Site Collaborators will equal the total number of users.

TABLE 2

Pulsed Field Facility: User Affiliations

	Users	NHMFL Affiliated Users ¹	Local Users ¹	University Users ^{2,4}	Industry Users ⁴	National Lab Users ^{3,4}
Senior Investigators, U.S.	74	22	23	32	0	42
Senior Investigators, non-U.S.	32	0	0	23	0	9
Postdocs, U.S.	26	9	7	12	0	14
Postdocs, non-U.S.	1	0	0	0	0	1
Students, U.S.	13	4	2	9	0	4
Students, non-U.S.	6	0	0	6	0	0
Technician, U.S.	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	152	35	32	82	0	70

1 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site. The sum of NHMFL-Affiliated and Local users equals what was formerly referred to as "Internal Investigators". **Note for Annual Reporting:** Due to programming limitations and the dynamic nature of information in this system, Local Users may include a few NHMFL-Affiliated users who left during the year and whose records have not yet been updated.

2 In addition to external users, all users with primary affiliations at FSU, UF, or FAMU are reported in this category, even if they are also NHMFL associates.

3 In addition to external users, users with primary affiliations at NHMFL/LANL are reported in this category.

4 The total of university, industry, and national lab users will equal the total number of users.

TABLE 3

Pulsed Field Facility: Users by Discipline

	Users	Condensed Matter Physics	Chemistry, Geochemistry	Engineering	Magnets, Mats., Testing, Instruments	Biology, Biochemistry, Biophysics
Senior Investigators, U.S.	74	62	9	1	2	0
Senior Investigators, non-U.S.	32	30	2	0	0	0
Postdocs, U.S.	26	20	6	0	0	0
Postdocs, non-U.S.	1	1	0	0	0	0
Students, U.S.	13	11	1	1	0	0
Students, non-U.S.	6	6	0	0	0	0
Technician, U.S.	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	152	130	18	2	2	0

TABLE 4

Pulsed Field Facility: Experimental Requests¹ for Magnet Time

Experimental Requests	Experimental Requests Granted	Experimental Requests Declined
165	126 (70.39%)	53 (29.61%)

¹ Due to operational differences, experimental requests for magnet time are measured differently among facilities. A request for NMR magnet time is measured in the number of days requested. A request for DC Field magnet time is measured in weeks. In the PFF, High B/T, EMR, and ICR facilities, the number of requests is equal to the number of experiments. For any given year, the time (or requests) granted and the time (or requests) declined may not equal the total number of requests. This is because (1) magnet time may be granted to experiments submitted in a prior year and/or (2) in NMR and DC Field facilities, the days or weeks granted may be more (as in the case of a user getting exceptional results) or less than what was requested due to operational limitations.

TABLE 5

Pulsed Field Facility: Research Proposals¹ Profile with Magnet Time

	Number of Proposals
Condensed Matter Physics	55
Chemistry, Geochemistry	3
Engineering	0
Magnets, Materials, Testing, Instruments	4
Biology, Biochemistry, Biophysics	0
TOTAL	62
	Number of Proposals
Minority ²	7
Female ³	8

¹ A "proposal" may have associated with it a single experiment or a group of closely related experiments. A PI may have more than one proposal.

² The number of proposals satisfying one of the following two conditions: (a) the PI is a minority OR (b) the PI is a non-minority working at a minority-serving college or university AND the proposal includes minority participants.

³ The number of proposals satisfying one of the following two conditions: (a) the PI is a female OR (b) the PI is a male working at a college or university for women AND the proposal includes female participants.

TABLE 6

Pulsed Field Facility: Operations Statistics Number of Magnet Days¹

	Supercond.	Short Pulse	Mid Pulse	Long Pulse	100 T	Single Turn	Total Days Allocated / User Affiliated	Percentage Allocated / User Affiliated
NHMFL-Affiliated ²	270.00	129.00	5.00	4.00	4.00	5.00	417.00	32.60%
Local ²	165.00	36.00	5.00	0.00	0.00	0.00	206.00	16.11%
U.S. University	193.00	78.00	5.00	5.00	6.00	58.00	345.00	26.97%
U.S. Govt. Lab.	5.00	64.00	0.00	0.00	0.00	13.00	82.00	6.41%
U.S. Industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
Non-U.S.	97.00	132.00	0.00	0.00	0.00	0.00	229.00	17.90%
Test, Calibration, Set-up, Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
TOTAL	730.00	439.00	15.00	9.00	10.00	76.00	1279.00	100.00%

¹ User Units are defined as magnet days. For the Pulsed Field Facility, one magnet day is defined as 12 hours in any pulsed magnet system.

For experiments in the superconducting magnets, one "magnet day" is defined as 24 hours of use.

² NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site. Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 7

Pulsed Field Facility: Operations by Discipline Number of Magnet Days¹

	Total Days ¹ Allocated / User Affil.	Condensed Matter Physics	Chemistry, Geochem.	Engineering	Magnets, Mats, Testing, Instruments	Biology, Biochemistry, Biophysics
NHMFL-Affiliated ²	417.00	282.00	0.00	0.00	135.00	0.00
Local ²	206.00	185.00	12.00	0.00	9.00	0.00
U.S. University	345.00	317.00	28.00	0.00	0.00	0.00
U.S. Govt. Lab.	82.00	82.00	0.00	0.00	0.00	0.00
U.S. Industry	0.00	0.00	0.00	0.00	0.00	0.00
Non-U.S.	229.00	229.00	0.00	0.00	0.00	0.00
Test, Calibration, Set-up, Maintenance	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	1279.00	1095.00	40.00	0.00	144.00	0.00

¹ User Units are defined as magnet days. For the Pulsed Field Facility, one magnet day is defined as 12 hours in any pulsed magnet system.

For experiments in the superconducting magnets, one "magnet day" is defined as 24 hours of use.

² NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site. Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 8

Pulsed Field Facility: New User PIs¹ (14)

Name	Organization	Proposal	Year of Magnet Time
Daou, Ramzy	Max Planck Institute for Chemical Physics of Solids	P01624	2011
Friedman, Jonathan	Amherst College	P01629	2011
Bulmer, John	AFRL	P01662	2011
Taylor, Antoniette	Los Alamos National Laboratory	P01775	2011
Wang, Yayu	Tsinghua University	P01778	2011
Cheong, Sang Wook	Rutgers University	P01793	2011
Tokunaga, Masashi	University of Tokyo ISSP	P01807	2011
Kondo, Akihiro	Univeristy of Tokyo	P01808	2011
Haga, Yoshinori	Japan Atomic Energy Agency	P01815	2011
Hwang, Harold	Stanford University	P01880	2011
Kwon, Yong-Seung	SungKyunKwon University	P01914	2011
McQueen, Tyrel	Johns Hopkins University	P01940	2011
May, Steven	Drexel University	P01957	2011
Raptis, Raphael	University of Puerto Rico	P01965	Scheduled 2012

¹ This table lists users serving as a principal investigator for the first time, and whose proposal was submitted during this year. It also shows the year in which magnet time was received. TBD stands for To Be Determined, indicating it has not yet been allotted magnet time.

2011 USER FACILITY STATISTICS

High B/T Facility



Users, Requests & Operations

Note: A user is an individual or a member of a research group that is allocated magnet time. The user does not have to be “on site” for the experiment. A researcher who sends samples for analysis; a scientist who uses new lab technologies to conduct experiments remotely; or a PI who sends students to the Magnet Lab, are all considered users. All user numbers reflect distinct individuals, i.e. if a user has multiple proposals (different scientific thrusts) or is allocated magnet time more than once during the year, he/she is counted only once.

TABLE 1

High B/T Facility: User Demographics

	Users	Female	Minority ¹	Users Present ^{3,7}	Users Operating Remotely ^{4,7}	Users Sending Sample ^{5,7}	Off-Site Collaborators ^{6,7}
Senior Investigators, U.S.	11	1	0	6	0	0	5
Senior Investigators, non-U.S.	4	0	1	1	0	0	3
Postdocs, U.S.	6	1	0	5	0	0	1
Postdocs, non-U.S.	0	0	0	0	0	0	0
Students ² , U.S.	3	1	1	3	0	0	0
Students ² , non-U.S.	0	0	0	0	0	0	0
Technician, U.S.	0	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0	0
TOTAL	24	3	2	15	0	0	9

1 Minority status includes American Indian, Alaska Native, Black or African American, Hispanic, Native Hawaiian or other Pacific Islander. Minority status excludes Asian and White-Not of Hispanic Origin

2 "Students" generally refers to graduate students, but may include a few undergraduate students.

3 "Users Present" includes users physically present in the MagLab user facility during the experiment AND any MagLab-Affiliated or Local users on the experiment.

4 "Users Operating Remotely" refers to users who operate the magnet system from a remote location. Remote operations are not currently available in all facilities.

5 "Users Sending Sample" refers to users who send the sample to the facility and the experiment is conducted by in-house user support personnel.

Users at UF, FSU, and LANL cannot be "sample senders" for facilities located on their campuses.

6 "Off-Site Collaborators" are scientific or technical participants on the experiment; who will not be present, sending sample, or operating the magnet system remotely; and who are not located on the campus of that facility (i.e., they are off-site).

7 The total of Users Present + Users Operating Remotely + Users Sending Sample + and Off-Site Collaborators will equal the total number of users.

TABLE 2

High B/T Facility: User Affiliations

	Users	NHMFL Affiliated Users ¹	Local Users ¹	University Users ^{2,4}	Industry Users ⁴	National Lab Users ^{3,4}
Senior Investigators, U.S.	11	4	1	8	0	3
Senior Investigators, non-U.S.	4	0	0	3	0	1
Postdocs, U.S.	6	2	3	3	0	3
Postdocs, non-U.S.	0	0	0	0	0	0
Students, U.S.	3	0	3	3	0	0
Students, non-U.S.	0	0	0	0	0	0
Technician, U.S.	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	24	6	7	17	0	7

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Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site. The sum of NHMFL-Affiliated and Local users equals what was formerly referred to as "Internal Investigators". **Note for Annual Reporting:** Due to programming limitations and the dynamic nature of information in this system, Local Users may include a few NHMFL-Affiliated users who left during the year and whose records have not yet been updated.

2 In addition to external users, all users with primary affiliations at FSU, UF, or FAMU are reported in this category, even if they are also NHMFL associates.

3 In addition to external users, users with primary affiliations at NHMFL/LANL are reported in this category.

4 The total of university, industry, and national lab users will equal the total number of users.

TABLE 3

High B/T Facility: Users by Discipline

	Users	Condensed Matter Physics	Chemistry, Geochemistry	Engineering	Magnets, Mats., Testing, Instruments	Biology, Biochemistry, Biophysics
Senior Investigators, U.S.	11	9	0	2	0	0
Senior Investigators, non-U.S.	4	3	1	0	0	0
Postdocs, U.S.	6	6	0	0	0	0
Postdocs, non-U.S.	0	0	0	0	0	0
Students, U.S.	3	3	0	0	0	0
Students, non-U.S.	0	0	0	0	0	0
Technician, U.S.	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	24	21	1	2	0	0

TABLE 4

High B/T Facility: Experimental Requests¹ for Magnet Time

Experimental Requests	Experimental Requests Granted	Experimental Requests Declined
10	8 (61.54%)	5 (38.46%)

¹ Due to operational differences, experimental requests for magnet time are measured differently among facilities. A request for NMR magnet time is measured in the number of days requested. A request for DC Field magnet time is measured in weeks. In the PFF, High B/T, EMR, and ICR facilities, the number of requests is equal to the number of experiments. For any given year, the time (or requests) granted and the time (or requests) declined may not equal the total number of requests. This is because (1) magnet time may be granted to experiments submitted in a prior year and/or (2) in NMR and DC Field facilities, the days or weeks granted may be more (as in the case of a user getting exceptional results) or less than what was requested due to operational limitations.

TABLE 5

High B/T Facility: Research Proposals¹ Profile with Magnet Time

	Number of Proposals
Condensed Matter Physics	4
Chemistry, Geochemistry	0
Engineering	0
Magnets, Materials, Testing, Instruments	0
Biology, Biochemistry, Biophysics	0
TOTAL	4
	Number of Proposals
Minority²	0
Female³	0

1 A "proposal" may have associated with it a single experiment or a group of closely related experiments. A PI may have more than one proposal.

2 The number of proposals satisfying one of the following two conditions: (a) the PI is a minority OR (b) the PI is a non-minority working at a minority-serving college or university AND the proposal includes minority participants.

3 The number of proposals satisfying one of the following two conditions: (a) the PI is a female OR (b) the PI is a male working at a college or university for women AND the proposal includes female participants.

TABLE 6

High B/T Facility: Operations Statistics Number of Magnet Days¹

	Total Days Allocated /User Affiliated	Percentage Allocated /User Affiliated
NHMFL-Affiliated ²	0.00	0.00%
Local ²	812.00	57.96%
U.S. University	392.00	27.98%
U.S. Govt. Lab.	140.00	9.99%
U.S. Industry	0.00	0.00%
Non-U.S.	0.00	0.00%
Test, Calibration, Set-up, Maintenance	57.00	4.07%
TOTAL	1401.00	100.00%

1 User Units are defined as magnet days. For the High B/T Facility, one magnet day is defined 24 hours in the superconducting magnets.

2 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites

(i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 7

High B/T Facility: Operations by Discipline Number of Magnet Days¹

	Total Days ¹ Allocated /User Affil.	Condensed Matter Physics	Chemistry, Geochem.	Engineering	Magnets, Matls, Testing, Instruments	Biology, Biochemistry, Biophysics
NHMFL-Affiliated ²	0.00	0.00	0.00	0.00	0.00	0.00
Local ²	812.00	812.00	0.00	0.00	0.00	0.00
U.S. University	392.00	392.00	0.00	0.00	0.00	0.00
U.S. Govt. Lab.	140.00	140.00	0.00	0.00	0.00	0.00
U.S. Industry	0.00	0.00	0.00	0.00	0.00	0.00
Non-U.S.	0.00	0.00	0.00	0.00	0.00	0.00
Test, Calibration, Set-up, Maintenance	57.00	57.00	0.00	0.00	0.00	0.00
TOTAL	1401.00	1401.00	0.00	0.00	0.00	0.00

¹ User Units are defined as magnet days. For the High B/T Facility, one magnet day is defined 24 hours in the superconducting magnets.

² NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites

(i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 8

High B/T Facility: New User PIs¹ (1)

Name	Organization	Proposal	Year of Magnet Time
Sun, Xuefeng	Hefei National Laboratory for Physical Sciences at the Microscale, University of Science and Technology of China	P01895	2012

¹ This table lists users serving as a principal investigator for the first time, and whose proposal was submitted during this year. It also shows the year in which magnet time was received. TBD stands for To Be Determined, indicating it has not yet been allotted magnet time.

2011 USER FACILITY STATISTICS

NMR/MRI Facility at FSU



Users, Requests & Operations

Note: A user is an individual or a member of a research group that is allocated magnet time. The user does not have to be “on site” for the experiment. A researcher who sends samples for analysis; a scientist who uses new lab technologies to conduct experiments remotely; or a PI who sends students to the Magnet Lab, are all considered users. All user numbers reflect distinct individuals, i.e. if a user has multiple proposals (different scientific thrusts) or is allocated magnet time more than once during the year, he/she is counted only once.

TABLE 1

NMR Facility: User Demographics

	Users	Female	Minority ¹	Users Present ^{3,7}	Users Operating Remotely ^{4,7}	Users Sending Sample ^{5,7}	Off-Site Collaborators ^{6,7}
Senior Investigators, U.S.	79	12	4	46	4	15	14
Senior Investigators, non-U.S.	22	1	1	11	0	6	5
Postdocs, U.S.	24	3	1	18	1	0	5
Postdocs, non-U.S.	3	0	0	3	0	0	0
Students ² , U.S.	52	19	4	48	2	2	0
Students ² , non-U.S.	5	1	0	3	0	2	0
Technician, U.S.	9	3	1	9	0	0	0
Technician, non-U.S.	2	1	0	2	0	0	0
TOTAL	196	40	11	140	7	25	24

1 Minority status includes American Indian, Alaska Native, Black or African American, Hispanic, Native Hawaiian or other Pacific Islander.

Minority status excludes Asian and White-Not of Hispanic Origin.

2 "Students" generally refers to graduate students, but may include a few undergraduate students.

3 "Users Present" includes users physically present in the MagLab user facility during the experiment AND any MagLab-Affiliated or Local users on the experiment.

4 "Users Operating Remotely" refers to users who operate the magnet system from a remote location. Remote operations are not currently available in all facilities.

5 "Users Sending Sample" refers to users who send the sample to the facility and the experiment is conducted by in-house user support personnel. Users at UF, FSU, and LANL cannot be "sample senders" for facilities located on their campuses.

6 "Off-Site Collaborators" are scientific or technical participants on the experiment; who will not be present, sending sample, or operating the magnet system remotely; and who are not located on the campus of that facility (i.e., they are off-site).

7 The total of Users Present + Users Operating Remotely + Users Sending Sample + and Off-Site Collaborators will equal the total number of users.

TABLE 2

NMR Facility: User Affiliations

	Users	NHMFL Affiliated Users ¹	Local Users ¹	University Users ^{2,4}	Industry Users ⁴	National Lab Users ^{3,4}
Senior Investigators, U.S.	79	20	12	74	2	3
Senior Investigators, non-U.S.	22	1	0	18	3	1
Postdocs, U.S.	24	7	9	23	1	0
Postdocs, non-U.S.	3	0	0	3	0	0
Students, U.S.	52	20	10	52	0	0
Students, non-U.S.	5	1	0	5	0	0
Technician, U.S.	9	5	3	9	0	0
Technician, non-U.S.	2	0	0	2	0	0
TOTAL	196	54	34	186	6	4

1 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites

(i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site. The sum of NHMFL-Affiliated and Local users equals what was formerly referred to as "Internal Investigators". **Note for Annual Reporting:** Due to programming limitations and the dynamic nature of information in this system, Local Users may include a few NHMFL-Affiliated users who left during the year and whose records have not yet been updated.

2 In addition to external users, all users with primary affiliations at FSU, UF, or FAMU are reported in this category, even if they are also NHMFL associates.

