

REPORTS

SUMMER EDITION

VOLUME 13 • NO. 3 • 2006

**ATTENTION USERS
HIGH B/T AND LANL:
USER SUPPORT
SCIENTISTS**

PAGE 8

**EDUCATION
AND OUTREACH
THRIVE AT THE
MAGNET LAB**

Page 18

**NEWS FROM
THE DC FIELD
FACILITY:
QUANTUM HALL EFFECT
IN GRAPHENE AT HIGH
MAGNETIC FIELDS**

PAGE 14

**NEWS FROM
AMRIS
A STUDY OF MODEL
 β -CELLS IN DIABETES
TREATMENT**

Page 16

NHMFL REPORTS

CONTENTS

**3 FROM THE DIRECTOR'S
DESK**

4 WAVELENGTHS

**6 FROM THE MAGNET LAB
SCIENCE COUNCIL**

INDIRECT-DETECTED HIGH-RESOLUTION ^{14}N
NMR SPECTROSCOPY OF SOLIDS

8 ATTENTION USERS
HIGH B/T AND LANL:
USER SUPPORT SCIENTISTS

**13 BIG PULSED MAGNETS
NEARING COMPLETION**

**14 NEWS FROM THE DC FIELD
FACILITY**

QUANTUM HALL EFFECT IN GRAPHENE AT
HIGH MAGNETIC FIELDS

16 NEWS FROM AMRIS
A STUDY OF MODEL β -CELLS IN DIABETES
TREATMENT

**18 EDUCATION AND
OUTREACH *THRIVE* AT
THE MAGNET LAB**

21 SAFETY AT THE NHMFL
WORKING SAFELY IN THE LAB – *PREVENT
ACCIDENTS BY WEARING PROPER ATTIRE!*

**22 MS&T DIRECTOR ACCEPTS
LEADERSHIP POSITION
WITH U.S. ITER PROJECT
OFFICE**

23 PEOPLE IN THE NEWS

PUBLISHED BY:
**NATIONAL
HIGH MAGNETIC FIELD
LABORATORY**
1800 EAST PAUL DIRAC DRIVE
TALLAHASSEE, FLORIDA 32310-3706

DIRECTOR:
GREG BOEBINGER

DIRECTOR, PUBLIC AFFAIRS:
SUSAN RAY

EDITING AND WRITING:
KATHY HEDICK

ART DIRECTION AND PRODUCTION:
WALTER THORNER

www.magnet.fsu.edu

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 write us at the address shown at left, call 850 644-6392, or e-mail hedick@magnet.fsu.edu.

FROM THE DIRECTOR'S DESK

Collaborations—particularly those with other magnet laboratories around the world—are an excellent means of fulfilling the laboratory's mission to advance magnet-related technologies and science and to promote U.S. economic competitiveness while advancing user facilities. Since its inception, the laboratory has worked hard to establish and expand working relationships with nearly every major high field facility in the world.

In mid-May, **NHMFL Associate Director of User Programs Alex Lacerda** traveled with **NSF Director for National Facilities Guebre X. Tessema** (the laboratory's program manager) to four of Europe's high magnetic field facilities, the:

- Grenoble High Magnetic Field Laboratory,
- National Pulsed Magnetic Field Laboratory in Toulouse, France,
- Dresden High Magnetic Field Laboratory, Germany, and the
- High Field Magnet Laboratory in Nijmegen, The Netherlands.

The purpose of the visit was to get a sense of the state of high magnetic field laboratories in Europe and to understand how the NHMFL fares in terms of organization, availability of instruments, uniqueness, and in magnet science and technology and user service. The purpose was also to explore areas of future cooperation between the NHMFL and its European counterparts.

In a summary report of the visit, Dr. Tessema noted that "Overall, the high field laboratories in Europe are growing. Funding is healthy for a wide spectrum of magnets (DC, superconductors, 45 Tesla hybrid, 100 Tesla short pulse...etc.), and for a combination of magnetic fields with FEL and synchrotron light sources. The leaders are young and quite optimistic about the future. Most of the lead scientists are former or current users of the NHMFL and have very strong ties with the NHMFL. The international role played by the NHMFL is quite apparent and many of the European labs recognize the leadership role of the NHMFL."

On the other hand, European labs, like our Japanese counterparts, are adapting technologies often developed at the NHMFL and expanding quickly into new areas, e.g. combining free electron lasers with high magnetic fields; developing very high field magnets for use with synchrotrons; and investing in more advanced high-energy capacitor banks to support research in pulsed fields.

The creation of high magnetic fields user facilities across the globe continues. In mid-August, Alex will represent the NHMFL at the High Field Symposium in Taipei, Taiwan. The symposium will investigate the possibility of establishing a new high magnetic fields user facility in Taiwan.

Sharing knowledge, educating and exchanging early career scientists and engineers, and driving new technologies are clearly advancing the state of the art in magnet science and expanding user research facilities for the benefit of all. The Magnet Lab will continue its efforts to expand international interactions, and our latest contribution to the effort is...sadly...