3 In addition to external users, users with primary affiliations at NHMFL/LANL are reported in this category.

4 The total of university, industry, and national lab users will equal the total number of users.

TABLE 3

NMR Facility: Users by Discipline

	Users	Condensed Matter Physics	Chemistry, Geochemistry	Engineering	Magnets, Matls., Testing, Instruments	Biology, Biochemistry, Biophysics
Senior Investigators, U.S.	79	3	12	11	2	51
Senior Investigators, non-U.S.	22	2	8	3	0	9
Postdocs, U.S.	24	0	2	2	0	20
Postdocs, non-U.S.	3	0	2	0	0	1
Students, U.S.	52	1	5	14	3	29
Students, non-U.S.	5	0	4	0	0	1
Technician, U.S.	9	0	1	2	1	5
Technician, non-U.S.	2	0	1	0	0	1
TOTAL	196	6	35	32	6	117

TABLE 4

NMR Facility: Experimental Requests¹ for Magnet Time

Days Requested	Days Granted	Days Declined
3346	2927 (71.20%)	1184 (28.80%)

¹ Due to operational differences, experimental requests for magnet time are measured differently among facilities. A request for NMR magnet time is measured in the number of days requested. A request for DC Field magnet time is measured in weeks. In the PFF, High B/T, EMR, and ICR facilities, the number of requests is equal to the number of experiments. For any given year, the time (or requests) granted and the time (or requests) declined may not equal the total number of requests. This is because (1) magnet time may be granted to experiments submitted in a prior year and/or (2) in NMR and DC Field facilities, the days or weeks granted may be more (as in the case of a user getting exceptional results) or less than what was requested due to operational limitations.

TABLE 5

NMR Facility: Research Proposals¹ Profile with Magnet Time

	Number of Proposals
Condensed Matter Physics	3
Chemistry, Geochemistry	21
Engineering	9
Magnets, Materials, Testing, Instruments	6
Biology, Biochemistry, Biophysics	50
TOTAL	89
	Number of Proposals
Minority ²	7
Female ³	11

1 A "proposal" may have associated with it a single experiment or a group of closely related experiments. A PI may have more than one proposal.

2 The number of proposals satisfying one of the following two conditions: (a) the PI is a minority OR (b) the PI is a non-minority working at a minority-serving college or university AND the proposal includes minority participants.

3 The number of proposals satisfying one of the following two conditions: (a) the PI is a female OR (b) the PI is a male working at a college or university for women AND the proposal includes female participants.

TABLE 6

NMR Facility: Operations Statistics Number of Magnet Days¹

	900	830	800	720	600	600 WB	600 WB2	500	500 E	Total Days Allocated /User Affiliated	Percent- age Allocated /User Affiliated
NHMFL-Affiliated ²	126.00	136.00	361.00	3.00	14.00	23.00	31.00	338.00	178.00	1210.00	41.34%
Local ²	108.00	0.00	0.00	50.00	0.00	293.00	213.00	0.00	32.00	696.00	23.78%
U.S. University	97.00	121.00	0.00	229.00	311.00	45.00	76.00	0.00	0.00	879.00	30.03%
U.S. Govt. Lab.	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	2.00	0.07%
U.S. Industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
Non-U.S.	29.00	56.00	0.00	9.00	9.00	0.00	37.00	0.00	0.00	140.00	4.78%
Test, Calibration, Set-up, Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
TOTAL	360.00	313.00	361.00	293.00	334.00	361.00	357.00	338.00	210.00	2927.00	100.00%

1 User Units are defined as magnet days. For the NMR Facility in Tallahassee, one magnet day is 24 hours in the superconducting magnets.

2 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 7

NMR Facility: Operations by Discipline Number of Magnet Days¹

	Total Days ¹ Allocated /User Affil.	Condensed Matter Physics	Chemistry, Geochem.	Engineering	Magnets, Matls, Testing, Instruments	Biology, Biochemistry, Biophysics
NHMFL-Affiliated ²	1210.00	0.00	295.00	344.00	74.00	497.00
Local ²	696.00	0.00	37.00	0.00	0.00	659.00
U.S. University	879.00	32.00	72.00	16.00	18.00	741.00
U.S. Govt. Lab.	2.00	0.00	0.00	0.00	0.00	2.00
U.S. Industry	0.00	0.00	0.00	0.00	0.00	0.00
Non-U.S.	140.00	0.00	87.00	0.00	18.00	35.00
Test, Calibration, Set-up, Maintenance	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	2927.00	32.00	491.00	360.00	110.00	1934.00

¹ User Units are defined as magnet days. For the NMR Facility in Tallahassee, one magnet day is 24 hours in the superconducting magnets.

² NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators"

TABLE 8

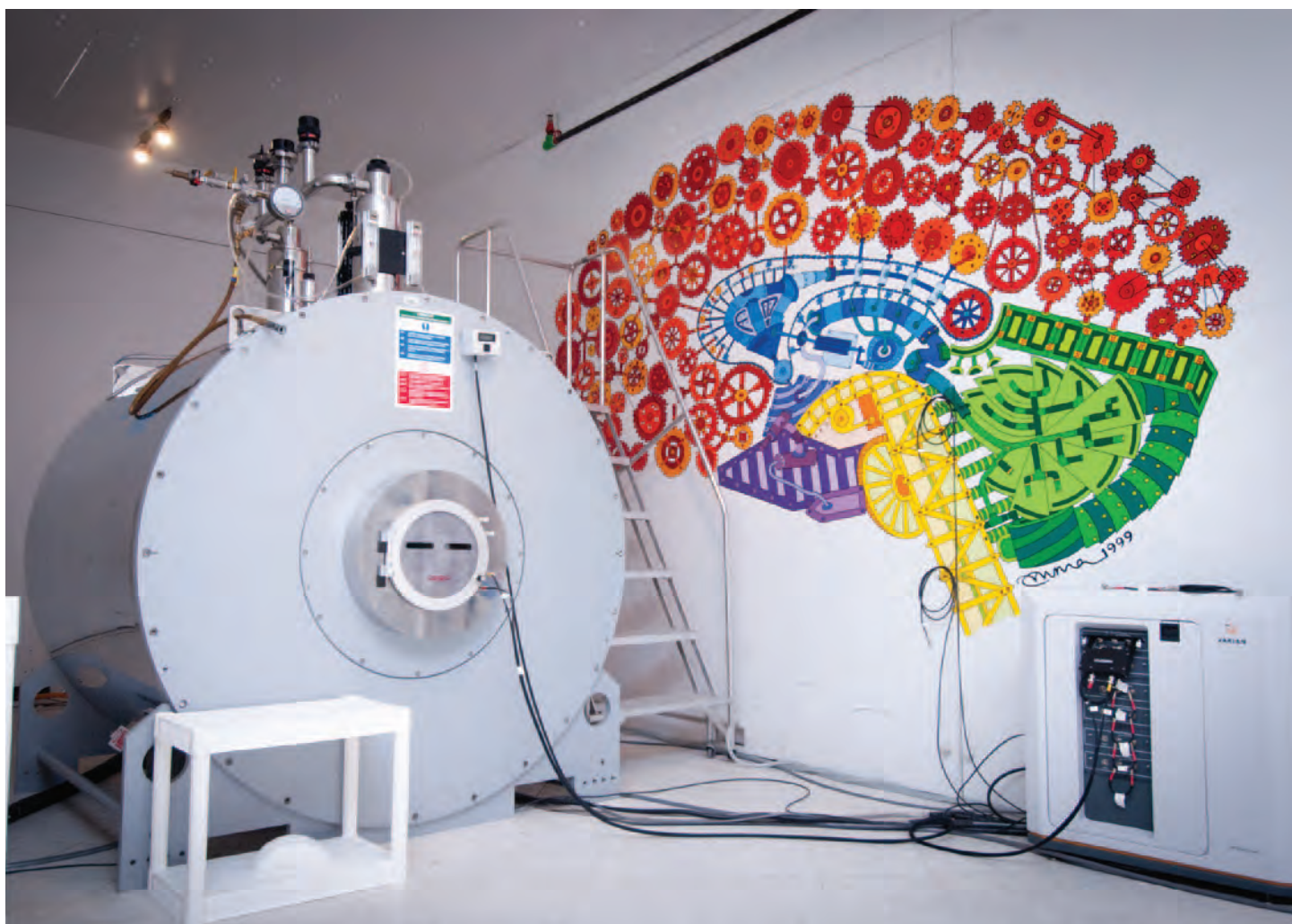
NMR Facility: New User PIs¹ (6)

Name	Organization	Proposal	Year of Magnet Time
Kojetin, Douglas	The Scripps Research Institute - Scripps Florida	P01653	2011
Zhou, Yi	Florida State University	P01697	2011
Saam, Brian	University of Utah	P01755	2011
Gimi, Barjor	Dartmouth Medical School	P01776	2011
Ren, Yuhao	Walker Cancer Research Institute	P01792	2011
Paravastu, Anant	FSU/FAMU College of Engineering	P01874	2011

¹ This table lists users serving as a principal investigator for the first time, and whose proposal was submitted during this year. It also shows the year in which magnet time was received. TBD stands for To Be Determined, indicating it has not yet been allotted magnet time.

2011 USER FACILITY STATISTICS

AMRIS Facility



Users, Requests & Operations

Note: A user is an individual or a member of a research group that is allocated magnet time. The user does not have to be “on site” for the experiment. A researcher who sends samples for analysis; a scientist who uses new lab technologies to conduct experiments remotely; or a PI who sends students to the Magnet Lab, are all considered users. All user numbers reflect distinct individuals, i.e. if a user has multiple proposals (different scientific thrusts) or is allocated magnet time more than once during the year, he/she is counted only once.

TABLE 1

AMRIS Facility: User Demographics

	Users	Female	Minority ¹	Users Present ^{3,7}	Users Operating Remotely ^{4,7}	Users Sending Sample ^{5,7}	Off-Site Collaborators ^{6,7}
Senior Investigators, U.S.	63	11	4	37	4	22	n/a
Senior Investigators, non-U.S.	19	1	1	2	6	11	n/a
Postdocs, U.S.	12	2	1	8	3	1	n/a
Postdocs, non-U.S.	12	1	0	8	2	2	n/a
Students ² , U.S.	33	6	2	20	1	12	n/a
Students ² , non-U.S.	22	5	2	16	2	4	n/a
Technician, U.S.	21	1	0	13	1	7	n/a
Technician, non-U.S.	9	1	0	4	3	2	n/a
TOTAL	191	28	10	108	22	61	n/a

1 Minority status includes American Indian, Alaska Native, Black or African American, Hispanic, Native Hawaiian or other Pacific Islander. Minority status excludes Asian and White-Not of Hispanic Origin

2 "Students" generally refers to graduate students, but may include a few undergraduate students.

3 "Users Present" includes users physically present in the MagLab user facility during the experiment AND any MagLab-Affiliated or Local users on the experiment. **See Note** at 7

4 "Users Operating Remotely" refers to users who operate the magnet system from a remote location. Remote operations are not currently available in all facilities.

5 "Users Sending Sample" refers to users who send the sample to the facility and the experiment is conducted by in-house user support personnel. Users at UF, FSU, and LANL cannot be "sample senders" for facilities located on their campuses.

6 "Off-Site Collaborators" are scientific or technical participants on the experiment; who will not be present, sending sample, or operating the magnet system remotely; and who are not located on the campus of that facility (i.e., they are off-site). **See Note** at 7.

7 The total of Users Present + Users Operating Remotely + Users Sending Sample + and Off-Site Collaborators will equal the total number of users.

Note: Data supporting the revised definitions for Users Present and Off-Site Collaborators was not captured in 2011, so it is reported as in previous years.

TABLE 2

AMRIS Facility: User Affiliations

	Users	NHMFL Affiliated Users ¹	Local Users ¹	University Users ^{2,4}	Industry Users ⁴	National Lab Users ^{3,4}
Senior Investigators, U.S.	63	10	23	58	0	5
Senior Investigators, non-U.S.	19	2	15	16	1	2
Postdocs, U.S.	12	0	6	9	0	3
Postdocs, non-U.S.	12	0	8	12	0	0
Students, U.S.	33	0	21	33	0	0
Students, non-U.S.	22	0	14	21	1	0
Technician, U.S.	21	4	10	19	2	0
Technician, non-U.S.	9	0	3	7	2	0
TOTAL	191	16	100	175	6	10

1 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site. The sum of NHMFL-Affiliated and Local users equals what was formerly referred to as "Internal Investigators". **Note for Annual Reporting:** Due to programming limitations and the dynamic nature of information in this system, Local Users may include a few NHMFL-Affiliated users who left during the year and whose records have not yet been updated.

2 In addition to external users, all users with primary affiliations at FSU, UF, or FAMU are reported in this category, even if they are also NHMFL associates.

3 In addition to external users, users with primary affiliations at NHMFL/LANL are reported in this category.

4 The total of university, industry, and national lab users will equal the total number of users.

TABLE 3

AMRIS Facility: Users by Discipline

	Users	Condensed Matter Physics	Chemistry, Geochemistry	Engineering	Magnets, Mats., Testing, Instruments	Biology, Biochemistry, Biophysics
Senior Investigators, U.S.	63	0	19	7	1	36
Senior Investigators, non-U.S.	19	0	7	3	0	9
Postdocs, U.S.	12	0	3	1	0	8
Postdocs, non-U.S.	12	0	3	1	0	8
Students, U.S.	33	0	11	1	3	18
Students, non-U.S.	22	0	7	1	0	14
Technician, U.S.	21	0	6	4	0	11
Technician, non-U.S.	9	0	2	2	0	5
TOTAL	191	0	58	20	4	109

TABLE 4

AMRIS Facility: Experimental Requests¹ for Magnet Time

Days Requested	Days Granted	Days Declined
>1800	1597	>200

1 Due to operational differences, experimental requests for magnet time are measured differently among facilities. A request for NMR magnet time is measured in the number of days requested. A request for DC Field magnet time is measured in weeks. In the PFF, High B/T, EMR, and ICR facilities, the number of requests is equal to the number of experiments. For any given year, the time (or requests) **granted** and the time (or requests) **declined** may not equal the total number of requests. This is because (1) magnet time may be granted to experiments submitted in a prior year and/or (2) in NMR and DC Field facilities, the days or weeks granted may be more (as in the case of a user getting exceptional results) or less than what was requested due to operational limitations.

TABLE 5

AMRIS Facility: Research Proposals¹ Profile with Magnet Time

	Number of Proposals
Condensed Matter Physics	0
Chemistry, Geochemistry	17
Engineering	4
Magnets, Materials, Testing, Instruments	0
Biology, Biochemistry, Biophysics	72
TOTAL	93
	Number of Proposals
Minority²	4
Female³	17

1 A "proposal" may have associated with it a single experiment or a group of closely related experiments. A PI may have more than one proposal.

2 The number of proposals satisfying one of the following two conditions: (a) the PI is a minority OR (b) the PI is a non-minority working at a minority-serving college or university AND the proposal includes minority participants.

3 The number of proposals satisfying one of the following two conditions: (a) the PI is a female OR (b) the PI is a male working at a college or university for women AND the proposal includes female participants.

TABLE 6

	Number of Magnet Days ¹								Total Days Allocated /User Affiliated	Percent- age Allocated /User Affiliated
	500 MHz NMR	600 MHz NMR/ MRI	600 MHz cryo	600 MHz cryo2	750 MHz wb	4.7 T / 33 cm	11.1 T / 40 cm	3 T whole body		
NHMFL-Affiliated ²	42	187	45	5	149	103	102	36	669	35%
Local ²	10	11	2	4	0	51	7	87	172	9%
U.S. University	5	20	53	0	105	1	12	2	198	10%
U.S. Govt. Lab.	0	0	11	0	0	3	0	0	14	.7%
U.S. Industry	0	0	0	0	0	0	0	0	0	0
Non-U.S.	121	1	8	5	0	2	0	0	137	7%
Development ³	37	73	66	121	63	21	54	2	437	23%
Test, Calibration, Set-up, Maintenance ⁴	34	34	34	16	34	24	77	40	293	15%
TOTAL	249	326	219	151	351	205	252	167	1920	100%

1 User Units are defined as magnet days. Magnet-day definitions for AMRIS instruments: Verticals (500, 600s, & 750 MHz), 1 magnet day = 24 hours (7 days/week). Horizontals (4.7, 11.1, and 3T), 1 magnet day = 8 hours (5 days/week). This accounts for the difficulty in running animal or human studies overnight. With additional staffing, the 11.1 T system went to an 8 hour/ 7day a week schedule in 2010. There is an annual 7 day holiday shutdown at UF so total days are based on a 51 week calendar. Magnet days were calculated by adding the total number of real hours used for each instrument and dividing by 24 (vertical) or 8 (horizontal).

Note: Due to the nature of the 4.7 T, 11 T and 3 T studies, almost all studies with external users were collaborative with UF investigators.

2 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site. Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators".

Note: All of the use in this category was paid by individual investigator grants and not the NHMFL.

3 Development was used for several purposes, primarily for establishing new capabilities such as building and testing coils, implementing new pulse sequences, and developing new protocols. **For merging with other NHMFL user tables, Development data will be added to Test, Calibration, Set-up, Maintenance.**

4 Note that each instrument has approximately the same number of hours for maintenance/testing and days are different due to definitions of magnet days on the different instruments.

TABLE 7

AMRIS Facility: Operations by Discipline Number of Magnet Days¹

	Total Days ¹ Allocated /User Affil.	Condensed Matter Physics	Chemistry, Geochem.	Engineering	Magnets, Matls, Testing, Instruments	Biology, Biochemistry, Biophysics
NHMFL-Affiliated ²	669	0	169	200	0	300
Local ²	172	0	72	0	0	100
U.S. University	198	0	98	0	0	100
U.S. Govt. Lab.	14	0	14	0	0	0
U.S. Industry	0	0	0	0	0	0
Non-U.S.	137	0	37	0	0	100
Development	437	0	37	100	200	100
Test, Calibration, Set-up, Maintenance	293	0	0	93	100	100
TOTAL	1920	0	427	393	300	800

1 User Units are defined as magnet days. Magnet-day definitions for AMRIS instruments: Verticals (500, 600s, & 750 MHz), 1 magnet day = 24 hours (7 days/week). Horizontals (4.7, 11.1, and 3T), 1 magnet day = 8 hours (5 days/week). This accounts for the difficulty in running animal or human studies overnight. With additional staffing, the 11.1 T system went to an 8 hour/ 7day a week schedule in 2010. There is an annual 7 day holiday shutdown at UF so total days are based on a 51 week calendar. Magnet days were calculated by adding the total number of real hours used for each instrument and dividing by 24 (vertical) or 8 (horizontal).

Note: Due to the nature of the 4.7 T, 11 T and 3 T studies, almost all studies with external users were collaborative with UF investigators.

2 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site. Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators".

Note: All of the use in this category was paid by individual investigator grants and not the NHMFL.

3 Development was used for several purposes, primarily for establishing new capabilities such as building and testing coils, implementing new pulse sequences, and developing new protocols. **For merging with other NHMFL user tables, Development data will be added to Test, Calibration, Set-up, Maintenance.**

4 Note that each instrument has approximately the same number of hours for maintenance/testing and days are different due to definitions of magnet days on the different instruments.