Saying goodbye to **John Miller, the director of Magnet Science and Technology**, who assumes an important new leadership position with the United States ITER Project at Oak Ridge National Laboratory. ITER stands for International Thermonuclear Experimental Reactor, which aims to demonstrate the scientific and technical feasibility of fusion power. This move returns John to his native state of Tennessee and to ORNL, where he spent nearly a decade in the Fusion Energy Division in the 70s and 80s. John joined the Magnet Lab in the early 90s and contributed greatly to the lab's start-up, the successful R&D of the 45 T Hybrid magnet, and the current strength and flexibility of the MS&T program. John led MS&T through a difficult transition several years ago, and he has implemented a vision to expand magnet capabilities, increase external funding, and broaden our international collaborations. Read more about John's next step on page 22 and learn more about **Mark Bird, who has been appointed interim director of MS&T**. I'm confident that Mark has the qualifications, leadership, and support necessary to continue John's legacy and to initiate new and challenging projects.

I've been in this position for just over two years now and continue to be impressed—*indeed awed*—by the research underway in our world-class facilities and by the people who are essential to operations and who drive our science, engineering, and educational programs. This issue—with three exceptional science features and profiles of user support scientists and educators—showcases these strengths exceptionally well. Enjoy the reading!

Rock and roll,

Greg



Greg Boebinger

Wavelengths

NSF Deputy Director Tours Tallahassee Facility

Kathie Olsen, deputy director of NSF, toured the lab in April as part of a visit to Florida State University that included giving the keynote speech at FSU's 2006 Research Recognition Dinner.



During her visit, Olsen stressed that education will be weighted heavily in this year's renewal proposal. **The emphasis on education is part of the Bush administration's "American Competitiveness Initiative,"** in which the NSF is tasked to help maintain the nation's global science and engineering leadership, something just about everyone agrees is in serious jeopardy.

Science education and outreach is especially important in this time of globalization. A recent report from the National Academy of Sciences found that America is losing its edge as the world leader in science and technology—an edge, the report says, that can only be maintained by increasing America's talent pool through "vastly improving K-12 science and mathematics education."

This sentiment was echoed by Olsen in a recent NSF newsletter: "We are ... responsible for helping to prepare the next generation of scientists and engineers, and the nation's skilled technology work force." You can read a transcript from "Meet NSF's New Deputy Director" on the NSF Web site: www.nsf.gov. See page 18 to learn about some of the lab's newest education activities.



Middle-School Students Take Center Stage

Students from the School of Arts and Sciences (SAS), a charter school in Tallahassee, capped off their Middle School Science Mentorship in May with presentations and celebration at the Magnet Lab.



Beginning in January of 2006, 13 of the students spent each Friday morning working alongside research scientists at the lab. The nine girls and four boys worked for months on their science projects, which they presented to their mentors, teachers, family and friends on May 11. Projects included the study of lava rocks, nuclear magnetic resonance, lasers, thermal expansion and microscopy, all through hands-on learning and experimentation. Other SAS students in the program worked with a local veterinarian and a computer consultant.

The SAS Middle School Science Mentorship is the brain child of Joan Crow, the wife of the founder of the lab, the late Jack Crow. The mentorship, administered through the lab's Center for Integrating Research and Learning, is designed to generate interest in science at an early age, especially in girls, so that the students will consider pursuing a science tract in school and follow it with a career in science.

It appears to be working, based on the paths of some former students from the mentorship program. One girl, **Sharmini Pitter, will start college this year as a geochemistry major.** Another young man, **Elliot Hawkes, is now entering Harvard as a science major.** And yet another entered Berkeley University as a chemistry major graduate student.

A student from the current program summed up his experience this way: "I have thoroughly enjoyed this mentorship and found that it helped strengthen my knowledge of science and my love for it."

Magnet Lab Middle School Science Mentors for 2006 included Michael Bizmus, Lloyd Engel, Bob Goddard, Andrew Harter, Phil Kuhns, Eric Palm, Arneil Reyes, Afi Sachi-Kocher, Robert Smith, Nicole Tibbetts, Hans van Tol, and Bob Walsh.

The SAS students

for 2006 were Isaac Bass, Erika Bertelsen, Linzie "Bo" Bogan, Krista Cunningham, Savvy Davy, Isabella Folmar, Ava Hildebrand, Max Harmony, Sarah Higbee-



Tindell, Daniel Jackson, Andrew Jernigan, Jessica Johns, Laura Johnson, Carolina Kidwell-Bozeman, Charlene Kormondy, Julia Kunberger, Erin Meisenzahl, Nitasha Menon, Haven Mills, Adam Smith, and Will Taber.



Magnet Lab Researchers Produce One of 2005's Top Physics Papers



A paper on shape memory effect is leaving a lasting impression on the world of condensed matter physics.

The paper, "Fermi surface as a driver for the shape-memory effect in AuZn" was recently selected by *Journal of Physics: Condensed Matter* as one of the Top Papers of 2005. The announcement was made in April.

The papers and review articles chosen for the 2005 Showcase received the highest praise from board referees and were the most highly downloaded articles of 2005. They are considered to be the very best contributions of the last year.