TABLE 8

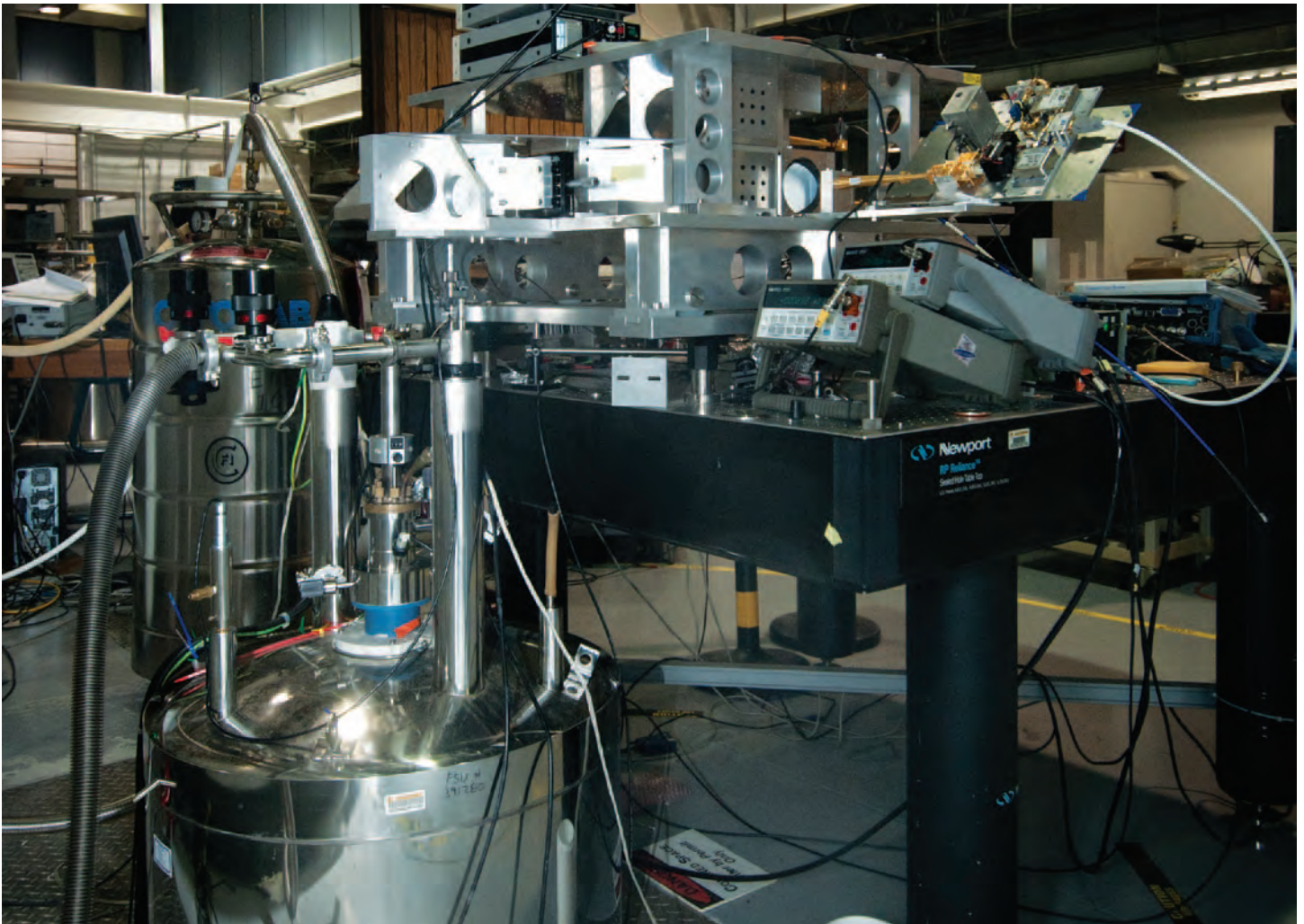
AMRIS Facility: New User Pls¹ (7)

Name	Organization	Proposal	Year of Magnet Time
Simon, John	Duke University	P01647	2011
Dotson, Vonetta	University of Florida	P01507	2011
Priestap, Horacio	Florida International University	P01764	2011
Heldermon, Coy	University of Florida	P01777	2011
Wright, Christine	University of Virginia	P01857	2011
Nader, Helena	Federal University of Sao Paulo	P01795	2011
Jorgensen, Charlotte	University of Southern Denmark	P01902	2011

1 This table lists users serving as a principal investigator for the first time, and whose proposal was submitted during this year. It also shows the year in which magnet time was received. TBD stands for To Be Determined, indicating it has not yet been allotted magnet time.

2011 USER FACILITY STATISTICS

EMR Facility



Users, Requests & Operations

Note: A user is an individual or a member of a research group that is allocated magnet time. The user does not have to be “on site” for the experiment. A researcher who sends samples for analysis; a scientist who uses new lab technologies to conduct experiments remotely; or a PI who sends students to the Magnet Lab, are all considered users. All user numbers reflect distinct individuals, i.e. if a user has multiple proposals (different scientific thrusts) or is allocated magnet time more than once during the year, he/she is counted only once.

TABLE 1

EMR Facility: User Demographics

	Users	Female	Minority ¹	Users Present ^{3,7}	Users Operating Remotely ^{4,7}	Users Sending Sample ^{5,7}	Off-Site Collaborators ^{6,7}
Senior Investigators, U.S.	34	3	1	12	0	3	19
Senior Investigators, non-U.S.	33	5	3	8	0	6	19
Postdocs, U.S.	6	0	0	4	0	0	2
Postdocs, non-U.S.	7	2	2	4	0	0	3
Students ² , U.S.	21	4	2	15	0	1	5
Students ² , non-U.S.	12	3	0	4	0	2	6
Technician, U.S.	0	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0	0
TOTAL	113	17	8	47	0	12	54

1 Minority status includes American Indian, Alaska Native, Black or African American, Hispanic, Native Hawaiian or other Pacific Islander.

Minority status excludes Asian and White-Not of Hispanic Origin.

2 "Students" generally refers to graduate students, but may include a few undergraduate students.

3 "Users Present" includes users physically present in the MagLab user facility during the experiment AND any MagLab-Affiliated or Local users on the experiment.

4 "Users Operating Remotely" refers to users who operate the magnet system from a remote location. Remote operations are not currently available in all facilities.

5 "Users Sending Sample" refers to users who send the sample to the facility and the experiment is conducted by in-house user support personnel. Users at UF, FSU, and LANL cannot be "sample senders" for facilities located on their campuses.

6 "Off-Site Collaborators" are scientific or technical participants on the experiment; who will not be present, sending sample, or operating the magnet system remotely; and who are not located on the campus of that facility (i.e., they are off-site).

7 The total of Users Present + Users Operating Remotely + Users Sending Sample + and Off-Site Collaborators will equal the total number of users.

TABLE 2

EMR Facility: User Affiliations

	Users	NHMFL Affiliated Users ¹	Local Users ¹	University Users ^{2,4}	Industry Users ⁴	National Lab Users ^{3,4}
Senior Investigators, U.S.	34	9	2	33	0	1
Senior Investigators, non-U.S.	33	0	0	29	0	4
Postdocs, U.S.	6	2	1	6	0	0
Postdocs, non-U.S.	7	0	0	7	0	0
Students, U.S.	21	3	5	20	0	1
Students, non-U.S.	12	0	0	11	0	1
Technician, U.S.	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	113	14	8	106	0	7

1 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local users equals what was formerly referred to as "Internal Investigators."

Note for Annual Reporting: Due to programming limitations and the dynamic nature of information in this system, Local Users may include a few NHMFL-Affiliated users who left during the year and whose records have not yet been updated.

2 In addition to external users, all users with primary affiliations at FSU, UF, or FAMU are reported in this category, even if they are also NHMFL associates.

3 In addition to external users, users with primary affiliations at NHMFL/LANL are reported in this category.

4 The total of university, industry, and national lab users will equal the total number of users.

TABLE 3

EMR Facility: Users by Discipline

	Users	Condensed Matter Physics	Chemistry, Geochemistry	Engineering	Magnets, Mats., Testing, Instruments	Biology, Biochemistry, Biophysics
Senior Investigators, U.S.	34	10	16	1	1	6
Senior Investigators, non-U.S.	33	7	18	1	0	7
Postdocs, U.S.	6	2	3	0	0	1
Postdocs, non-U.S.	7	4	3	0	0	0
Students, U.S.	21	5	10	2	1	3
Students, non-U.S.	12	2	10	0	0	0
Technician, U.S.	0	0	0	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	113	30	60	4	2	17

TABLE 4

EMR Facility: Experimental Requests¹ for Magnet Time

Experimental Requests	Experimental Requests Granted	Experimental Requests Declined
40	42 (72.41%)	16 (27.59%)

¹ Due to operational differences, experimental requests for magnet time are measured differently among facilities. A request for NMR magnet time is measured in the number of days requested. A request for DC Field magnet time is measured in weeks. In the PFF, High B/T, EMR, and ICR facilities, the number of requests is equal to the number of experiments. For any given year, the time (or requests) granted and the time (or requests) declined may not equal the total number of requests. This is because (1) magnet time may be granted to experiments submitted in a prior year and/or (2) in NMR and DC Field facilities, the days or weeks granted may be more (as in the case of a user getting exceptional results) or less than what was requested due to operational limitations.

TABLE 5

EMR Facility: Research Proposals¹ Profile with Magnet Time

	Number of Proposals
Condensed Matter Physics	10
Chemistry, Geochemistry	26
Engineering	0
Magnets, Materials, Testing, Instruments	1
Biology, Biochemistry, Biophysics	3
TOTAL	40

	Number of Proposals
Minority²	2
Female³	5

1 A "proposal" may have associated with it a single experiment or a group of closely related experiments. A PI may have more than one proposal.

2 The number of proposals satisfying one of the following two conditions: (a) the PI is a minority OR (b) the PI is a non-minority working at a minority-serving college or university AND the proposal includes minority participants.

3 The number of proposals satisfying one of the following two conditions: (a) the PI is a female OR (b) the PI is a male working at a college or university for women AND the proposal includes female participants.

TABLE 6

EMR Facility: Operations Statistics Number of Magnet Days¹

	17 T	12 T	Mossbauer	Total Days Allocated /User Affiliated	Percentage Allocated /User Affiliated
NHMFL-Affiliated ²	7.00	0.00	5.00	12.00	2.47%
Local ²	38.00	10.00	13.00	61.00	12.58%
U.S. University	73.00	21.00	70.00	164.00	33.81%
U.S. Govt. Lab.	0.00	36.00	0.00	36.00	7.42%
U.S. Industry	0.00	0.00	0.00	0.00	0.00%
Non-U.S.	93.00	81.00	38.00	212.00	43.71%
Test, Calibration, Set-up, Maintenance	0.00	0.00	0.00	0.00	0.00%
TOTAL	211.00	148.00	126.00	485.00	100.00%

1 User Units are defined as magnet days. For the EMR Facility, one magnet day is defined as 24 hours in superconducting magnets.

2 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 7

EMR Facility: Operations by Discipline Number of Magnet Days¹

	Total Days ¹ /User Affil.	Condensed Matter Physics	Chemistry, Geochem.	Engineering	Magnets, Matls, Testing, Instruments	Biology, Biochemistry, Biophysics
NHMFL-Affiliated ²	12.00	2.00	10.00	0.00	0.00	0.00
Local ²	61.00	0.00	25.00	0.00	0.00	36.00
U.S. University	164.00	17.00	87.00	0.00	8.00	52.00
U.S. Govt. Lab.	36.00	36.00	0.00	0.00	0.00	0.00
U.S. Industry	0.00	0.00	0.00	0.00	0.00	0.00
Non-U.S.	212.00	101.00	111.00	0.00	0.00	0.00
Test, Calibration, Set-up, Maintenance	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	485.00	156.00	233.00	0.00	8.00	88.00

¹ User Units are defined as magnet days. For the EMR Facility, one magnet day is defined as 24 hours in superconducting magnets.

² NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 8

EMR Facility: New User PIs¹ (13)

Name	Organization	Proposal	Year of Magnet Time
Lawes, Gavin	Wayne State University	P01634	2011
Lattner, Susan	Florida State University	P01638	2011
Sakiyama, Hiroshi	Yamagata University	P01642	2011
Colvin, Vicki	Rice University	P01664	2011
Rangachari, Vijay	University of Southern Mississippi	P01679	2011
Schenkel, Thomas	Lawrence Berkeley National Laboratory	P01745	2011
Aliaga-Alcalde, Nuria	ICREA & UB	P01817	2011
Moomaw, Ellen	Kennesaw State University	P01872	2011
Lysenko, Andriy	Taras Shevchenko National University of Kyiv	P01893	2011
Steinbock, Oliver	Florida State University	P01963	TBD
Pajerowski, Daniel	National Institute of Standards and Technology	P01971	2011
Cl�rac, Rodolphe	Centre de Recherche Paul Pascal	P01977	2011
Holmes, Stephen	University of Missouri-St. Louis	P01979	2011

¹ This table lists users serving as a principal investigator for the first time, and whose proposal was submitted during this year. It also shows the year in which magnet time was received. TBD stands for To Be Determined, indicating it has not yet been allotted magnet time.

2011 USER FACILITY STATISTICS

ICR Facility



Users, Requests & Operations

Note: A user is an individual or a member of a research group that is allocated magnet time. The user does not have to be “on site” for the experiment. A researcher who sends samples for analysis; a scientist who uses new lab technologies to conduct experiments remotely; or a PI who sends students to the Magnet Lab, are all considered users. All user numbers reflect distinct individuals, i.e. if a user has multiple proposals (different scientific thrusts) or is allocated magnet time more than once during the year, he/she is counted only once.

TABLE 1

ICR Facility: User Demographics

	Users	Female	Minority ¹	Users Present ^{3,7}	Users Operating Remotely ^{4,7}	Users Sending Sample ^{5,7}	Off-Site Collaborators ^{6,7}
Senior Investigators, U.S.	57	12	0	20	0	30	7
Senior Investigators, non-U.S.	12	1	1	1	0	6	5
Postdocs, U.S.	12	3	1	11	0	0	1
Postdocs, non-U.S.	2	0	1	0	0	0	2
Students ² , U.S.	27	16	2	22	0	3	2
Students ² , non-U.S.	1	0	0	0	0	1	0
Technician, U.S.	1	0	0	1	0	0	0
Technician, non-U.S.	0	0	0	0	0	0	0
TOTAL	112	32	5	55	0	40	17

1 Minority status includes American Indian, Alaska Native, Black or African American, Hispanic, Native Hawaiian or other Pacific Islander.

Minority status excludes Asian and White-Not of Hispanic Origin

2 "Students" generally refers to graduate students, but may include a few undergraduate students.

3 "Users Present" includes users physically present in the MagLab user facility during the experiment AND any MagLab-Affiliated or Local users on the experiment.

4 "Users Operating Remotely" refers to users who operate the magnet system from a remote location. Remote operations are not currently available in all facilities.

5 "Users Sending Sample" refers to users who send the sample to the facility and the experiment is conducted by in-house user support personnel. Users at UF, FSU, and LANL cannot be "sample senders" for facilities located on their campuses.

6 "Off-Site Collaborators" are scientific or technical participants on the experiment; who will not be present, sending sample, or operating the magnet system remotely; and who are not located on the campus of that facility (i.e., they are off-site).

7 The total of Users Present + Users Operating Remotely + Users Sending Sample + and Off-Site Collaborators will equal the total number of users.

TABLE 2

ICR Facility: User Affiliations

	Users	NHMFL Affiliated Users ¹	Local Users ¹	University Users ^{2,4}	Industry Users ⁴	National Lab Users ^{3,4}
Senior Investigators, U.S.	57	9	8	44	9	4
Senior Investigators, non-U.S.	12	0	0	8	1	3
Postdocs, U.S.	12	6	3	12	0	0
Postdocs, non-U.S.	2	0	0	0	0	2
Students, U.S.	27	6	9	27	0	0
Students, non-U.S.	1	0	0	1	0	0
Technician, U.S.	1	1	0	1	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	112	22	20	93	10	9

1 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites

(i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site. The sum of NHMFL-Affiliated and Local users equals what was formerly referred to as "Internal Investigators". **Note for Annual Reporting:** Due to programming limitations and the dynamic nature of information in this system, Local Users may include a few NHMFL-Affiliated users who left during the year and whose records have not yet been updated.

2 In addition to external users, all users with primary affiliations at FSU, UF, or FAMU are reported in this category, even if they are also NHMFL associates.

3 In addition to external users, users with primary affiliations at NHMFL/LANL are reported in this category.

4 The total of university, industry, and national lab users will equal the total number of users.

TABLE 3

ICR Facility: Users by Discipline

	Users	Condensed Matter Physics	Chemistry, Geochemistry	Engineering	Magnets, Mats., Testing, Instruments	Biology, Biochemistry, Biophysics
Senior Investigators, U.S.	57	0	32	1	0	24
Senior Investigators, non-U.S.	12	0	6	5	0	1
Postdocs, U.S.	12	0	7	0	1	4
Postdocs, non-U.S.	2	0	2	0	0	0
Students, U.S.	27	0	18	1	2	6
Students, non-U.S.	1	0	1	0	0	0
Technician, U.S.	1	0	1	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	112	0	67	7	3	35

TABLE 4

ICR Facility: Experimental Requests¹ for Magnet Time

Experimental Requests	Experimental Requests Granted	Experimental Requests Declined
112	138 (97.18%)	4 (2.82%)

¹ Due to operational differences, experimental requests for magnet time are measured differently among facilities. A request for NMR magnet time is measured in the number of days requested. A request for DC Field magnet time is measured in weeks. In the PFF, High B/T, EMR, and ICR facilities, the number of requests is equal to the number of experiments. For any given year, the time (or requests) granted and the time (or requests) declined may not equal the total number of requests. This is because (1) magnet time may be granted to experiments submitted in a prior year and/or (2) in NMR and DC Field facilities, the days or weeks granted may be more (as in the case of a user getting exceptional results) or less than what was requested due to operational limitations.

TABLE 5

ICR Facility: Research Proposals¹ Profile with Magnet Time

	Number of Proposals
Condensed Matter Physics	0
Chemistry, Geochemistry	58
Engineering	0
Magnets, Materials, Testing, Instruments	10
Biology, Biochemistry, Biophysics	16
TOTAL	84

	Number of Proposals
Minority²	2
Female³	20

1 A "proposal" may have associated with it a single experiment or a group of closely related experiments. A PI may have more than one proposal.

2 The number of proposals satisfying one of the following two conditions: (a) the PI is a minority OR (b) the PI is a non-minority working at a minority-serving college or university AND the proposal includes minority participants.

3 The number of proposals satisfying one of the following two conditions: (a) the PI is a female OR (b) the PI is a male working at a college or university for women AND the proposal includes female participants.