"It makes all the long nights in the lab worthwhile when the result provokes so much interest," said **Ross McDonald, the paper's lead author**. McDonald is a scientist in the Pulsed Field Facility in Los Alamos, N.M.

The paper greatly contributes to the advancement of materials science. As stated in the Showcase summary, "the data and calculations provide direct evidence about the role of the band-electron system and its Fermi surface in the shape memory effect, showing that band-structure/property relations are an important consideration for the design of future shape memory alloys."



Mysteries Unravel with Help of Ancient Chinese Warriors

Ancient Chinese warriors are yet again helping scientists from the Magnet Lab and their collaborators unravel some of the mysteries of the natural world.

It all starts with a pigment called Han purple that was used more than 2,000 years ago to color Xi'an terra cotta warriors of the Qian Dynasty. The pigment is known in the scientific world as $BaCuSi_2O_6$ —and when Magnet Lab scientists exposed it to very high magnetic fields and very low temperatures, it entered a state of matter that is rarely observed.



Photographs and image creation by John Griffin, Michael Davidson, and Marcelo Jaime. Crystals in the picture provided by Suchitra Sebastian, Philip Tanedo, Peter Brooks, and Ian Fisher

The most recent research, published in the June 1 issue of the journal *Nature*, shows that at the lowest temperature point at which the change of state occurs—called the Quantum Critical Point—the Han purple pigment actually loses a dimension: it goes from 3D to 2D. Theoretical physicists have postulated that this kind of dimensional reduction might help explain some mysterious properties of other materials (high temperature superconductors and metallic magnets known as "heavy fermions" for example) near the absolute zero of temperature, but until now, a change in dimension had not been experimentally observed.

The experiment was performed at the laboratory's DC Field Facility at FSU by **Neil Harrison of NHMFL-LANL** and **Suchitra Sebastian from Stanford University**, in collaboration with **Peter Sharma and Marcelo Jaime of the Magnet Lab at LANL**, **Luis Balicas from the NHMFL-Tallahassee**, **Ian Fisher of Stanford**, and **Naoki Kawashima of the University of Tokyo**. **Eric Palm and Tim Murphy at the Tallahassee facility** provided invaluable user support.



Lab Emphasizing Commitment to Safety

Visitors and regular users might have noticed that the Safety department is now posting "Laboratory Information" signs at the entrance of the labs. These postings contain such information as emergency contacts, lab hazards, and location of safety equipment.

This is part of an ongoing effort to communicate important laboratory information and make employees, visitors, users, and emergency personnel aware of the hazards that may exist in the labs. Read more about safety at the lab on page 21.



ICR Publications Recognized

Papers from the NHMFL ICR Program were recently recognized as the most-cited papers over the past 10 years in two of mass spectrometry's most prestigious journals. The papers appear in *Mass Spectrometry Reviews* (also the #1 most-cited journal in all of spectroscopy) and the *Journal of the American Mass Spectrometry Society*. The recognition was announced at the May 2006 American Society for Mass Spectrometry annual conference in Seattle.

Marshall, A.G.; Hendrickson, C.L. and Jackson, G.S., "Fourier Transform Ion Cyclotron Resonance Mass Spectrometry: A Primer," *Mass Spectrom. Rev.*, **17**, 1-35 (1998). (440 citations; next closest was 201)

Senko, M.W.; Hendrickson, C.L.; Emmett, M.R.; Shi, S.D.-H. and Marshall, A.G., "External Accumulation of Ions for Enhanced Electrospray Ionization Fourier Transform Ion Cyclotron Resonance Mass Spectrometry", *J. Am. Soc. Mass Spectrom.*, **8**, 970-976 (1997). (259 citations; next closest was 167)

from the MAGNETLAB SCIENCE COUNCIL



Rafael
Bruschweiler
Science Council
Member

A unique strength of nuclear magnetic resonance (NMR) spectroscopy is that it can be applied to a broad range of atomic nuclei across the periodic table. Differential interaction strengths, however, preclude the practical use of certain isotopes to obtain valuable information on the structure and dynamics of their chemical environment. One of these elements is Nitrogen-14, which is the dominant nitrogen isotope in nature and which is part of many molecules in chemistry and biochemistry. The strong quadrupolar interaction and the relatively low Larmor frequency of this nucleus make traditional NMR measurements challenging. Zhehong Gan,¹ a scholar scientist at the Magnet Lab in Tallahassee, and Geoffrey Bodenhausen's group (University of Lausanne, Switzerland)² have independently developed a novel approach for solids that indirectly detects this nucleus via the neighboring Carbon-13 spins under magic-angle spinning thereby overcoming the above-mentioned resolution and sensitivity issues. The good results obtained when applied to a small peptide demonstrate the strong potential of this technique for a wide range of chemical systems including macromolecules.

Indirect-Detected High-Resolution ¹⁴N NMR Spectroscopy of Solids

Z. Gan, NHMFL

The nitrogen atom is one of the most important elements in organic, inorganic, biological, and material chemistry. Until now nitrogen NMR has been mostly done with the ¹⁵N isotope for its favorable NMR properties of a spin-1/2. The abundant ¹⁴N isotope (99.6%) is a spin-1 that possesses nuclear quadrupolar moment. Large quadrupolar interaction with electric-field-gradient makes ¹⁴N lines very broad in both solution and solid. The low gyromagnetic ratio (70 MHz Larmor frequency at 900 MHz magnet) makes direct ¹⁴N NMR detection even more difficult. Because of these difficulties, little ¹⁴N NMR has been done in the past despite strong interest in electric-field-gradient tensors accessible only through ¹⁴N. ¹⁴N quadrupolar coupling is sensitive to local molecular environment. Many important chemical and biological processes such as hydrogen-bond, protonation, and metal binding can be probed by measuring ¹⁴N quadrupolar coupling. This report presents a method development using indirect ¹⁴N detection via

nearby ¹³C and magic-angle spinning to overcome the sensitivity and resolution difficulties for ¹⁴N NMR.^{1,2} It also proposes a robust approach of measuring ¹⁴N quadrupolar coupling from the indirect detected high resolution spectra.

Magic-angle sample spinning (MAS) is the standard method for obtaining high spectral resolution in solids by averaging out the broadening from anisotropic second-rank spin interactions such as dipolar coupling, chemical shift anisotropy, and quadrupolar coupling. Precise magic-angle setting (<0.01°) and rotor synchronization make high-resolution ¹⁴N spectra possible even with quadrupolar couplings two orders of magnitude larger than typical sample spinning frequency.^{3,4} Unfortunately the magic-angle spinning also averages the direct dipolar coupling between ¹⁴N and nearby ¹³C needed for the indirect detection. The pulse sequence in Figure 1 shows a HMQC-type pulse sequence for two-dimensional ¹⁴N/¹³C correlation under magic-angle spinning using the *J* and residual dipolar couplings. The scalar *J*-coupling is invariant under MAS and typical coupling constants in proteins and polypeptides are $^1J_{NCO} \sim 11\text{Hz}$, $^1J_{NCA} \sim 5 - 8\text{Hz}$, $^2J_{NCA} \sim 3 - 6\text{Hz}$. The slow buildup of coherence $C_x \rightarrow \sin(\pi J\tau)C_yS_z$ with a small coupling competes with the decay from ¹³C *T*₂ relaxation. The much larger

SCIENCE
COUNCIL



Lev
Gor'kov
Chair



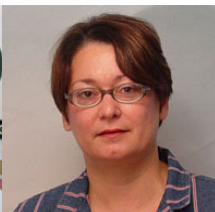
James
Brooks



David
Larbalestier



Albert
Migliori



Carol
Nilsson



Glenn
Walter

dipolar coupling is modulated by MAS and the secular dipolar coupling term is averaged to zero. The non-secular $^{14}\text{N}/^{13}\text{C}$ dipolar coupling terms are non-negligible due to the large ^{14}N quadrupolar interaction and partially remain under MAS. The residual dipolar coupling $D_Q C_z (s^2 - 3s_z^2)/3$ has an isotropic term

$$D_Q^{iso} = \frac{9}{10} \frac{C_q}{\nu_N} d [(3 \cos^2 \vartheta_d - 1)/2 - \eta \sin^2 \vartheta_d \cos 2\varphi_d / 2] \quad (1)$$

often dominates over the scaled $l = 4$ anisotropic term, causing a 2-to-1 ($m = \pm 1, 0$) splitting to carbons directly bonded to a ^{14}N . This residual dipolar coupling is significant at low magnetic fields and has been frequently observed in ^{13}C MAS spectra in the past. At high field (14.1 T), the residual dipolar coupling is expected ~ 30 Hz for amide $^{14}\text{N}/^{13}\text{C}$ spin pairs significantly larger than the J -coupling constants. This coupling requires a coherence transfer time $\tau \sim 15$ ms to establish correlations between direct-bonded $^{14}\text{N}/^{13}\text{C}$ spins.

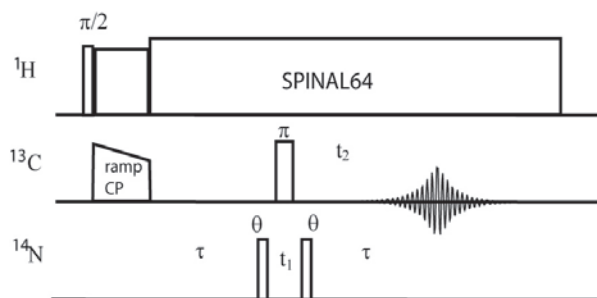


Figure 1. HMQC pulse sequence for $^{14}\text{N}/^{13}\text{C}$ correlation under MAS. The evolution time t_1 is rotor synchronized and the magic-angle is precisely set for a complete average of the first-order quadrupolar shift.