TABLE 6

ICR Facility: Operations Statistics Number of Magnet Days¹

	14.5 T Hybrid	9.4 T Passive	9.4 T Active	Total Days Allocated /User Affiliated	Percentage Allocated /User Affiliated
NHMFL-Affiliated ²	56.00	178.00	38.00	272.00	31.37%
Local ²	50.00	73.00	138.00	261.00	30.10%
U.S. University	104.00	107.00	4.00	215.00	24.80%
U.S. Govt. Lab.	7.00	21.00	0.00	28.00	3.23%
U.S. Industry	3.00	44.00	5.00	52.00	6.00%
Non-U.S.	24.00	15.00	0.00	39.00	4.50%
Test, Calibration, Set-up, Maintenance ⁴	0.00	0.00	0.00	0.00	0.00%
TOTAL	244.00	438.00	185.00	867.00	100.00%

1 For the ICR Facility, one magnet day is defined as 24 hours of use.

2 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site. Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 7

ICR Facility: Operations by Discipline Number of Magnet Days¹

	Total Days¹ Allocated /User Affil.	Condensed Matter Physics	Chemistry, Geochem.	Engineering	Magnets, Mats, Testing, Instruments	Biology, Biochemistry, Biophysics
NHMFL-Affiliated ²	272.00	0.00	85.00	0.00	166.00	21.00
Local ²	261.00	0.00	207.00	0.00	0.00	54.00
U.S. University	215.00	0.00	149.00	0.00	0.00	66.00
U.S. Govt. Lab.	28.00	0.00	17.00	0.00	0.00	11.00
U.S. Industry	52.00	0.00	50.00	0.00	0.00	2.00
Non-U.S.	39.00	0.00	21.00	0.00	0.00	18.00
Test, Calibration, Set-up, Maintenance	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	867.00	0.00	529.00	0.00	166.00	172.00

¹ For the ICR Facility, one magnet day is defined as 24 hours of use.

² NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 8

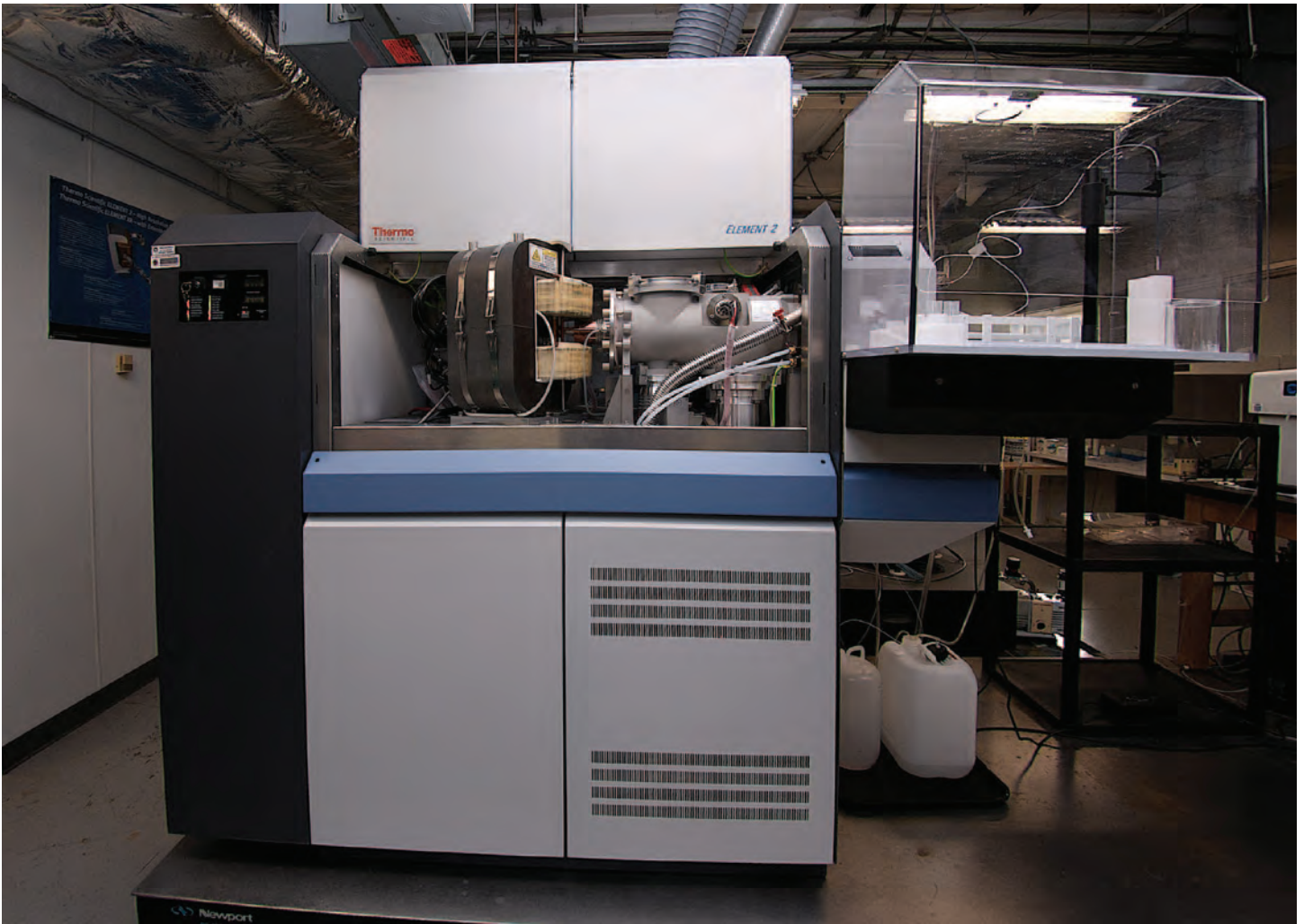
ICR Facility: New User PIs¹ (15)

Name	Organization	Proposal	Year of Magnet Time
Huettel, Markus	Florida State University	P01537	2010
Silliman, Brian	University of Florida	P01552	2011
Dumroese, Debbie	Rocky Mountain Research Station	P01603	2011
Shi, Quan	China University of Petroleum	P01613	2011
Doucet, Jocelyn	Services Kengtek Inc.	P01670	2011
Mead, Ralph	University of North Carolina - Wilmington	P01765	2011
Whitehead, Andrew	Louisiana State University	P01806	2011
Liao, Yuhong	State Key Laboratory of Organic Geochemistry	P01811	2011
Pavlostathis, Spyros	Georgia Institute of Technology	P01818	2011
Bell, Susan	University of South Florida	P01858	2011
Jaffe, Rudolf	Florida International University	P01887	2011
Slater, Peter	ConocoPhillips Company	P01889	2011
Foreman, Christine	Montana State University	P01890	2011
Davidson, Michael	NHMFL	P01907	2011
Martin, Jacob	University of Auckland	P01948	2011

¹ This table lists users serving as a principal investigator for the first time, and whose proposal was submitted during this year. It also shows the year in which magnet time was received. TBD stands for To Be Determined, indicating it has not yet been allotted magnet time.

2011 USER FACILITY STATISTICS

Geochemistry Facility



Users, Requests & Operations

Note: A user is an individual or a member of a research group that is allocated magnet time. The user does not have to be “on site” for the experiment. A researcher who sends samples for analysis; a scientist who uses new lab technologies to conduct experiments remotely; or a PI who sends students to the Magnet Lab, are all considered users. All user numbers reflect distinct individuals, i.e. if a user has multiple proposals (different scientific thrusts) or is allocated magnet time more than once during the year, he/she is counted only once.

TABLE 1

Geochemistry Facility: User Demographics

	Users	Female	Minority ¹	Users Present ^{3,7}	Users Operating Remotely ^{4,7}	Users Sending Sample ^{5,7}	Off-Site Collaborators ^{6,7}
Senior Investigators, U.S.	18	4	1	16	0	2	0
Senior Investigators, non-U.S.	2	2	0	2	0	0	0
Postdocs, U.S.	7	3	0	7	0	0	0
Postdocs, non-U.S.	0	0	0	0	0	0	0
Students ² , U.S.	29	20	0	29	0	0	0
Students ² , non-U.S.	0	0	0	0	0	0	0
Technician, U.S.	2	1	0	2	0	0	0
Technician, non-U.S.	0	0	0	0	0	0	0
TOTAL	58	30	1	56	0	2	0

1 Minority status includes American Indian, Alaska Native, Black or African American, Hispanic, Native Hawaiian or other Pacific Islander.

Minority status excludes Asian and White-Not of Hispanic Origin.

2 "Students" generally refers to graduate students, but may include a few undergraduate students.

3 "Users Present" includes users physically present in the MagLab user facility during the experiment AND any MagLab-Affiliated or Local users on the experiment.

4 "Users Operating Remotely" refers to users who operate the magnet system from a remote location. Remote operations are not currently available in all facilities.

5 "Users Sending Sample" refers to users who send the sample to the facility and the experiment is conducted by in-house user support personnel. Users at UF, FSU, and LANL cannot be "sample senders" for facilities located on their campuses.

6 "Off-Site Collaborators" are scientific or technical participants on the experiment; who will not be present, sending sample, or operating the magnet system remotely; and who are not located on the campus of that facility (i.e., they are off-site).

7 The total of Users Present + Users Operating Remotely + Users Sending Sample + and Off-Site Collaborators will equal the total number of users.

TABLE 2

Geochemistry Facility: User Affiliations

	Users	NHMFL Affiliated Users ¹	Local Users ¹	University Users ^{2,4}	Industry Users ⁴	National Lab Users ^{3,4}
Senior Investigators, U.S.	18	9	4	16	0	2
Senior Investigators, non-U.S.	2	0	0	1	0	1
Postdocs, U.S.	7	6	1	7	0	0
Postdocs, non-U.S.	0	0	0	0	0	0
Students, U.S.	29	18	9	29	0	0
Students, non-U.S.	0	0	0	0	0	0
Technician, U.S.	2	2	0	2	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	58	35	14	55	0	3

1 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local users equals what was formerly referred to as "Internal Investigators".

2 In addition to external users, all users with primary affiliations at FSU, UF, or FAMU are reported in this category, even if they are also NHMFL associates.

3 In addition to external users, users with primary affiliations at NHMFL/LANL are reported in this category.

4 The total of university, industry, and national lab users will equal the total number of users.

TABLE 3

Geochemistry Facility: Users by Discipline

	Users	Condensed Matter Physics	Chemistry, Geochemistry	Engineering	Magnets, Mats., Testing, Instruments	Biology, Biochemistry, Biophysics
Senior Investigators, U.S.	18	0	14	0	0	4
Senior Investigators, non-U.S.	2	0	2	0	0	0
Postdocs, U.S.	7	0	7	0	0	0
Postdocs, non-U.S.	0	0	0	0	0	0
Students, U.S.	29	0	25	0	0	4
Students, non-U.S.	0	0	0	0	0	0
Technician, U.S.	2	0	2	0	0	0
Technician, non-U.S.	0	0	0	0	0	0
TOTAL	58	0	50	0	0	8

TABLE 4

Geochemistry Facility: Experimental Requests¹ for Magnet Time

Days Requested	Days Granted	Days Declined
565	565 (100%)	0 (0%)

¹ Due to operational differences, experimental requests for magnet time are measured differently among facilities. A request for NMR magnet time is measured in the number of days requested. A request for DC Field magnet time is measured in weeks. In the PFF, High B/T, EMR, and ICR facilities, the number of requests is equal to the number of experiments. For any given year, the time (or requests) granted and the time (or requests) declined may not equal the total number of requests. This is because (1) magnet time may be granted to experiments submitted in a prior year and/or (2) in NMR and DC Field facilities, the days or weeks granted may be more (as in the case of a user getting exceptional results) or less than what was requested due to operational limitations.

TABLE 5

Geochemistry Facility: Research Proposals¹ Profile with Magnet Time

	Number of Proposals
Condensed Matter Physics	0
Chemistry, Geochemistry	18
Engineering	0
Magnets, Materials, Testing, Instruments	0
Biology, Biochemistry, Biophysics	2
TOTAL	20

	Number of Proposals
Minority ²	0
Female ³	6

1 A "proposal" may have associated with it a single experiment or a group of closely related experiments. A PI may have more than one proposal.

2 The number of proposals satisfying one of the following two conditions: (a) the PI is a minority OR (b) the PI is a non-minority working at a minority-serving college or university AND the proposal includes minority participants.

3 The number of proposals satisfying one of the following two conditions: (a) the PI is a female OR (b) the PI is a male working at a college or university for women AND the proposal includes female participants.

TABLE 6

Geochemistry Facility: Operations Statistics Number of Magnet Days¹

	MC-ICP-MS Neptune	ELEMENT ⁴	Delta XP	Total Days Allocated /User Affiliated	Percentage Allocated /User Affiliated
NHMFL-Affiliated ²	170	90	175	435	69%
Local ²	0	50	20	70	11%
U.S. University	5	10	0	15	2.5%
U.S. Govt. Lab.	5	0	10	15	2.5%
U.S. Industry	0	0	0	0	0%
Non-U.S.	0	0	0	0	0%
Test, Calibration, Set-up, Maintenance	25	50	20	95	15%
TOTAL	205	200	225	630	100%

1 User Units are defined as magnet days. For the Geochemistry Facility, one magnet day is defined as 12 hours on the instrument.

2 NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

3 This instrument was replaced by a new version (ELEMENT2) in October of this year.

TABLE 7

Geochemistry Facility: Operations by Discipline Number of Magnet Days¹

	Total Days ¹ Allocated /User Affil.	Condensed Matter Physics	Chemistry, Geochem.	Engineering	Magnets, Mats, Testing, Instruments	Biology, Biochemistry, Biophysics
NHMFL-Affiliated ²	435	0	415	0.00	0	20
Local ²	70	0	35	0.00	0	35
U.S. University	15	0	15	0.00	0	0
U.S. Govt. Lab.	15	0	15	0.00	0	0
U.S. Industry	0	0	0	0.00	0	0
Non-U.S.	0	0	0	0.00	0	0
Test, Calibration, Set-up, Maintenance	95	0	95	0.00	0	0
TOTAL	630	0	575	0.00	0	55

¹ User Units are defined as magnet days. For the Geochemistry Facility, one magnet day is defined as 12 hours on the instrument.

² NHMFL-Affiliated users are defined as anyone in the lab's personnel system [i.e. on our Web site/directory], even if they travel to another site.

Local users are defined as any non-NHMFL-Affiliated researchers originating at any of the institutions in proximity to the MagLab sites (i.e. researchers at FSU, UF, FAMU, or LANL), even if they travel to another site.

The sum of NHMFL-Affiliated and Local usage equals what was formerly referred to as usage by "Internal Investigators."

TABLE 8

Geochemistry Facility: New User PIs¹ (0)

There were no new user Principal Investigators in the Geochemistry Facility during 2011.

APPENDIX B

Research Reports by Category

At the end of each year, Magnet Lab users and faculty at FSU, UF, and LANL submit brief abstracts of their experiments, research, and scholarly endeavors. In 2011, 444 research reports in 18 categories were reviewed and approved by facility or department directors, and all are published online: <http://www.magnet.fsu.edu/usershub/publications/researchreportsonline.aspx>. The reports are searchable by facility, category, first author, PI, keywords, or general search.

Biochemistry – 46 Reports

Facility	PI	Title
CMT/E	Brüschweiler, R., NHMFL and FSU Department of Chemistry and Biochemistry	Iterative Optimization of Molecular Mechanics Force Fields from NMR Data of Full-Length Proteins in their Native Environment
EMR	Angerhofer, A., University of Florida, Department of Chemistry	Transitions Between Higher Spin Manifolds of Mn(II) in Oxalate Decarboxylase
EMR	Moomaw, E.W., Kennesaw State University, Chemistry and Biochemistry	Kinetic and Spectroscopic Characterization of Bicupin Oxalate Oxidase and Putative Active Site Mutants
ICR	Fajer, P.G., FSU, Molecular Biophysics	Complexation and Calcium-Induced Conformational Changes in the Cardiac Troponin Complex Monitored by Hydrogen/Deuterium Exchange and FT-ICR Mass Spectrometry
ICR	Guo, M., Scripps, Biochemistry	Structural Context for Mobilization of a Human tRNA Synthetase from its Cytoplasmic Complex
ICR	Kelleher, N.L., U. Illinois Urbana, Genomic Biology	Identification of Phosphorylated Human Peptides by Accurate Mass Measurement Alone
ICR	Marshall, A.G., FSU, NHMFL, Chemistry	Valence Parity to Distinguish c' and z Ions from Electron Capture Dissociation/Electron Transfer Dissociation of Peptides: Effects of Isomers, Isobars, and Proteolysis Specificity
ICR	Marshall, A.G., FSU, NHMFL, Chemistry	Algae Polar Lipids Characterized by Online Liquid Chromatography Coupled with Hybrid Linear Quadrupole Ion Trap/Fourier Transform Ion Cyclotron Resonance Mass Spectrometry
ICR	Nilsson, C.L., Pfizer, Biochemistry	High Mass Accuracy and Resolution Facilitate Identification of Glycosphingolipids and Phospholipids
ICR	Rouse, J.C., Pfizer	Unit Mass Baseline Resolution for an Intact 148 kDa Therapeutic Monoclonal Antibody by Fourier Transform Ion Cyclotron Resonance Mass Spectrometry
ICR	Roux, K.H., FSU, Molecular Biophysics	Epitope Mapping of a 95 kDa Antigen in Complex with Antibody by Solution-Phase Amide Backbone Hydrogen/Deuterium Exchange Monitored by Fourier Transform Ion Cyclotron Resonance Mass Spectrometry
ICR	Sang, Q.-X., FSU, Chemistry	Differential Phosphopeptide Expression in a Benign Breast Tissue, and Triple-Negative Primary and Metastatic Breast Cancer Tissues from the Same African-American Woman by LC-LTQ/FT-ICR Mass Spectrometry
ICR	Sang, Q.-X.A., FSU, Chemistry	Characterization of the Phosphoproteome in Androgen-Repressed Human Prostate Cancer Cells by Fourier Transform Ion Cyclotron Resonance Mass Spectrometry
ICR	Yang, X.-L., Scripps, Biochemistry	Dispersed Disease-Causing Neomorphic Mutations on a Single Protein Promote the Same Localized Conformational Opening
AMRIS	Dossey, A.T., USDA-ARS	Continued Discovery of Defensive Chemistry in Walkingstick Insects (Order Phasmatodea)
AMRIS	Fanucci, G.E., University of Florida, Chemistry	¹ H, ¹⁵ N and ¹³ C NMR Backbone Assignment of Multi-Drug Resistant HIV-1 Protease (HIV-1PR) Variant, MDR 769 and ¹⁵ N Spin Relaxation Studies of Subtype B D3ON HIV-1PR

APPENDIX B: RESEARCH REPORTS BY CATEGORY

Facility	PI	Title
AMRIS	Fanucci, G.E., University of Florida, Chemistry	Backbone Assignment of HIV-1 Protease Variants and ¹⁵ N Relaxation Measurement
AMRIS	Fanucci, G.E., University of Florida, Chemistry	Characterizing Conformational Changes in SAPs with Solution NMR
AMRIS	Gamcsik, M.P., University of North Carolina, Biomedical Engineering	MRI/S Studies of Glycine and Glutathione Metabolism in a Rat Mammary Tumor
AMRIS	Long, J.R., University of Florida	Partitioning, Dynamics, and Orientation of Lung Surfactant Peptide KL4 in Phospholipid Bilayers
AMRIS	Long, J.R., University of Florida	Solid State ² H and ³¹ P NMR Characterization of Lung Surfactant Preparations
AMRIS	Long, J.R., University of Florida	Structural Analysis of the C-Terminus of Lung Surfactant Protein B (SP-B)
AMRIS	Long, J.R., University of Florida	Structural Studies of Adhesin Protein P1
AMRIS	Nader, H.B., UNIFESP, Biochemistry	Analysis and Identification of Contaminants in Heparin Raw Materials
NMR	Brüschweiler, R., Florida State University, Chemistry & Biochemistry	Characterization of the Structural Dynamics of Human MDM2 Interaction with p53 by Multi-dimensional NMR Spectroscopy
NMR	Brüschweiler, R., Florida State University, Chemistry & Biochemistry	Molecular Basis for Kinetic Cooperativity and Allosteric Activation of Human Glucokinase
NMR	Brüschweiler, R., Florida State University, Chemistry & Biochemistry	Toward a Predictive Understanding of Slow Methyl Group Dynamics in Proteins
NMR	Brüschweiler, R., Florida State University, Chemistry & Biochemistry	In Silico Elucidation of the Recognition Dynamics of Ubiquitin
NMR	Brüschweiler, R., Florida State University, Chemistry & Biochemistry	Ca ²⁺ Binding Alters the Interdomain Flexibility Between the Two Cytoplasmic Calcium-binding Domains in the Na ⁺ /Ca ²⁺ Exchanger
NMR	Brüschweiler, R., Florida State University, Chemistry & Biochemistry	Deconvolution of Chemical Mixtures with High Complexity by NMR Consensus Trace Clustering
NMR	Can, T.V., FSU Physics	Magic Angle Spinning Solid State NMR Studies of Conductance Domain of M2 Proton Channel
NMR	Cotten, M., Hamilton College, Chemistry	Structural Investigations of Antimicrobial Piscidin Bound to Aligned Cholesterol-Containing Lipid Bilayers
NMR	Cross, T.A., Florida State University, Chemistry and Biochemistry	Structural Studies of M. tuberculosis Integral Membrane Protein Rv1861 in a Lipid Bilayer Environment
NMR	Cross, T.A., FSU, Chemistry and Biochemistry	Thermo-Stable Bicelles to Study Membrane Protein, LspA, by Oriented Sample Solid-State NMR
NMR	Cross, T.A., NHMFL and FSU, Chemistry & Biochemistry	CrgA: a Mtb Membrane Protein Structure Determination by NMR Spectroscopy
NMR	Cross, T.A., NHMFL & Chemistry and Biochemistry, FSU	The Influence of Membrane Mimetic Environments on Membrane Protein Structures & a Tool for Validating Native Structures
NMR	Cross, T.A., NHMFL & FSU, Chemistry and Biochemistry	Is MgtC, A Potential Drug Target in M. tuberculosis, Inhibited by MgtR?
NMR	Cross, T.A., NHMFL	Structural Study of M2 Proton Channel In Situ by Solid State MAS NMR
NMR	Eisenmesser, E.Z., Assistant Professor, Biochemistry & Molecular Genetics	Interleukin-8 Exhibits Inherent Dynamics Localized to its Receptor Binding Surface
NMR	Eisenmesser, E.Z., University of Colorado Denver, Biochemistry & Molecular Genetics	Comparing Micro-Millisecond Motions Among Different Cyclophilin Family Members
NMR	Long, J.R., University of Florida	Characterization of Hydrogen Bonding in Amphiphilic Peptide Helices via REDOR
NMR	Paravastu, A.K., Florida State University, Chemical and Biomedical Engineering	Solid State NMR Analysis of Oligomeric Structures of the 42-Residue Amyloid-β peptide
NMR	Polenova, T., University of Delaware, Chemistry and Biochemistry	Solid-State NMR Structural and Dynamics Studies of HIV-1 Protein Assemblies
NMR	Smirnov, S.L., Western Washington University, Chemistry	The Solution Structure of D6 Domain of Villin, an Actin-Bundling Protein
NMR	Smirnov, S.L., Western Washington University, Chemistry	Structural Characterization of the DNA-binding Domain of the Xenopus NO38 Chaperone Complexed with its Duplex DNA Target.
NMR	Tian, F., Penn State College of Medicine, Biochemistry and Molecular Biology	Structural Analysis of a Recombinant Protein in Native Escherichia coli Membranes

Biology – 34 Reports

Facility	PI	Title
DC Field	Valles, Jr., J.M., Brown University, Physics	Probing Protist Swimming Mechanics using Magnetic Force Buoyancy Variation
EMR	Bienkiewicz, E.A., FSU, College of Medicine	EPR Analysis of an Intrinsically Disordered Amino-Proximal Domain of Prion Protein
EMR	Liu, A., Georgia State University, Chemistry	Biochemical, Structural and Spectroscopic Studies on the Metal Centers in Hydroxyanthranilic Acid Dioxygenase
EMR	Reinherz, E.L., Harvard Medical School, Dana-Farber Cancer Institute	Antibody-Mediated Mechanics on a Membrane-Embedded HIV gp41 Segment by EPR
EMR	Tian, C.T., University of Science and Technology of China	Pulsed EPR Distance Measurements of Escherichia Doli Diacylglycerol Kinase Homotrimer by DEER (Double Electron-Electron Resonance)
AMRIS	Blackband, S.J., University of Florida, Neuroscience	Quantitative Diffusion MR Microscopy of Porcine Neurons
AMRIS	Dotson, V.M., University of Florida, Clinical and Health Psychology	Structural and Functional Brain Changes in Late-Life Major and Minor Depression
AMRIS	Edison, A.S., UF/NHMFL, Biochemistry & Molecular Biology	Identification of a Female-specific Mating Pheromone in <i>Panagrellus redivivus</i>
AMRIS	Edison, A.S., UF/NHMFL, Biochemistry & Molecular Biology	<i>Caenorhabditis elegans</i> Produces Several Novel Glucosides of 1-Hydroxyphenazine, a Toxin Released by <i>Pseudomonas aeruginosa</i>
AMRIS	Helderman, C., University of Florida	Characterization of Brain Morphology in Mucopolysaccharidosis Type IIIB Affected Mice Using Magnetic Resonance Imaging
AMRIS	Jorgensen, C., University of Southern Denmark, Institute of Biology	Phosphorus Cycling in Wetlands and Riparian Zones
AMRIS	Mareci, T.H., University of Florida, Biochemistry and Molecular Biology	Gd-Albumin Relaxivity in the Rat Thalamus <i>In Vivo</i> at 11.1 T
AMRIS	Naylor, G.J.P., College of Charleston, Biology	Shark Virtual Comparative Anatomy Using MRI
AMRIS	Simpson, N.E., University of Florida, Medicine	Development of a Choline Calibration Curve to Monitor an Implanted Bioartificial Organ
AMRIS	Su, L.M., University of Florida, Urology	Fiber Tract Mapping in Isolated Sections of Human Prostate at High Field
AMRIS	Vestergaard-Poulsen, P.E., University of Aarhus, Denmark	DWI and Quantitative Modeling of Hippocampal Neurite Loss in Chronic Stress
AMRIS	Walter, G.A., University of Florida, Physiology	Chemical Shift-Based Imaging and Modeling of Dystrophic Muscle
AMRIS	Walter, G.A., University of Florida, Physiology	MR Microscopy of Muscular Dystrophy in the Diaphragm of a Rat Model
AMRIS	Walter, G.A., University of Florida, Physiology	MRI and DTI Characterization of Severe Contusion Injury at 17.6T
AMRIS	Walter, G.A., University of Florida, Physiology	Morphological Characterization of a New Model of Spinal Cord Injury Without Reloading Using 3D ¹ H MRI
AMRIS	Walter, G.A., University of Florida, Physiology	Quantitative Measurement of Skeletal Muscle Perfusion Using Arterial Spin Labeling NMR Imaging at High (4.7T) and Ultra-High Field (11.1T/17.6T)
AMRIS	Walter, G.A., University of Florida, Physiology	Gd Doped Silica Nanoparticles Encapsulating ICG
AMRIS	Walter, G.A., University of Florida, Physiology	Gene Transfer of Arginine Kinase to Skeletal Muscle Monitored with ³¹ P-MRS: A comparison of adeno-associated virus and adenovirus delivery methods
AMRIS	Walter, G.A., University of Florida, Physiology	Myocardium Transverse Relaxation Time in mdx Mice Following Uphill Running
AMRIS	Walter, G.A., University of Florida, Physiology	Manganese-Silica Hybrid Nanostructures as MRI Contrast Agents
AMRIS	Walter, G.A., University of Florida, Physiology	Evaluation of Muscle Bioenergetics in a New Rat Model of Disuse Using Dynamic ³¹ P Spectroscopy at High Field (11T)
NMR	Grant, S.C., NHMFL-FSU, Chemical & Biomedical Engineering	Tracking Neuroprogenitor Cells After Traumatic Brain Injury with 21.1 T MR Microscopy
NMR	Grant, S.C., NHMFL-FSU, Chemical & Biomedical Engineering	Tracking Human Mesenchymal Stem Cells in Association with Stroke Utilizing ¹ H and ²³ Na Nuclei at 21.1 T
NMR	Levenson, C.W., FSU College of Medicine	MR Imaging of the Rodent Traumatic Brain Injury at 21.1 T
NMR	Schepkin, V.D., NHMFL, CIMAR	3D Partial Volume Effects During Low Gamma MRI
NMR	Schepkin, V.D., NHMFL, CIMAR	<i>In vivo</i> Chlorine MR Imaging at 21.1 T
NMR	Schepkin, V.D., NHMFL, CIMAR	Tumor Resistance and <i>in vivo</i> Sodium MR Imaging at 21.1 T

Facility	PI	Title
NMR	Wszolek, K., Mayo Clinic, Neurology	High Resolution MRI at 21.1 T of the Hippocampus and Temporal Lobe White Matter in the Differential Classification of Alzheimer's Disease and Diffuse Lewy Body Disorder
NMR	Zhu, P.Z., University of Michigan	Effects of Glycation on Diabetic Bone Studied by Solid-State NMR

Chemistry – 45 Reports

Facility	PI	Title
DC Field	Knappenberger, K.L., Florida State University, Chemistry and Biochemistry	Magneto-Optical Photoluminescence Studies of Isolated and Aggregated Semiconductor Nanoscale Materials at Ultralow Temperatures
DC Field	Krzystek, J., NHMFL Tallahassee, CMS	High-Frequency and -Field EPR of a Series of Hexapyrazole-coordinated Complexes of High-Spin Fe(II)
DC Field	Musfeldt, J.L., University of Tennessee, Chemistry	Manipulating the Singlet-Triplet Equilibrium in Organic Biradical Materials
EMR	Christou, G., University of Florida	Mn ₇ : A Species at the Classical/Quantum Spin Interface
EMR	Colvin, V.L., Rice University, Rice University	Investigation of Novel Iron Material's Composition via Mössbauer Spectroscopy
EMR	Dalal, N.S., Florida State University, Chemistry	Direct Evidence from EPR for Multiple Configurations of Uncommon Paddlewheel Re ₂ ⁷⁺ Compounds Surrounded by an Unsymmetrical Bicyclic Guanidinate
EMR	Dalal, N.S., Florida State University, Department of Chemistry and Biochemistry	D Tensor Determination in a Potential Single Molecule Magnet, Cr ₃ (dpa) ₄ Cl ₂ -CH ₂ Cl ₂
EMR	Dinse, K.-P., FU Berlin, Physics	Characterization and Quantification of Reduced Sites on Supported Vanadium Oxide Catalysts using High-Frequency EPR
EMR	Kokozay, V.N., Kiev University, Ukraine, Chemistry	Novel Heterometallic Complexes Featuring Unusual Tetra- {CoIII2FeIII2(μ-O)6} and Octanuclear {CoIII4FeIII4(μ-O)14} Cores
EMR	Kovacs, Z., UT Southwestern Medical Center, Advanced Imaging Research Center	Electron Spin Resonance (ESR) and Dynamic Nuclear Polarization (DNP) Studies of Galvinoxyl Free Radical
EMR	Kovacs, Z., UT Southwestern Medical Center, Advanced Imaging Research Center	DPPH as DNP Polarizing Agents: ESR Investigation at 94 GHz and 240 GHz
EMR	Krzystek, J., NHMFL, CMS	Frequency-Domain Magnetic Resonance Spectroscopy of High-Spin Fe(II) Ions
EMR	Kyritsis, P., University of Athens, Greece, Chemistry	Magnetostructural Correlations in [Ni(II){(OPPh ₂ (EPPH ₂ N) ₂ (sol) ₂ }] Complexes, E = S, Se; sol = dmf, thf, Derived by HFEP, Magnetometry and Theoretical Calculations
EMR	Lysenko, A., Kiev University, Ukraine, Chemistry	Structure and Magnetic Behavior of Cu(II)- Metal Organic Frameworks Supported by 1,2,4-Triazolyl-Bifunctionalized Adamantane Scaffold
EMR	Reger, D., University of South Carolina, Chemistry	Metal-Metal Interactions in Copper(II) Carboxylate Dimers Prepared from Ligands Designed to Form a Robust π...π Stacking Synthron
EMR	Sakiyama, H., Yamagata University, Chemistry	An HFEP Study of a Dinuclear nickel(II) Complex
EMR	Sarkar, B., Universitaet Stuttgart, Institut für Anorganische Chemie	HFEP Studies on Mono- and Di-Nuclear High-Spin Transition Metal Complexes of Novel Chelating Ligands Based on Tris(triazole)amines and Quinones
EMR	Strouse, G.F., Florida State University	Spin Relaxation in Mn-doped CdSe Quantum Dots
EMR	Sunatsuki, Y., Okayama University, Chemistry	A Single Tripodal Ligand Stabilizing Three Different Oxidation States (II, III, and IV) of Manganese
EMR	Telser, J., Roosevelt University, Biological, Chemical and Physical Sciences	HFEP Studies of Vanadocene (Bis(cyclopentadienyl)vanadium(II), Cp ₂ V)
EMR	Telser, J., Roosevelt University, Biological, Chemical and Physical Sciences	HFEP of Mn(III) Corrole and Corrolazine Complexes in Frozen Solution
EMR	Veige, A.S., University of Florida, Chemistry	High Frequency EPR Study of a Cr(IV)-O-Cr(IV) Dimer Complex
EMR	Venkatraman, R., Jackson State University, Chemistry	High-Field EPR Studies on Nitrogen-Based Adducts of Copper(II) Levulinate
EMR	Wojciechowski, K., Warsaw University of Technology, Analytical Chemistry	Determination of a Small Isotropic Exchange Integral from High-Field EPR Spectra
ICR	Asomaning, S., Baker Hughes	Characterization of Naphthenic Acids in Crude Oils and Naphthenates by Electrospray Ionization FT-ICR Mass Spectrometry

Facility	PI	Title
ICR	Hsu, C.S., Future Fuels Institute, Chemistry	Compositional Boundaries for Fossil Hydrocarbons
ICR	Hsu, C.S., Future fuels Institute, Chemistry	Petroleomics: Advanced Molecular Probe for Petroleum Heavy Ends
ICR	Juyal, P., NALCO	Analysis and Identification of Biomarkers and Origin of Color in a Bright Blue Crude Oil
ICR	Rodgers, R.P., FSU, NHMFL, Chemistry	Petroleum Analysis
AMRIS	Gower, L.B., University of Florida, Materials Science and Engineering	Detection of a Non-Classical, Prenucleation, Liquid Phase of Calcium Carbonate
AMRIS	Hamilton, T.D., Barry University, Physical Sciences	NMR Characterization of Tetra-Meso-Substituted Porphyrins Synthesized Without Solvent
AMRIS	Long, J.R., University of Florida	Solid State ^{13}C NMR Characterization of an Incommensurately Modulated Structure
AMRIS	Luesch, H., University of Florida	Veraguamides A-G, Novel Cyclic Hexadepsipeptides with Antiproliferative Activity from the Marine Cyanobacterium <i>Symploca</i> cf. <i>hydroides</i> from Guam
AMRIS	Luesch, H., University of Florida	Pitipeptolides C-F, Antimycobacterial Cyclodepsipeptides from the Marine Cyanobacterium <i>Lyngbya majuscula</i> from Guam
AMRIS	Priestap, H.A., Florida International University	NMR Analyses of a New Tetrapyrrole
AMRIS	Simon, J.D., University of Virginia, Chemistry	Exploration of the Chemical Signatures of Extant and Fossil Melanin
AMRIS	Williams, R.F., Los Alamos National Laboratory	Probing Molecular Interactions of Simulants for Chemical Warfare Agents on/in Environmental Materials by Chemical Shift Magnetic Resonance Imaging (CS-MRI)
NMR	Dalal, N., Florida State University, Chemistry and Biochemistry	Detection of Ethyl Group Orientation in Petroporphyrins by Solid State NMR
NMR	Dalal, N., Florida State University, Chemistry and Biochemistry	Probing the Origin of Unexpected Splitting in ^{31}P CP-MAS of Hydrogen-Bonded Ferroelectrics at 21.1 T
NMR	Hernandez-Maldonado, A.J., University of Puerto Rico - Mayaguez, Department of Chemical Engineering	^1H and ^{23}Na MAS NMR of Cationic Species in CO_2 Selective $\text{M}^{\text{n+}}$ -SAPO-34 ($\text{M}^{\text{n+}} = \text{Sr}^{2+}$ or Ba^{2+})
NMR	Hernandez-Maldonado, A.J., University of Puerto Rico - Mayaguez, Department of Chemical Engineering	MAS NMR Characterization of the Nanoporous Flexible Titanosilicate UPRM-5 Prepared Using Tetrapropylammonium and Tetrabutylammonium Cations
NMR	Jakobsen, H.J., Aarhus University, Aarhus, Denmark, Chemistry	Resolving the First Scalar J-Coupling Between Two Quadrupolar Nuclei in Solid-State NMR
NMR	Lim, L., East Carolina University, Chemistry	Characterization of Lignocellulosic Biomass using Solid-State NMR Spectroscopy
NMR	Yang, Y., Xiamen University, Department of Chemistry	Understanding Microscopic Kinetics of Lithium Manganese Silicate Lithium Ion Battery Materials by Multinuclear ^{29}Si and ^6Li Solid-State NMR
NMR	Zhu, P., University of Michigan	^{43}Ca and ^{31}P MAS Solid-State NMR Analysis of Fluorohydroxyapatite