A key feature of the experiment is the rotor synchronous t_1 between the two ^{14}N pulses for indirect ^{14}N frequency encoding. The rotor synchronization along with magic-angle setting is critical for a complete average of the large first-order quadrupolar coupling. Typical rf field strength of the ^{14}N pulses, ~ 50 kHz, is not sufficient compared to quadrupolar frequency offsets of MHz. A pair of $\sim 30^\circ$ pulses yields approximately 10~15% efficiency for the single-quantum ^{14}N frequency encoding. Despite of this loss, the overall sensitivity still gains significantly from detection via ^{13}C , a nucleus with ~ 3 times higher gyro-magnetic ratio and about two orders of magnitude narrower lines than ^{14}N . The high spectral resolution and sensitivity of indirect ^{13}C detection are demonstrated with a natural abundant polypeptide Ala.Gly.Gly (note only $\sim 1\%$ ^{14}N being detected in the sample). All expected peaks for direct-bonded $^{14}\text{N}/^{13}\text{C}$ pairs are well separated by the ^{13}C chemical shift in Figure 2.

Along the indirect dimension, the ^{14}N peaks show large shifts from their isotropic chemical shift positions. These shifts along with the broadening are the result of the second-order quadrupolar effect. The second-order quadrupolar shift of a spin-1 can be expressed by the ratios of its expansion coefficients to well-studied central transition of half-integer spins⁴

$$R_0 = -4/5, R_2 = 1/10, R_4 = -2/15. \quad (2)$$

It is important to note that the ratios for the anisotropic terms R_2 and R_4 are much smaller than the isotropic term R_0 . The isotropic second-order quadrupolar shift

$$\delta_Q^{iso} = \frac{1}{20} \left(\frac{\chi_q}{\nu_0} \right)^2, \quad (3)$$

is much larger than the anisotropic broadening with the R_2 term averaged to zero and the R_4 term scaled by MAS. The measurement of the isotropic quadrupolar shift leads to the determination of the parameter χ_q representing the magnitude of the quadrupolar coupling tensor

$$\chi_q = \frac{eQ}{h} \sqrt{V_{xx}^2 + V_{yy}^2 + V_{zz}^2} = \sqrt{\frac{3+\eta^2}{2}} C_q. \quad (4)$$

For nitrogen, the down-field quadrupolar shift can be easily separated from the chemical shift obtained by a ^{15}N NMR MAS experiment as illustrated in Figure 2.

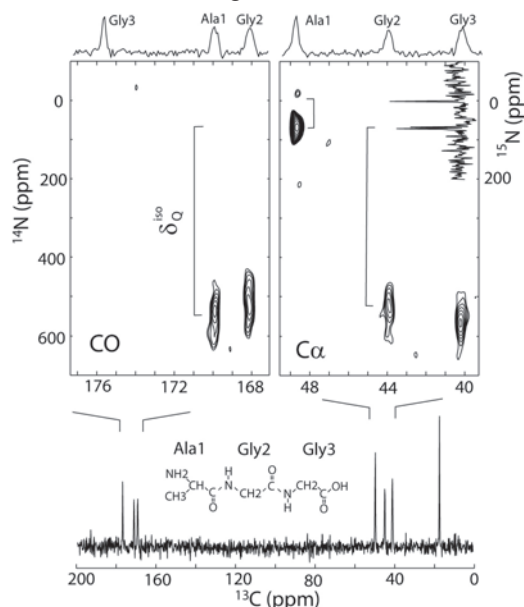


Figure 2. $^{14}\text{N}/^{13}\text{C}$ correlation spectrum of natural abundant Ala.Gly.Gly. The spectrum was acquired using the 600 MHz Bruker DRX NMR spectrometer at the NRMFL in Tallahassee. Other experimental parameters are 15 ms τ , 25 kHz MAS with 2.5 mm rotor, 16 t_1 increments, 8 K scans, 2 μs ^{14}N pulse with 50 kHz ν_1 , SPINAL64 ^1H decoupling with 125 kHz ν_1 . The vertical brackets indicate the isotropic second-order quadrupolar shift δ_Q^{iso} from the chemical shift measured by a separate ^{15}N MAS experiment shown on the right. The nitrogen chemical shift is referenced to solid NH_4Cl . Because of the large second-order quadrupolar shifts, the amide ^{14}N peaks have been de-aliased after doubling the spectral window from 25 to 50 kHz.

For amide nitrogen, the quadrupolar shift can be over 600 ppm at 14.1 T (43.35 MHz ν_N) with quadrupolar coupling constants in the range of 3~4 MHz. For AGG, $\chi_q = 4.29 \pm 0.05$ and 4.13 ± 0.05 MHz are obtained from the 490 and 454 ppm quadrupolar shifts, respectively, measured for Ala1 and Gly2 (the different quadrupolar shifts also assign the pairing of CO and C α connecting amide nitrogen in the polypeptide). The results are in good agreements with $\chi_q = 4.32$ and 4.05 MHz calculated with $C_q = 3.2 \pm 0.1$ and 3.0 ± 0.1 MHz and $\eta = 0.8 \pm 0.2$ reported in a previous single-crystal study of AGG.⁵

In conclusion, indirect detection of ^{14}N through J and residual dipolar couplings with nearby ^{13}C overcomes the resolution and sensitivity limitations of acquiring ^{14}N NMR spectra. The result of a model polypeptide demonstrates that large quadrupolar couplings up to 4 MHz such as those of amide nitrogen can be measured precisely from the isotropic second-order quadrupolar shift. In the past, little has been learned on nitrogen quadrupolar coupling for molecules with multiple nitrogen sites and large quadrupolar coupling constants. The high spectral resolution and sensitivity of indirect detection make the measurement and the use of ^{14}N quadrupolar coupling possible for large molecules. It should be mentioned that the measurement with AGG has been carried out with only ~1% (^{13}C natural abundance) of the ^{14}N spins in the sample. Isotope enrichment can increase the sensitivity by an order of magnitude for applications with large and complex systems such as proteins and nucleic acids.