Condensed Matter Technique Development – 8 Reports

Facility	PI	Title
DC Field	Boebinger, G.S., NHMFL	Specific Heat Instrumentation and Measurements on the Cuprate Superconductor YBCO
DC Field	Brooks, J.S., NHMFL at Florida State University, Physics	Fabrication of Sticky Stamp Electrodes for Low Temperature and High Magnetic Field Electronic Transport Measurement of Mesoscopic Sized Sample
DC Field	Hannahs, S., NHMFL	Improvement of the Rotating Probes at the NHMFL DC Field Facility
DC Field	Hilton, D.J., University of Alabama at Birmingham, Physics	Decoherence in a High-Mobility Two-Dimensional Electron Gas
DC Field	Murphy, T.P., NHMFL	Magnetic Field Calibration of RuO_2 Thermometers
DC Field	Suslov, A.V., NHMFL	Electromagnetic Acoustic Transducer (EMAT) in the GHz Frequency Range
Pulsed Field	Kemper, J.B., Florida State University, Department of Physics/NHMFL	Calibration of Resistive Thermometers in Pulsed Fields to 45 Teslas
Pulsed Field	Kohama, Y., NHMFL, Tokyo University	Development of AC Measurement of Thermal Conductivity

Engineering Materials – 14 Reports

Facility	PI	Title
DC Field	Chabanov, A., University of Texas at San Antonio, Physics	Microwave Faraday Effect in 1D Magnetophotonic Crystals
DC Field	Howarth, T.R., Naval Sea Systems Command Division Newport	Acoustic Characterization of Magnetorheological Fluids
DC Field	Ludtka, G.M., Oak Ridge National Laboratory, Materials Science & Technology Division	Enhanced Performance Materials through Thermomagnetic Processing Solubility Enhancement and Nanoparticle Dispersion Strengthening
DC Field	Molodov, D.A., RWTH Aachen University, Institute of Physical Metallurgy and Metal Physics	Discontinuous Measurements of Magnetically Driven Motion of Specific Symmetrical Grain Boundaries in Zn
DC Field	Zhang, L., Northeastern University, China, Key Laboratory of Electromagnetic Processing of Materials (Ministry of Education)	Engineering Magnetic Properties of Nanocomposite Magnet by High Magnetic Field
DC Field	Zhou, X.L., Kunming University of Science and Technology, China, NHMFL	Magnetic Field-promoted Anomalous Pearlite at Early Phase Transformation Stages
AMRIS	Vasenkov, S., University of Florida, Chem. Eng.	Investigation of Gas Transport in Carbon Molecular Sieve Membranes by Multinuclear Pulsed Field Gradient NMR
AMRIS	Vasenkov, S., University of Florida, Chem. Eng.	Diffusion in Mixtures of Room Temperature Ionic Liquids and Carbon Dioxide by Pulsed Field Gradient (PFG) NMR
AMRIS	Vasenkov, S., University of Florida, Chem. Eng.	Gas Transport in Aluminosilicate Nanotubes by Diffusion NMR
MS & T	Han, K., NHMFL	Impacts of Heat Treatment on Properties and Microstructure of Cu16at%Ag Conductors
NMR	Alamo, R.G., FAMU-FSU College of Engineering, Chemical and Biomedical Engineering	Morphological and Kinetic Partitioning of Comonomer in Random Propylene 1-Butene Copolymers
NMR	An, L., University of Central Florida, AMPAC	NMR Studies on Structures of Polymer-Derived Amorphous SiCN Ceramics
NMR	Paravastu, A.K., Florida State University, Chemical and Biomedical Engineering	Solid State NMR Structural Analysis of Nanofibers Formed via Self-Assembly of RADA16-I Designer Peptides
NMR	Paravastu, A.K., Florida State University, Chemical and Biomedical Engineering	Solid State 19F NMR Light-Induced Isomerization of Azobenzene Glassy Polymer Networks

Geochemistry – 23 Reports

Facility	PI	Title
Geochem.	Chanton, J.P., Earth Ocean and Atmospheric Science, FSU	Radiocarbon Analysis of the Gulf Oil Spill
Geochem.	Du, X., FSU, Earth Ocean and Atmospheric Sciences	Variability and Periodicity in Precipitation and Discharge of the Red River
Geochem.	Froelich, P.N., Froelich Educational Services	Speleothem Trace Element Signatures: A Modern Hydrologic Geochemical Study of Cave Drip Waters and Farmed Calcite
Geochem.	Hirschmann, M.M., U. Minnesota, Geology & Geophysics	First-Row Transition Element (FRTE) Partitioning Between Garnet Peridotite and Near-Solidus Melts: Implications for OIB Source Mineralogy
Geochem.	Humayun, M., Florida State University, Earth, Ocean & Atmospheric Science	Iron Geochemistry of the Earth's Silicate Mantle
Geochem.	Humayun, M., Florida State University, Earth, Ocean & Atmospheric Science	Siderophile Element Abundances in Metal-Sulfide Assemblages from the Almahata Sitta Ureilite, a.k.a. Asteroid 2008 TC3
Geochem.	Humayun, M., Florida State University, Earth, Ocean & Atmospheric Science	W-Os Isotope Systematics of Iron Meteorites: GCR Irradiation and Chronology
Geochem.	Landing, W.M., FSU, EOAS	Determination of Low Concentration Iron and Other Trace Elements by Octopole Collision/Reaction Cell (CRC) Quadrupole-ICP-MS
Geochem.	Landing, W.M., FSU, EOAS	GEOTRACES: Aerosol and Rainwater Sampling and Analysis
Geochem.	Landing, W.M., FSU, EOAS	Sampling and Analysis of Trace Metals in the Sea Surface Microlayer

Facility	PI	Title
Geochem.	Landing, W.M., FSU, EOAS	Collaborative Research: A Novel Tracer Approach to Estimate the Atmospheric Input of Trace Elements Into the Global Ocean
Geochem.	Landing, W.M., FSU, EOAS	Mercury and Trace Element Deposition in the Northern Gulf of Mexico: Contributions from Local, Regional and Distant Sources
Geochem.	Landing, W.M., FSU, EOAS	Isotopic Composition of Species-Specific Atmospheric Mercury (Hg)
Geochem.	Odom, L., Geochemistry - NHMFL, Earth Ocean and Atmospheric Sciences	The Isotopic Composition of Atmospheric Mercury
Geochem.	Salters, V.J.M., NHMFL & FSU, Earth Ocean and Atmospheric Sciences	Pore Water Profile of Lithium Isotopes from Deep Sea Drilling Project (DSDP) Sites 1262 and 1267 (Walvis Ridge)
Geochem.	Salters, V.J.M., NHMFL & FSU, Earth Ocean and Atmospheric Sciences	Domains of Depleted Mantle; Deep Melting But Limited Crustal Thickness
Geochem.	Salters, V.J.M., NHMFL and FSU, Earth Ocean and Atmospheric Sciences	The Middle Jurassic Flood Basalts of Southeastern North America
Geochem.	Salters, V.J.M., NHMFL and FSU, Earth Ocean and Atmospheric Sciences	Ultra Depleted Mantle at the Gakkel Ridge Based on Hafnium and Neodymium Isotopes
Geochem.	Salters, V.J.M., NHMFL/FSU, Earth Ocean and Atmospheric Sciences	Accurate and Precise Determination of Mg Isotopes by Multi Collector Inductively Coupled Mass Spectrometry (MC-ICP-MS)
Geochem.	Wang, Y., FSU, EOAS	Isotopic Niche Overlap of Two Planktivorous Fish in Southern China
Geochem.	Wang, Y., NHMFL and Florida State University, EOAS	Late Neogene Environmental Changes in the Central Himalaya Related to Tectonic Uplift and Orbital Forcing
ICR	Cooper, W.T., FSU, Chemistry	Influence of Acidification on the Optical Properties and Molecular Composition of Dissolved Organic Matter
NMR	Vugmeyster, L., University of Alaska Anchorage	Characterization of Unfrozen Water In Soils of Dry Valleys of Antarctica

Graphene – 16 Reports

Facility	PI	Title
CMT/E	Vafek, O., NHMFL, FSU	Analysis of Fermions on a Honeycomb Bilayer Lattice with Finite-range Interactions in the Weak-Coupling Limit
DC Field	Andrei, E.Y., Rutgers University, Physics & Astronomy	Symmetry Breaking of Electronic States in Graphene Manifested Through Electrical Transport in High Magnetic Field
DC Field	Chen, Y.P., Department of Physics, Purdue University	Magnetotransport in Graphene Nanostructures: Disorder and Interaction Physics for Dirac Fermions
DC Field	Du, X., Stony Brook University, Physics and Astronomy	Magnetically Induced Phases in Suspended Graphene
DC Field	Jiang, Z., Georgia Tech, Physics	Infrared Magneto-Transmission of Graphene Nanoribbons Arrays
DC Field	Kim, P., Columbia University, Physics	Evidence for Skyrmionic Excitations in Graphene
DC Field	Lau, C.N., University of California, Riverside, Dept of Physics	Stacking-Dependent Band Gap and Quantum Transport in Trilayer Graphene
DC Field	Lau, C.N., University of California, Riverside, Physics	Transport Spectroscopy of Symmetry-Broken Insulating States in Bilayer Graphene
DC Field	Newell, D.B., NIST	Centimeter Scale CVD Graphene Quantum Hall for Quantum Resistance Standard
DC Field	Shepard, K.L., Columbia University, Electrical Engineering	Spin Characterization of Graphene's $\nu = 0$ State
DC Field	Smirnov, D., NHMFL	Magneto-Phonon Resonance in Graphite
DC Field	Smirnov, D., NHMFL	Infrared Photoconductivity of Graphene
DC Field	Szkopek, T., McGill University, Electrical and Computer Engineering	High Magnetic Field Measurement of Hydrogenated Graphene

Facility	PI	Title
DC Field	Tutuc, E., The University of Texas at Austin, Electrical and Computer Engineering	Magnetotransport Properties of Quasi-Free-Standing Epitaxial Graphene Bilayer on SiC
DC Field	Ye, P.D., Purdue University, Electrical and Computer Engineering	Quantum-Hall Plateau-Plateau Transition in Top-Gated Epitaxial Graphene Grown on SiC (0001)
Pulsed Field	Kono, J., Rice University, Electrical and Computer Engineering/Physics	Circular Polarization Dependent Cyclotron Resonance in Large-Area Graphene at Ultrahigh Magnetic Fields

Kondo/Heavy Fermion Systems – 10 Reports

Facility	PI	Title
DC Field	Harrison, N., LANL	Emergence of an Unreconstructed Fermi Surface from the Hidden Order of URu ₂ Si ₂
DC Field	Sakai, H., Japan Atomic Energy Agency, Advanced Science Research Center	²⁹ Si-NMR Study of URu ₂ Si ₂ Under High Field: Investigation of the 22 T anomaly found within the hidden order phase and its critical behavior around 35 T
DC Field	Schmiedeshoff, G.M., Occidental College, Physics	The Phase Diagram of YbAgGe with Magnetic Fields Along the c-Axis
DC Field	Terashima, T., Natl. Inst. Mat. Sci.	de Haas-van Alphen Measurements on the Rattling-Induced Superconductor KO ₂ O ₆
Pulsed Field	Bauer, E.D., LANL	Localized 5f Electrons in Superconducting PuCoIn ₅
Pulsed Field	Haga, Y., Japan Atomic Energy Agency	Fermi Surface Study on PuIn ₃ Using Proximity Detector Circuits
Pulsed Field	Martin, I., LANL	A Geometrical Hall Effect in a Magnetically Frustrated Metal
Pulsed Field	Nakotte, H., New Mexico State University, Department of Physics	Specific Heat of UCu _{5.5} Al _{6.5} and UCu _{5.75} Al _{6.25}
Pulsed Field	Schmiedeshoff, G., Occidental College	Probing the Magnetic Field Induced Novel Phase in YbAgGe by Specific Heat
Pulsed Field	Tozer, S.W., NHMFL	High Pressure Pulsed Magnetic Field Studies of the Lifshitz Transition in CeIn ₃

Magnet Technology – 14 Reports

Facility	PI	Title
ASC	Larbalestier, D.C., NHMFL-FSU, ASC	Mechanical Decoupling of REBCO Coated Conductors in High Field Coils Using Thin-Walled Heat-Shrink Tubing Insulation to Prevent Stress-Induced Damage
DC Field	Larbalestier, D.C., NHMFL	Layer Wound Superconducting Coil Generating 35.4 T Made from REBCO Coated Conductor
DC Field	Painter, T.A., NHMFL	Development of Modified Transverse Shims for Medium Homogeneity Resistive Magnets
DC Field	Weggel, R., Particle Beam Lasers	Tests of YBCO Double Pancake Coils in a Background Field of 20 T
MS & T	Bai, H., MST	Helium Gas Trapped in 32 T HTS Magnet
MS & T	Chen, J., NHMFL, MS&T	Structural Finite Element Analysis of the HZB Series Connected Hybrid Insert Housing Under Operating Conditions
MS & T	Dixon, I.R., NHMFL, MS&T	Nb ₃ Sn-Nb ₃ Sn Series Joint Qualification for the Series-Connected Hybrid Magnets
MS & T	Dixon, I.R., NHMFL, MS&T	Impedance Measurements on a CICC Model Coil for the National Science Foundation and Helmholtz Zentrum Berlin Series-Connected Hybrid Magnets
MS & T	Markiewicz, W.D., NHMFL/FSU	Insulation of Coated Conductors for High Field Magnet Applications
MS & T	Marshall, W.S., NHMFL, MS&T	Measurements of the Extent of Coil Degassing Prior to Epoxy Impregnation for the Series-Connected Hybrid Outsert Coils
MS & T	Weijers, H.W., NHMFL, MS&T	Computation of AC Losses in REBCO Coils of the 32T All-Superconducting Magnet
MS & T	Weijers, H.W., NHMFL, MS&T	HTS Current Lead Development for the NHMFL Series-Connected Hybrid
NMR	Brey, W.W., NHMFL	Improved NMR Field Mapping for Powered Magnets
Pulsed Field	Tokunaga, M., ISSP, The University of Tokyo	Development of a Probe for the Measurements of the Magneto-Caloric Effects in Pulsed Fields

Magnetic Resonance Technique Development – 30 Reports

Facility	PI	Title
DC Field	Brey, W., NHMFL	Reducing Temporal Field Fluctuations in Powered Magnets by Combining Inductive and NMR Measurements
EMR	Hill, S., NHMFL and FSU, Physics	Cavity Perturbation Technique: The Effects of Crystal Size on The EPR Spectra of Fe ₈
ICR	Hendrickson, C.L., FSU, NHMFL, Chemistry	Predator Data Station: A Fast Data Acquisition System for Advanced FT-ICR MS Experiments
ICR	Hendrickson, C.L., FSU, NHMFL, Chemistry	Excitation of Radial Ion Motion in an rf-Only Multipole Ion Guide Immersed in a Strong Magnetic Field Gradient
ICR	Hendrickson, C.L., FSU, NHMFL, Chemistry	Coulombic Shielding During Ion Cyclotron Excitation in FT-ICR Mass Spectrometry
ICR	Hendrickson, C.L., FSU, NHMFL, Chemistry	Electrically Compensated Fourier Transform Ion Cyclotron Resonance Cell for Complex Mixture Mass Analysis
ICR	Hendrickson, C.L., FSU, NHMFL, Chemistry	A Novel 9.4 Tesla FTICR Mass Spectrometer with Improved Sensitivity, Mass Desolution, and Mass Range
ICR	Marshall, A.G., FSU, NHMFL, Chemistry	Parts-Per-Billion Fourier Transform Ion Cyclotron Resonance Mass Measurement Accuracy with a “Walking” Calibration Equation
ICR	Rodgers, R.P., FSU, NHMFL, Chemistry	Atmospheric Pressure Laser-Induced Acoustic Desorption Chemical Ionization Fourier Transform Ion Cyclotron Resonance Mass Spectrometry for the Analysis of Complex Mixtures
AMRIS	Edison, A.S., UF/NHMFL, Biochemistry & Molecular Biology	1.5-mm HTS Probe Design for 600 MHz NMR
AMRIS	Long, J.R., University of Florida, Biochemistry/AMRIS	Development and Characterization of Proton Imaging Coils for Horizontal Bore Magnet Systems
AMRIS	Magin, R.L., UIC, Bioengineering	Evidence of Changes in Gray/White Matter in Epileptic Rat Brain Using Fractional Order Diffusion Tensor Imaging (fDTI) at 17.6 T
AMRIS	Mareci, T.H., UF, Biochemistry and Molecular Biology	Modulation of Cu-Sn Alloy Magnetic Susceptibility and Measurement Using MRI
AMRIS	Ozarslan, E., NIH	Development of a New MRI Contrast Method; Temporal Scaling of Diffusion
AMRIS	Stanisz, G.J., University of Toronto, Medical Biophysics	Oscillating and Pulsed Gradient Diffusion Magnetic Resonance Microscopy (MRM)
NMR	Amoureux, J.P., University of Lille-1	A Comparative Study of ¹ H Homonuclear Decoupling Sequences at Ultra-Fast Magic-Angle Spinning
NMR	Brey, W.W., NHMFL	Simulations of the Electromagnetic Field in NMR Low-E Coils
NMR	Cross, T.A., NHMFL, CIMAR/NMR	Correlation Restraints from Oriented Sample Solid State NMR Applied for a Structure of an α -helical Membrane Protein, KdpF
NMR	Fu, R., NHMFL	High-Resolution Stray Field Imaging Probe for <i>in situ</i> Lithium Ion Battery Studies
NMR	Gan, Z., NHMFL	An Efficient Amplification Pulse Sequence for Measuring Chemical Shift Anisotropy Under Fast Magic-Angle Spinning
NMR	Gan, Z., NHMFL	Measurement of Chemical Shift Anisotropy for the Backbone Sites of U- ¹³ C, ¹⁵ N-Enriched Proteins CSA Amplification
NMR	Gan, Z., NHMFL	Sensitivity-Enhancement Using the Carr-Purcell Meiboom-Gill Sequence for Separating ⁷⁷ Se Magic-Angle Spinning Sidebands of Germanium Selenide Glasses
NMR	Gan, Z., NHMFL	Obtaining Isotropic NMR Spectra of Paramagnetic Battery Materials with Large Anisotropic Broadening
NMR	Gor'kov, P.L., NHMFL	Efficient Triple-Resonance MAS Probe for Biological Solid-State NMR at 900 MHz
NMR	Grant, S.C., NHMFL-FSU, Chemical & Biomedical Engineering	Gadolinium- and Dysprosium-Encapsulating Ultra-Short Single-Walled Carbon Nanotubes as Intracellular Labeling Agents for High Magnetic Fields
NMR	Magin, R.L., U. Illinois - Chicago, Bioengineering	Field and Temperature Dependence of Parameters Extracted from Quantitative Magnetization Transfer Imaging at High B ₀ Fields
NMR	Nevzorov, A.A., NCSU, Chemistry	Testing High-Power B ₁ Fields for High-Resolution Separated Local Field Experiments in Oriented-Sample NMR
NMR	Van Sciver, S.W., NHMFL/FSU, Mechanical Engineering	MRI of Adsorbed Water in Solid Foams at 21.1 T

Facility	PI	Title
Pulsed Field	Ayala-Valenzuela, O.E., LANL	Thermally Detected Electron Paramagnetic Resonance (TD-EPR)
Pulsed Field	Ayala-Valenzuela, O.E., LANL	g-Factor Anisotropy Measurement in the Molecular Magnet $[\text{Cu}(\text{HF}_2)(\text{pyz})_2]\text{TaF}_6$ by Means of Thermally Detected Electron Paramagnetic Resonance (TD-EPR)

Magnetism & Magnetic Materials – 81 Reports

Facility	PI	Title
ASC	Xin, Y., NHMFL/FSU, MST	Atomic Structure and Electronic Structure of an $\text{AA}_3\text{B}_4\text{O}_{12}$ Double-Perovskite $\text{CaCu}_3\text{Ir}_4\text{O}_{12}$ by STEM Imaging and EELS Techniques
CMT/E	Bonesteel, N.E., FSU, Physics	Scaling Analysis of Random Singlet Phase Formation
CMT/E	Choi, E.S., NHMFL	Magneto-electric Effect in NdCrTiO_5
CMT/E	Winter, L.E., NHMFL/FSU, Physics	A Comparative Study of $\text{Mn}_{1-x}\text{Co}_x\text{V}_2\text{O}_4$ Focusing on Dielectric and RF Measurements
DC Field	Balicas, L., NHMFL	High Field Magnetic Phase Diagram of Low Dimensional Spin Gap Compound $\text{Pb}_2\text{V}_3\text{O}_9$
DC Field	Beedle, C.C., NHMFL	Photoluminescent Studies of Manganese Based Single-Molecule Magnets
DC Field	Buettgen, N., Center for Electronic Correlations and Magnetism, University of Augsburg, Germany	NMR Experiments in the Antiferromagnetic $S = 1/2$ Chain Compound LiCuVO_4
DC Field	Choi, E.S., NHMFL	Spin-Flop Transitions and Phase Diagrams of Antiferromagnet SrNdFeO_4 Probed by Dielectric Constant Measurements
DC Field	Dalal, N.S., FSU, Chemistry	Probing the Magnetic Field Driven Ising Quantum Criticality of the Square-Lattice $\text{Cr}(\text{dien})(\text{O}_2)_2 \cdot \text{H}_2\text{O}$
DC Field	Furis, M., University of Vermont, Physics	Magnetic Circular Dichroism (MCD) of Copper Phthalocyanine Crystalline Thin Films in the Florida HELIX Magnet
DC Field	Hoch, M.J.R., NHMFL	Evolution of the Spin Structure with Temperature in the Extended kagome YBaCo_4O_7
DC Field	Hong, T., Oak Ridge National Laboratory	Wilson Ratio of a Tomonaga-Luttinger Liquid in a Spin-1/2 Heisenberg Ladder
DC Field	Hosokoshi, Y., Osaka Prefecture University, Physical Science	Calorimetric Study of Organic Triangular Antiferromagnets TNN-CH3CN and TIM-CH3CN in High Magnetic Fields
DC Field	Jo, Y.J., Kyungpook National University, Physics	Anisotropic Metamagnetism of Rare-Earth Tetraborides and Germanides
DC Field	Kimura, T., Osaka University, Division of Materials Physics	High-Magnetic-Field Effect on Interplay Between Sm and Mn Moments in SmMnO_3
DC Field	Lee, Y.S., MIT, Physics	Specific Heat Measurement on an $S=1/2$ Kagome Antiferromagnet
DC Field	McGill, S.M., Florida State University, NHMFL	Spin-Lattice Coupling in Low-Dimensional Spin Dimer: $\text{SrCu}_2(\text{BO}_3)_2$
DC Field	Mitrovic, V.F., Brown University, Physics	Effects of the Applied Magnetic Field Orientation on the Ground State of Cs_2CuBr_4
DC Field	Shatruk, M., Florida State University, Department of Chemistry and Biochemistry	High-field Studies of Anomalous Magnetism of $\text{La}_{1-x}\text{R}_x\text{Co}_2\text{P}_2$ ($R = \text{Pr}, \text{Nd}$) Phases
DC Field	Shulyatev, D., MISIS, Moscow, Russia	Investigation of $(\text{La}_{0.85}\text{Sr}_{0.15})_y\text{MnO}_{3+d}$ Single Crystals
DC Field	Takano, Y., UF, Physics	Magnetic Phase Diagram of the Spin-1/2 Triangular-Lattice Antiferromagnet Cs_2CuCl_4
DC Field	Telser, J., Roosevelt University, Biological, Chemical and Physical Sciences	HFEPR of Magnetic Materials with Unusual Optical Properties: $\text{YIn}_{1-x}\text{Mn}_x\text{O}_3$
DC Field	Tsujii, H., Kanazawa University, Department of Physics, Faculty of Education	Magnetic Phase Diagram of the Quasi-One Dimensional Antiferromagnet $\text{BaCo}_2\text{V}_2\text{O}_8$
DC Field	Zhou, H.D., NHMFL	Magnetic Phase Diagram of a New Magnetic Triangular Lattice System
EMR	Bonanni, A. (Alberta), Johannes Kepler Universität, Linz-Austria, Semiconductor and Solid State Physics	Magnetic Resonances of Mn^{3+} in $(\text{Ga},\text{Mn})\text{N}$
EMR	Brechin, E.K., U. Edinburgh, Chemistry	High-Frequency EPR Studies of Molecular Magnets Based on Mn^{III} Dimers
EMR	Choi, K.-Y., Chung-Ang Univ.	Spin Relaxations of Cu^{2+} doped $\text{Ca}(\text{PO}_3)_2$ Glasses Studied by Pulsed EPR
EMR	Hill, S., NHMFL and FSU, Physics	Quantum Tunneling of Magnetization in Trigonal Single-Molecule Magnets

Facility	PI	Title
EMR	Holmes, S.M., University of Missouri-St. Louis, Chemistry	EPR Studies of CN Bridged Fe ₂ ^{III} N ^{III} Complexes and Their Mononuclear Fe ^{III} Building-Blocks
EMR	Lattner, S.E., Florida State University, Chemistry	R ₃₃ Fe ₁₄ B ₂₅ C ₃₄ (R = La, Ce) and R ₃₃ Fe ₁₃ B ₁₈ C ₃₄ (R = Ce, Pr): Complex Intermetallics Featuring Borocarbide-capped Iron Clusters Grown from Rare-Earth/transition Metal Eutectic Fluxes
EMR	Lawes, G., Wayne State University, Physics and Astronomy	Mössbauer Studies on Multiferroic FeVO ₄
EMR	Long, J.R., UC Berkeley, Chemistry	High-field EPR Studies of a Mononuclear Co ^{II} Molecular Magnet
EMR	Long, J.R., UC Berkeley, Chemistry	High-frequency EPR studies of a ReZn chain
EMR	Pajerowski, D., NIST	EPR Investigations of Photomagnetic Effects in the Heterobimetallic Complex [Nd(DMF) ₄ (H ₂ O) ₃ (μ-NC)Fe(CN) ₅] · H ₂ O
EMR	Yang, E.-C., Fu Jen Catholic University, Chemistry	EPR Study of Tetranuclear Terbium (III) and Gadolinium (III) Clusters
EMR	Yang, E.-C., Fu Jen University, Chemistry	EPR Studies of the Half-integer Spin (S = 19/2) Single-molecule Magnet Mn ₆ ^{III} Mn ^{II} -heamp
EMR	Zorko, A., Jožef Stefan Institute, Ljubljana, Slovenia	Spin Correlations in the Kagome Compound Kapellasite as Seen by ESR
EMR	Zvyagin, S.A., Dresden High Magnetic Field Laboratory (HLD), Helmholtz-Zentrum Dresden-Rossendorf (HZDR)	Two-Magnon Bound States in the Spin-1 AFM Chain System DTN: High-field ESR Studies
High B/T	Yin, L., University of Florida, Physics	Magneto-Electric Effect of the Bose-Glass Phase in NiCl _{1.85} Br _{0.15} -4SC(NH ₂) ₂ at Low Temperatures
High B/T	Yin, L., University of Florida	Magnetic Susceptibility Measurements of the Bose Glass Phase in NiCl _{1.85} Br _{0.15} -4SC(NH ₂) ₂ at Low Temperatures
AMRIS	Walter, G.A., University of Florida, Physiology	Magnetic/NIR Quantum Dots for Optical & MR Imaging
Pulsed Field	Argyriou, D., Helmholtz-Zentrum Berlin für Materialien und Energie	Investigation of the Role of Spin-Texture on the Electronic State in Sodium Cobaltate
Pulsed Field	Ayala-Valenzuela, O.E., LANL	Proximity Detector Oscillator Dynamic Susceptibility of [Fe ₈] in Pulsed Magnetic Fields
Pulsed Field	Canfield, P., Ames Lab and ISU Physics	Large Magnetoresistance in the Paramagnetic State of RPtBi (R = Gd and Lu)
Pulsed Field	Cheong, S., Rutgers University, Physics	Specific Heat and Magnetization Measurements in RInO ₃ (R = Tm and Dy)
Pulsed Field	Correa, V.F., CNEA, Argentina	Magnetization at High Magnetic Fields in Gd _{2/3} Ca _{1/3} MnO ₃
Pulsed Field	Daou, R., MPI, CPFS	Microstrain-Sensitivity Magnetostriction of SrCu ₂ (BO ₃) ₂ to 97.4 Tesla
Pulsed Field	Friedman, J.R., Amherst College, Physics	Speed of Sound in Single-Molecule Magnets
Pulsed Field	Frontzek, M., ORNL	Multiferroic Behavior of CuCrO ₂ in High Magnetic Fields
Pulsed Field	Hoch, M.J.R., FSU, Physics	Spin-State Crystallization in LaCoO ₃ in Magnetic Fields Approaching 100 Tesla
Pulsed Field	Kamihara, Y.K., Keio University, Applied Physics and Physico-Informatics (APPI)	Schottky-Like Anomaly Observed in a Heavy Fermion Metal, La _{0.5} Ce _{0.5} FePO.
Pulsed Field	Kim, K.H., Seoul National University, Physics and Astronomy	Thermodynamic Study of a Field-Induced Phase Transition in Multiferroic Ba ₂ CoGe ₂ O ₇
Pulsed Field	Kondo, A., ISSP, University of Tokyo	Magnetoresistance and Magnetic Phase Diagram of CeOs ₂ Al ₁₀
Pulsed Field	Kondo, A., ISSP, University of Tokyo	Observation of the Shubnikov-de Haas Oscillations in CeRu ₂ Al ₁₀
Pulsed Field	Landee, C.P., Clark University	High field Specific Heat of S=1/2 Quasi 2D Antiferromagnet, Cu(C ₄ H ₄ N ₂) ₂ (ClO ₄) ₂
Pulsed Field	Manson, J., Eastern Washington University, Chemistry and Biochemistry	Pulsed Field Magnetization and Electric Polarization Measurements of CoCl ₂ -2thiourea
Pulsed Field	Manson, J., Eastern Washington University, Chemistry and Biochemistry	Specific Heat of CoCl ₂ -2thiourea and CoCl ₂ -4thiourea
Pulsed Field	Manson, J.L., Eastern Washington University, Chemistry and Biochemistry	Temperature-Dependent Magnetization of Quasi-1D [Ni(HF ₂)(3-Clpy) ₄]BF ₄
Pulsed Field	Manson, J.L., Eastern Washington University, Chemistry and Biochemistry	Specific Heat Study of the Quasi-2D S = 1 Quantum Magnet NiBr ₂ (pyz) ₂ (pyz = pyrazine)
Pulsed Field	Manson, J.L., Eastern Washington University, Chemistry and Biochemistry	Specific Heat Study of the Quasi-1D S = 1 Quantum Magnet [Ni(HF ₂)(3-Clpy) ₄]BF ₄

APPENDIX B: RESEARCH REPORTS BY CATEGORY

Facility	PI	Title
Pulsed Field	Manson, J.L., Eastern Washington University, Chemistry and Biochemistry	Temperature-Dependent Magnetization of the $S = 1/2$ Quasi-2D Quantum Magnet $\text{Ag}(\text{nic})_2$
Pulsed Field	Manson, J.L., Eastern Washington University, Chemistry and Biochemistry	Pulsed-Field Magnetization of the $S = 1$ Antiferromagnet $\beta\text{-}[\text{Ni}(\text{HF}_2)(\text{pyrazine})_2]\text{PF}_6$
Pulsed Field	Manson, J.L., Eastern Washington University, Chemistry and Biochemistry	Pulsed-Field Magnetization of the $S = 1$ Quasi-1D Quantum Magnet $[\text{Ni}(\text{HF}_2)(3\text{-Clpy})_4]\text{BF}_4$
Pulsed Field	Manson, J.L., Eastern Washington University, Chemistry	High-field Magnetization of the $S = 1/2$ Spiral Chain $[\text{Cu}(\text{pym})(\text{H}_2\text{O})_4]\text{SiF}_6$ Up to 85 T
Pulsed Field	Manson, J.L., Eastern Washington University	Temperature- and Field-dependent Magnetization Studies of the 1D Zig-Zag Chain $\text{NiCl}_2(\text{H}_2\text{O})_2(\text{pyzdo})$
Pulsed Field	Manson, J.L., Eastern Washington University	Anisotropic Specific Heat of $S=1/2$ Quasi-1D Antiferromagnet $[\text{Cu}(\text{N}_2\text{C}_4\text{H}_4)(\text{H}_2\text{O})_4]\text{SiF}_6 \cdot \text{H}_2\text{O}$
Pulsed Field	Manson, J.L., EWU, Chemistry	EPR Measurements of $[\text{Cu}(\text{pym})(\text{H}_2\text{O})_4]\text{SiF}_6$
Pulsed Field	Mira, J., Universidade de Santiago de Compostela, Spain	Multiferroic Behavior in the New Double Perovskite $\text{Lu}_2\text{MnCoO}_6$
Pulsed Field	Paduan-Filho, A., U. de Sao Paulo, Brazil	Bose-glass Phase at the Boundary of Bose-Einstein Condensates in Quantum Magnets
Pulsed Field	Rivadulla, F., Universidade de Santiago de Compostela, Spain	Electrical Polarization and Magnetization Measurements in CdV_2O_4
Pulsed Field	Ronning, F., LANL	Fermi Surface of Ce_2RhIn_8
Pulsed Field	Ronning, F., LANL	Fermi Surface in PrPt_2In_7
Pulsed Field	Ronning, F., LANL	Heat Capacity in CePt_2In_7
Pulsed Field	Rueegg, C., Paul Scherrer Institute, Laboratory for Neutron Scattering	Cascade of Field-Induced Phase Transitions in the Frustrated Spin-Gap System BiCu_2PO_6
Pulsed Field	Rueegg, C., PSI, LDM	High Field Magnetostriction of Frustrated Spin Ladder System BiCu_2PO_6
Pulsed Field	Schlueter, J.A., ANL	High-Field Magnetization of the 1D $\text{CuBr}_2(\text{pyzO})(\text{H}_2\text{O})_2$ and 2D $\text{CuBr}_2(\text{pyz})$ up to 92 T
Pulsed Field	Schuller, K., UC San Diego	Substrate-Controlled Ferromagnetism in Iron-Phthalocyanine Films Due to 1D Fe Chains
Pulsed Field	Taylor, A., LANL, MPA-CINT	Magnetoelectric Coupling in TbMnO_3 Thin Film
Pulsed Field	Tokunaga, M., ISSP, The University of Tokyo	Magneto-Caloric Effect on LaCoO_3
UF Physics	Meisel, M.W., UF, Physics	Effects of Pressure on the Magnetic Properties of $\text{K}_x\text{Co}_6[\text{Fe}(\text{CN})_6]_x \cdot m\text{H}_2\text{O}$
UF Physics	Meisel, M.W., UF, Physics	Photomagnetic and Spin-Crossover Behavior of $[\text{Fe}^{\text{II}}(\text{TPMA})(\text{XBIM})](\text{ClO}_4)_2$

Molecular Conductors – 6 Reports

Facility	PI	Title
DC Field	Brooks, J.S., NHMFL at Florida State University, Physics	Angular-Dependent Magnetothermopower in a Multiband Organic Conductor
DC Field	Brooks, J.S., NHMFL/FSU, Physics	Investigation of the Low-Dimensional Organic Conductor $\text{Per}_2[\text{Pt}(\text{mnt})_2]$
DC Field	Kang, W., Ewha Womans University, Physics	High Field Behavior of Kartsovnik-Kajita-Yamaji Resonance Peaks and the Coherence Peak of Quasi-Two-Dimensional Electrons
DC Field	Maesato, M., Kyoto University, Chemistry	Investigation of FISDW in the p-d Hybrid Q1D Magnetic Conductor
DC Field	Park, Y.W., Seoul National University, Department of Physics and Astronomy	Distinctive Magneto Conductance of One-Dimensional Polymer Nanofibers
DC Field	Uji, S., National Institute for Materials Science	Fermi Surfaces of Two Dimensional p-d Systems, $k\text{-}(\text{BDH-TTP})_2\text{FeX}_4$ ($\text{X}=\text{Br}$ and Cl)