¹ Gan, Z.H., *J. Am. Chem. Soc.*, **128**, 6040-6041 (2006).

² Antonijevic, S.; Cavadini, S.; Lupulescu, A. and Bodenhausen, G., 4th European Conference on Solid State NMR, Chamonix, France, September, 2005; 47th ENC, Asilomar, California, April 2006.

³ Gan, Z.H., *J. Am. Chem. Soc.*, **122**, 3242-3243 (2000).

⁴ Gan, Z.H., *J. Chem. Phys.*, **114**, 10845-10853 (2001).

⁵ Stewart, P.L.; Valentine, K.G. and Opella, S.J., *J. Magn. Reson.*, **71**, 45-61 (1987).

ATTENTION USERS

USER SUPPORT SCIENTISTS: HIGH B/T AND LANL

This is the second in a series of articles that features the user support scientists of the Magnet Lab. The last issue presented profiles of the 15 scientists in Tallahassee who work closely with users of the DC Field Facility. This issue presents colleagues at the Pulsed Field Facility at LANL and at the High B/T Facility at the University of Florida. Later issues will re-introduce scientists who support users of NMR, MRI/S, ICR, EMR, and Geochemistry facilities.

Supporting Users of the High B/T Facility

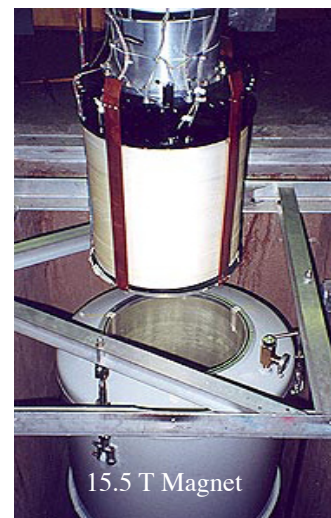
Jian-Sheng Xia received his Ph.D. in physics from the University of Science and Technology of China in 1989. The designer and builder of the nuclear demagnetization cryostat in use with the High B/T Facility, Xia has been the facility's key scientist since its inception. His creations include a novel PrNi₅ coolant stage combined with copper, a Pt NMR thermometer, a ^3He melting curve thermometer, and a tin heat switch. The most recent addition to this list is a sample chamber that employs liquid ^3He for thermal contact between the coolant and the sample, equipped with a built-in sample rotator that is actuated with a separate volume of ^3He . Some samples, such as two-dimensional electrons of heterojunctions, cannot be cooled even to 40 mK by simply immersing them in the mixing chamber of a dilution refrigerator or by gluing them to a cold finger metallically connected to a coolant. The special design of Xia's sample chamber allows the temperature of such difficult-to-cool samples to reach a few millikelvin.



JIAN-SHENG XIA

Xia's research interests range from low-dimensional electrons to quantum fluids and solids, heavy fermion systems, and quantum magnetism. Because an experiment at temperatures below 10 mK requires continuous operation of the cryostat for several months and relies on the in-house expertise in refrigeration and small-signal processing, all experiments at the High B/T are conducted as collaborations between the users and Xia. He has been involved in transport measurements of two-dimensional electrons and holes, NMR, viscosity measurements using a vibrating-wire technique, ac magnetometry, pressure measurements using Straty-Adams strain gauges, and superfluid-density measurements using a torsion pendulum.

jsxia@phys.ufl.edu



15.5 T Magnet

Supporting Users of the Pulsed Field Facility

The Pulsed Field Facility scientific support staff have a slightly different role with respect to helping users conduct their experiments than their colleagues in Tallahassee. The experimental techniques used in pulsed magnetic field experiments vary significantly from those used in DC magnets. Pulsed field systems are not nearly as common as DC magnet systems hence many of our NHMFL-PFF users have little to no experience performing experiments in pulsed magnetic fields. This lack of experience in pulsed field systems could result in less than satisfactory results were it not for the world-class support staff. The staff members highlighted in this article are absolutely the best in their game and when users make the journey to the high desert of New Mexico, they can rest assured that their support is at the cutting edge of pulsed magnetic field technique, experience, and scientific credibility. Although our magnetic fields are among the highest in the world, our focus is on the science and high quality data that are achievable only with high quality scientists. Listed below are their interests and contact information.



CHUCK MIELKE

Head of NHMFL/Los Alamos Users Program

Fedor Balakirev graduated from the Moscow Institute of Physics and Technology in 1991 and received his Ph.D. in physics from Rutgers University in 1997. He conducted his postdoctoral research at Bell Labs and at the NHMFL-LANL. His research interests involve studies of unconventional superconductors, as well as other strongly correlated systems. In recent years, his experimental work has focused on studies of the high temperature superconductors in pulsed magnetic fields.



FEDOR BALAKIREV

magnetometers in collaboration with Prof. Ho Bun Chan of the University of Florida and Luis Balicas at NHMFL-FSU, which should substantially enhance the laboratory's capabilities for sensitive magnetization measurements in DC and pulsed fields.

fedor@lanl.gov

Balakirev is an expert in electronics and data acquisition techniques in pulsed magnetic fields. He has designed a number of key data acquisition solutions and sensitive measurement techniques currently in use at the Pulsed Field Facility. He is involved in development of unique signal recovery techniques, such as the Magnet Lab "digital lock-in," aimed to bring the signal-to-noise performance close to information theory limits. Balakirev is also working to develop silicon-based micromechanical

Jon Betts received his education in electrical engineering from Oxford CFE UK. Before joining the Magnet Lab at LANL, Betts worked for Oxford Instruments both in the United Kingdom and the United States for 20 years specializing in ultra

low temperature systems. Betts has developed systems for measuring resonant ultra sound in magnetic fields up to 20 T and temperatures from 300 mK to 700 K, and he has also developed a calorimetry for measuring the heat capacity of biological samples. Betts has also been involved in the development of low noise calorimetry for use in the 45 T



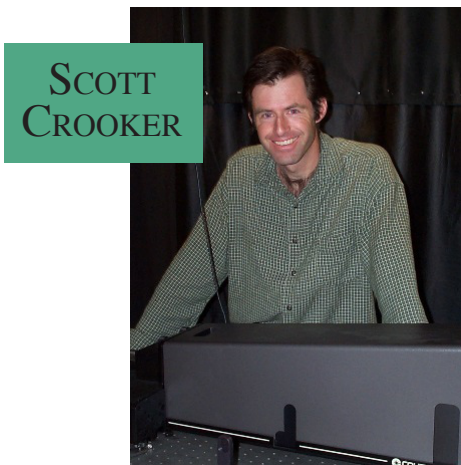
**JON
BETTS**

Hybrid magnet, operated at the Magnet Lab in Tallahassee. His current research interests include the elastic properties of plutonium, linear magnetoresistance at high magnetic fields, and heat capacity of DNA.

jbbetts@lanl.gov

Scott Crooker received a Ph.D. in physics from the University of California at Santa Barbara in 1997, following a bachelor's degree at Cornell University. He joined the Magnet Lab at LANL in 1998 as a postdoctoral fellow and has continued working there as a full-time staff member since 2000.

His current research projects include 2-D magneto-optical imaging of optically- and electrically-injected spin currents in semiconductors for "spintronic" applications, and separately, using methods for ultrasensitive magneto-optical Faraday



**SCOTT
CROOKER**

rotation to passively "listen" to the intrinsic, stochastic magnetization fluctuations that exist in an equilibrium spins system (spin noise spectroscopy).

In the high magnetic fields available at the NHMFL-LANL, Crooker is involved in a number of experiments and the development of new capabilities, including: (1) the study of spin-polarized excitons in CdSe nanocrystal quantum dots using spin-polarized resonant Raman spectroscopy; (2) charged excitons in II-VI magnetic and nonmagnetic 2D electron gases; (3) Aharonov-Bohm phases in carbon nanotubes using ultrahigh magnetic fields to 75 T, as probed by polarized magneto-optical absorption spectroscopy (with Jun Kono at Rice University); and (4) ultrafast terahertz spectroscopy of correlated-electron systems using miniature fiber-coupled photoconductive THz emitters and detectors that work directly in the cryogenic bore of a high-field magnet.

crooker@lanl.gov or <http://public.lanl.gov/crooker/>

Neil Harrison earned his Ph.D. from Bristol University in England in 1993, where he was attempting to observe quantum oscillations in the magnetization of high temperature superconductors. Harrison subsequently went to Leuven where he worked with Fritz Herlach before coming to Los Alamos. Harrison currently provides technical support for users who measure magnetization or quantum oscillations in the magnetization in magnetic fields up to and above 45 T. He recently won the Los Alamos Fellows Prize for research in high magnetic fields.

nharrison@lanl.gov



**NEIL
HARRISON**



MARCELO JAIME

Marcelo Jaime earned his Ph.D. in physics from the Universidad de Cuyo and Instituto Balseiro in Bariloche, Argentina, in 1994. His background is in the use of tungsten carbide anvil pressure cells for experiments of electrical and thermal transport in condensed matter. He moved to the United States in 1995 to work with Myron Salamon as a postdoctoral research associate at the University of Illinois at Urbana-Champaign. As a postdoc, Jaime focused on the physics of manganites, and he found early evidence for small polaron transport in the colossal magnetoresistance manganites using electrical resistivity, thermoelectric power, and Hall effect results combined. After moving to Los Alamos in 1997 to work with Roman Movshovich of LANL, Jaime built a calorimeter for use in the NHMFL 60 T Long Pulse magnet at LANL and the 45 T Hybrid magnet in Tallahassee. Movshovich and Jaime received the Los Alamos Teamwork Award for this development.