Other Condensed Matter – 27 Reports

Facility	PI	Title
CMT/E	Brooks, J.S., NHMFL, Physics	Chemical Pressure Effects on Structural, Magnetic, and Transport Properties of $Mn_{1-x}Co_xV_2O_4$
CMT/E	Dobrosavljevic, V., NHMFL, Physics	Nearly Frozen Coulomb Liquids
CMT/E	Gor'kov, L.P., FSU, NHMFL	Strong Electron-Phonon Interactions and Polaronic Effects in Compounds with Transition-Metals-Atoms
CMT/E	Rikvold, P.A., FSU, Physics	Computational Materials Science and Statistical Mechanics
DC Field	Behnia, K., ESPCI, LPEM	Angle-Dependent Nernst Effect in Bismuth Up to 45 T
DC Field	Birge, N.O., Michigan State University, Physics and Astronomy	Magneto-Transport Measurements of Topological Insulator Epitaxial Thin Films
DC Field	Chen, Y.P., Purdue University, Physics and ECE	Magneto-Transport in Bi_2Se_3 : Shubnikov-de Haas Oscillation and Quantum Hall Effect
DC Field	Gleeson, J.T., Kent State University	High Field Magneto-Optical Studies of Liquid Crystals and Complex Fluids
DC Field	Goldhaber-Gordon, D., Stanford Univ., Physics	Electrolyte Gate-Controlled Kondo Effect in $SrTiO_3$
DC Field	Hussey, N.E., University of Bristol, Physics	Anomalous Magnetoresistance in the Quasi-One-Dimensional Conductor $Li_{0.9}Mo_6O_{17}$
DC Field	Jarillo-Herrero, P., Massachusetts Institute of Technology, Physics	Quantum Transport in Density-Controlled Topological Insulator Devices
DC Field	Khodaparast, G., Virginia Tech	Time Resolved Magneto-Photoluminescence in Er3N@C80 Metallofullerenes
DC Field	Kim, J.S., POSTECH, Physics	Dirac Fermions in a Bi Square Net in $SrMnBi_2$ Single Crystals
DC Field	Kono, J., Rice University, Electrical and Computer Engineering	Magneto-Absorption Spectroscopy of Armchair-Enriched, Carbon Nanotube Aqueous Suspensions with the Split-Helix Magnet
DC Field	Levy, J., University of Pittsburgh, Physics & Astronomy	Quantum Transport in Nanostructures at the Interface of $LaAlO_3/SrTiO_3$
DC Field	Li, L., University of Michigan	Coexistence of Magnetism and Two-Dimensional Superconductivity at Oxide Interface
DC Field	Murphy, S.Q., University of Oklahoma, Physics	Search for Semi-Metal to Insulator Transition in Quantum Confined Sb Films
DC Field	Musfeldt, J.L., University of Tennessee, Chemistry	Magnetoelectric Coupling in $\alpha-Fe_2O_3$ Amplified by Collective Transition
DC Field	Ong, N.P., Princeton University, Physics	High-field Shubnikov de Haas Oscillations in the Topological Insulator Bi_2Te_2Se
DC Field	Petrovic, C., Brookhaven National Laboratory, Condensed Matter and Materials Science	Quantum Transport of Two-Dimensional (2D) Dirac Fermions in $SrMnBi_2$
DC Field	Ramesh, R., Lawrence Berkeley National Laboratory and University of California at Berkeley, Materials Science and Engineering and Physics	Magneto-Transport in $LaAlO_3-SrTiO_3$: Probing interface electron gas dimensionality
DC Field	Smirnov, D., NHMFL	Temperature Dependence of Raman-Active Phonons in Bi_2Se_3 and Sb_2Te_3
DC Field	Warusawithana, M.P., FSU/NHMFL, Dept. of Physics	Signatures of Two-Dimensional Conductivity at Oxide Interfaces
DC Field	Zhang, C., Peking University, International Center for Quantum Materials	Coexistence of Bulk and Surface Shubnikov-de Haas Oscillations in Bi_2Se_3
NMR	Saam, B., University of Utah, Physics and Astronomy	Investigations of Microscopic Chaos in CaF2 NMR Lineshapes
Pulsed Field	Hellman, F., University of California - Berkeley, Department of Physics	Dielectric Breakdown Voltage and Capacitance Measurements on Relaxor Ferroelectrics
Pulsed Field	Hwang, H., Stanford	Angle Dependent Magneto-Transport in 2D 0.1% δ -doped STO

Quantum Fluids & Solids – 7 Reports

Facility	PI	Title
CMT/E	Yang, K., NHMFL	Theoretical Studies of Quantum Hall Liquids and Other Topological States of Matter
High B/T	Sullivan, N.S., University of Florida, Physics	NMR Relaxation Times of HD Molecules Trapped in the Cages of a Metal Organic Framework
High B/T	Sullivan, N.S., University of Florida, Physics	Theory Nuclear Spin-Lattice Relaxation of ^3He Impurities in Solid ^4He
High B/T	Sullivan, N.S., University of Florida, Physics	Anomalous Dynamics of Solid ^4He at Low Temperatures: Analysis of NMR Studies
High B/T	Yin, L., University of Florida, Physics	Precision Measurements of the Dielectric Constant of Solid ^4He at Low Temperatures
Pulsed Field	Shekhter, A., LANL, NHMFL, Pulsed Field Facility	Resonant Ultrasound Measurements on Single Crystal Hg1201 Cuprate
UF Physics	Sullivan, N.S., University of Florida, Physics	Active Feedback Duplexer for Fast Recovery Detection in Solid State NMR

Qubits and Quantum Entanglement – 8 Reports

Facility	PI	Title
CMT/E	Vafek, O., NHMFL	Quantum Hall Effect in a Singly and Doubly Connected Three-Dimensional Topological Insulator
DC Field	Bokor, J., University of California, Berkeley	Engineering CMOS-Compatible Quantum Dot Qubits for Local and Non-Local On-Chip Quantum Communication
EMR	Chiorescu, I., NHMFL	Tunable Multi-photon Rabi Oscillations in an Electronic Spin System
EMR	Chiorescu, I., NHMFL	Multi-photon Rabi Oscillations in High Spin Paramagnetic Impurity
EMR	Choi, K.-Y., Chung-Ang Univ.	Coherent Manipulation of Electron Spins in the $\{\text{Cu}_3\}$:NS Spin Triangle Complex
EMR	Coronado, E., University of Valencia, Chemistry	Mitigation of Decoherence in Holmium Polyoxometalate Single-molecule Magnets
EMR	Schenkel, T., Lawrence Berkeley National Laboratory	Electrical Detection of Magnetic Resonance in Silicon MOSFETs at High Magnetic Fields
Pulsed Field	Crooker, S.A., NHMFL- Los Alamos	Spin Fluctuations in Potassium-41: An Investigation of Spin Noise in a Homogeneously-Broadened System

Semiconductors – 25 Reports

Facility	PI	Title
CMT/E	Brooks, J.S., NHMFL at Florida State University, Physics	Fabrication and Characterization of Silk-Based Organic Thin Film Transistor
CMT/E	Jiang, Z., Georgia Institute of Technology, School of Physics	Thermal Expansion Coefficients of Bi_2Se_3 and Sb_2Te_3 Crystals
CMT/E	Popovic, D., NHMFL, FSU, Physics	Non-Gaussian Conductance Noise in a Strongly Disordered 2D Electron System in Si
DC Field	Drichko, I.L., A.F. Ioffe Physicotechnical Institute	Acoustic Studies of AC Conductivity Mechanisms in n-GaAs/AlGaAs in the Integer and Fractional Quantum Hall Effect Regime
DC Field	Du, R.-R., Rice University, Physics and Astronomy	Quantum Spin Hall Effect in InAs/GaSb Quantum Wells
DC Field	Engel, L.W., NHMFL	Microwave Spectroscopy of 2D Electron Systems with Controlled Alloy Disorder
DC Field	Gervais, G., McGill University	High Magnetic Field Measurement of Single Intrinsic InN Nanowires
DC Field	Jaroszynski, J., NHMFL	Quantum Hall Ferromagnet at Crossing of Spin Subbands of the Lowest Landau Level
DC Field	Kono, J., Rice University	Time-Resolved Evidence for Superfluorescent Radiation from Quantum Wells in Strong Magnetic Fields
DC Field	Pusep, Y.A., Instituto de Física de São Carlos, Universidade de São Paulo	Magneto-optical Probe of Quantum Hall States in a Wide Parabolic Well Modulated by Random Potential
DC Field	Schnyders, H.S., Grand Valley State University, Physics	Magnetoresistance Measurement in a Quantifiable N-Type/P-Type Composite
DC Field	Shayegan, M., Princeton University, Dept. Electrical engineering	Anomalous Robustness of the $\nu = 5/2$ Fractional Quantum Hall Effect Near a Sharp Phase Boundary

Facility	PI	Title
DC Field	Yakunin, M.V., Institute of Metal Physics, Ekaterinburg, Russia	Quantum Hall Ferromagnetism in HgTe/HgCdTe Quantum Wells
DC Field	Zudov, M.A., University of Minnesota, School of Physics & Astronomy	Giant Microwave Photoresistivity Effect in Very High Mobility Quantum Hall Systems
EMR	Zvanut, M.E., University of Alabama at Birmingham, Physics	High Field Pulsed ^{14}N , ^{29}Si and ^{13}C Electron Nuclear Double Resonance of Nitrogen Centers in Silicon Carbide
High B/T	Pan, W., Sandia National Lab	Novel Fractional Quantum Hall Effect in Two-Dimensional Electron Systems
Pulsed Field	Crooker, S.A., NHMFL- Los Alamos	Spin Noise of Holes and Hole-Nuclear Couplings in (In,Ga)As Quantum Dots
Pulsed Field	Crooker, S.A., NHMFL- LANL	Copper-Doped Inverted Core-Shell Nanocrystals with Permanent Optically Active Holes
Pulsed Field	Crooker, S.A., NHMFL- LANL	Spin-Polarized Mn^{2+} Emission from Mn-Doped Colloidal Semiconductor Nanocrystals
Pulsed Field	Doorn, S.K., CINT - LANL	Fluorescent Single-Walled Carbon Nanotube Aerogels in Surfactant-Free Environments
Pulsed Field	Gamelin, D.R., University of Washington, Chemistry	Circularly-Polarized Mn^{2+} Photoluminescence in Colloidal Doped Quantum Dots
Pulsed Field	Klimov, V.I., Chemistry Division, LANL	A Photosensitive Diluted Magnetic Semiconductor Based on Copper-doped II-VI Semiconductor Nanocrystals
Pulsed Field	Kohama, Y., LANL, LANL, Pulsed Field Facility	Heat Conductivity Measurements on Single Crystal Underdoped YBCO Cuprates: AC Technique Measurements
Pulsed Field	Picraux, S.T., CINT - LANL	Electrical Detection of Spins in Si Nanowires
Pulsed Field	Wang, Y., Tsinghua University, Physics	High Field Transport Measurement on Topological Insulator Thin Films

Superconductivity Applied – 17 Reports

Facility	PI	Title
ASC	Hellstrom, E.E., ASC - NHMFL	High Critical Current Density in Superconducting Ba-122 Ferro-Pnictide Wires
ASC	Larbalestier, D.C., NHMFL-FSU, ASC	Doubled Critical Current Density in Bi-2212 Wires by Reduction of Gas Bubble Density
ASC	Larbalestier, D.C., ASC - NHMFL	Quantitative Metallographic Deconstruction of SULTAN-Tested ITER CICC and Evidence for Bending-Strain Induced Filament Cracking Under Cyclic Loading
ASC	Larbalestier, D.C., ASC - NHMFL	The Study of Anisotropy and Industrial Defects in YBCO Coated Conductors Under In-Plane Reversible Strain
ASC	Larbalestier, D.C., ASC - NHMFL	Bubbles as a Major Current Obstacle in Bi2212 Round Wires – Understanding and Reduction of Bubbles
ASC	Larbalestier, D.C., ASC - NHMFL	a-Axis Grains as Important Current-Limiting Defects in State-of-the-Art REBCO Coated Conductor
ASC	Larbalestier, D.C., ASC-NHMFL, FSU	Tc Distribution in Nb_3Sn Wires Determined by Specific Heat Measurements
ASC	Larbalestier, D.C., ASC-NHMFL	Angular Dependence of J_c at Elevated Temperatures
ASC	Lee, P.J., ASC - NHMFL	Understanding of Suppressed Superconductivity on the Surface of Superconducting RF Quality Niobium for Particle Accelerating Cavities
DC Field	Cardwell, D., University of Cambridge, Engineering	Extremely High Flux Pinning Force in Single Grain RE-Ba-Cu-O Bulk Superconductors Containing Nano-Scale Pinning Centers
DC Field	Chiesa, L., Tufts University, Mechanical Eng	Characterization of Superconducting Bronze Wires Under Pure Bending Load
DC Field	Christen, D.K., ORNL	Anisotropy of the Irreversibility Field for REBCO Thin Films Up to 45T
DC Field	Jaroszynski, J., NHMFL	Angular Dependence of Irreversibility Field for YBCO Thin Films with Controlled Pinning Defects at Very High Magnetic Fields
DC Field	van der Laan, D.C., National Institute of Standards and Technology	Critical Current Measurement at 4.2 K Up to 20 T of $\text{REBa}_2\text{Cu}_3\text{O}_{7-d}$ Coated Conductor Cables Designed for High-Field Magnet Applications
MS & T	Walsh, R.P., NHMFL, MS&T	Physical, Electrical, and Mechanical Properties of Contemporary YBCO Conductors for the 32 T Superconducting Magnet Design
Pulsed Field	Ayala-Valenzuela, O.E., LANL	Optimization of ENABLE Growth Conditions of NbN Films for Superconducting Nanowire Single Photon Detectors
Pulsed Field	Bulmer, J., HyperTech Inc.	Response of YBCO to Subcritical, Injected DC Current and 4MT/s Pulsed Magnetic Field

Superconductivity Basics – 33 Reports

Facility	PI	Title
CMT/E	Popovic, D., NHMFL, FSU, Physics	Dynamic Charge Order and Superconductivity in Lightly Doped $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ Thin Films
DC Field	Boebinger, G.S., NHMFL	Search For Reentrance or Enhancement of Superconductivity in 2D Cuprate Interfaces
DC Field	Bozovic, I., Brookhaven National Laboratory	Magnetotransport in $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ Grown via Molecular Beam Epitaxy
DC Field	Coldea, A.I., Oxford University, Physics	Quantum Oscillations in the 111 Iron Pnictide Superconductors: LiFeAs and LiFeP
DC Field	Fisher, I.R., Stanford University	High Magnetic Field Studies of Iron Arsenide Superconductor
DC Field	Greven, M., University of Minnesota, School of Physics and Astronomy	High Field Specific Heat of $\text{HgBa}_2\text{CuO}_{4+d}$
DC Field	Gurevich, A., Old Dominion University	Anomalous Irreversibility in the Superconducting State of LiFeAs
DC Field	Halperin, W.P., Northwestern University, Physics and Astronomy	Spin Density Wave Near the Vortex Cores of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$
DC Field	Halperin, W.P., Northwestern University, Physics and Astronomy	Field Dependence of Spin Lattice Relaxation Rate in $\text{Ba}_{0.67}\text{K}_{0.33}\text{Fe}_2\text{As}_2$ in High Magnetic Field
DC Field	Kartsovnik, M.V., Walther-Meissner-Institute	Classical and Quantum Oscillations in the Magnetoresistance of e-doped $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_4$
DC Field	Kim, K.H., Seoul National University, Department of Physics and Astronomy	Upper Critical Behavior of Optimally Doped $\text{Sr}(\text{Fe},\text{Ni})_2\text{As}_2$ Superconductor
DC Field	Nikolo, M., St. Louis University, Physics	Magnetic Flux Pinning Properties of the Iron-Pnictide Superconductors $\text{Ba}(\text{Fe}_{0.91}\text{Co}_{0.09})_2\text{As}_2$, $\text{Ba}(\text{Fe}_{0.93}\text{Co}_{0.07})_2\text{As}_2$, and $\text{Ba}(\text{Fe}_{0.95}\text{Co}_{0.05})_2\text{As}_2$
DC Field	Popovic, D., NHMFL, FSU, Physics	Magnetic-Field-Driven Superconductor-Insulator Transition in Underdoped $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$
DC Field	Sebastian, S.E., University of Cambridge, Physics	Chemical Potential Oscillations Reveal Single Fermi Surface Pocket in Underdoped Cuprates
DC Field	Stewart, G.R., UF Physics	Low Temperature Specific Heat vs. Field of Fe Pnictide Superconductors–Nodal or Not?
DC Field	Taillefer, L., Université de Sherbrooke, Physics	Quantum Oscillations in the Thermoelectric Properties of $\text{YBa}_2\text{Cu}_3\text{O}_{6.54}$
DC Field	Tozer, S.W., NHMFL	Fermi Surface of BaFe_2As_2 Under Pressure in the Reconstructed State
DC Field	Tranquada, J.M., Brookhaven National Laboratory	Superconductivity and Competing Order in $\text{La}_{2-x}\text{Ba}_x\text{CuO}_4$
DC Field	Xi, X., University of Florida, Department of Physics	Critical Fields and Critical Temperature of Type-II Superconducting Thin Films
DC Field	Zheng, G.Q., Okayama University, Physics	High-Field NMR Study of the Pseudogap Ground State in High-Tc Copper-Oxides
Pulsed Field	Batlogg, B., ETH Zurich, Switzerland	Quantum Oscillations of the Superconductor LaRu_2P_2 : Comparable mass enhancement $\lambda \approx 1$ in Ru and Fe phosphides
Pulsed Field	Canfield, P., Ames Lab and ISU Physics	Anisotropic H_{c2} Measurement on the $\text{K}_{0.8}\text{Fe}_{1.76}\text{Se}_2$ Superconductor
Pulsed Field	Canfield, P., Ames Lab and ISU Physics	Upper Critical Fields and Two-Band Superconductivity in $\text{Sr}_{1-x}\text{Eu}_x(\text{Fe}_{0.89}\text{Co}_{0.11})_2\text{As}_2$
Pulsed Field	Canfield, P., Ames Lab and ISU Physics	Investigation of Anisotropic H_{c2} in Co-Doped BaFe_2As_2 Compounds
Pulsed Field	Cava, R., Princeton University, Chemistry	Anisotropic H_{c2} Determined Up to 92 T and the Signature of Two-Band Superconductivity in $\text{Ca}_{10}(\text{Pt}_4\text{As}_8)((\text{Fe}_{1-x}\text{Pt}_x)_2\text{As}_2)_3$ Superconductor
Pulsed Field	Harrison, N., Los Alamos National Laboratory	Multiple Quantum Oscillation Frequencies from Nodal Pocket in Underdoped Cuprates
Pulsed Field	Larbalestier, D.C., ASC-NHMFL, FSU	Upper Critical Field Enhanced by Doping and Strain in Fe-Based Superconductors
Pulsed Field	Marcenat, C., CEA-Grenoble, INAC	Scaling Properties of Magnetotransport at the Quantum Critical Point in $\text{BaFe}_2(\text{As}_{1-x}\text{P}_x)_2$
Pulsed Field	Moll, P., Laboratory for Solid State Physics, ETH Zurich, Switzerland	Superconducting Critical Current Measurements in Pulsed Magnets
Pulsed Field	Serquis, A., Centro Atómico Bariloche, CNEA; Instituto Balseiro, UNCuyo; CONICET, Bariloche, Argentina)	Mg-B Site Doping Effects on the Upper Critical Field Temperature Dependence of MgB_2 Samples with CaCO_3 Additions
Pulsed Field	Shekhter, A., LANL, Pulsed Field Facility	Resonant Ultrasound Spectroscopy (RUS) Measurements on Ultra-High Quality Underdoped YBCO Single Crystal Cuprates: Design of the RUS probe for samples in the sub-milligram mass range
Pulsed Field	Shekhter, A., LANL, Pulsed Field Facility	Resonant Ultrasound Measurements on Single Crystal Hg1201 Cuprate
Pulsed Field	Yuan, H., Zhejiang University, Physics, China	Upper Critical Field and Thermally Activated Flux Flow in $\text{Tl}_{0.58}\text{Rb}_{0.42}\text{Fe}_{1.72}\text{Se}_2$

APPENDIX C

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1800 E. Paul Dirac Drive
Tallahassee, FL 32301-8350

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