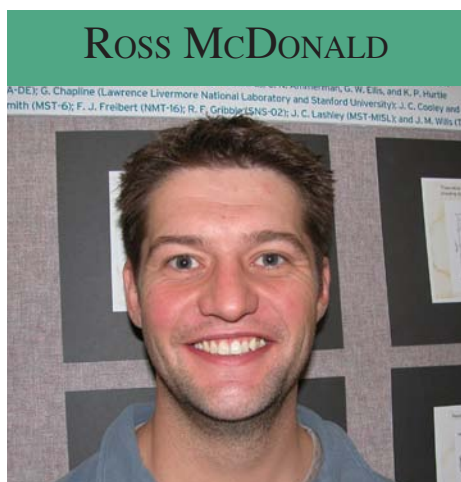
In 2000 Jaime joined the NHMFL Pulsed Field Facility at Los Alamos as a technical staff member. His current areas of interest include the search for exotic phases and quantum criticality in strongly correlated electron systems and quantum magnets when external parameters, such as doping and high magnetic fields, are used to tilt the balance between competing ground states. The techniques developed by Jaime and close collaborators for the Magnet Lab users program include specific heat, Hall effect, Seebeck effect, magnetoresistance and most recently thermal conductivity, which

are usually combined with magnetization and dHvA oscillations to attack challenging problems in condensed matter physics.

mjaime@lanl.gov

Ross D. McDonald received his Ph.D. in condensed matter physics from the University of Oxford and joined the Magnet Lab as a postdoc at Los Alamos in 2001. During his postdoctoral appointment and subsequent staff position, he has developed new instrumentation for conducting GHz-frequency, complex-conductivity experiments in millisecond-duration, pulsed magnetic fields. His current interests involve extending the application of rf and GHz technique to higher intensity and shorter duration magnetic fields, for example, the 300 T, microsecond duration, single turn magnet system. The goal of this effort is to measure a wide variety of correlated electron systems including elemental plutonium and other actinide based *f*-electron materials in extreme B/T environments. His expertise includes a variety of experimental techniques and measurements, such as GHz frequency conductivity of organic molecular metals, EPR measurements of quantum magnet systems; angle dependent torque magnetization used to map the fermiology of shape-memory alloys, the upper critical field of unconventional superconductors, non-linear electrodynamics of systems ranging from charge density wave systems to semiconductor heterostructures, and the development of charge density wave field effect transistor devices.

rmcd@lanl.gov



ROSS McDONALD

A*DE); G. Chapline (Lawrence Livermore National Laboratory and Stanford University); J. C. Cooley and Smith (MST-6); F. J. Freibert (NMT-16); R. F. Gribova (SNS-02); J. C. Lathrey (MST-MISL); and J. M. Wils (T-

Albert Migliori received his bachelor's and master's degrees in physics from Carnegie Mellon University (1968 and 1970) and continued his studies at the University of Illinois, where he earned his Ph.D. in 1973 for his work on the proximity effect in weak coupling superconductors. Later that year, Migliori joined Los Alamos National Laboratory as a Director's Postdoctoral Fellow. He won a DOE energy-related postdoc in 1975, and in 1976 he became a staff member at LANL. Migliori is co-discoverer of acoustic heat engines and is the leading expert in the use of resonant ultrasound spectroscopy as a solid-state physics tool. These accomplishments earned him R&D100 awards in 1991 and 1994, a Federal Laboratory Consortium Award for Excellence in Technology Transfer in 1993, and a Los Alamos National Laboratory Distinguished Performance Award in 1994. He is a fellow of the American Physical Society, and of the Los Alamos National Laboratory, and holds 22 patents. Migliori is the author of over 150 publications, five book chapters, and one book. Recent interests include elasticity of plutonium, microstructure in metals, and research and instrument development in high magnetic fields.

migliori@lanl.gov

ALBERT MIGLIORI



DWIGHT RICKEL



Dwight Rickel received his Ph.D. in physics from the University of Arizona in 1973. This was followed by a postdoctoral fellowship appointment at Duke University. After leaving Duke, he started a career in applied physics, spending five years in industry working in environmental sciences and non-proliferation.

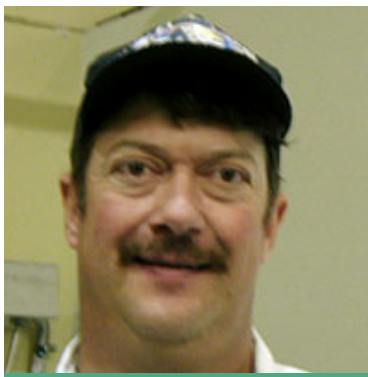
In 1980, Rickel joined Los Alamos National Laboratory—continuing his work in non-proliferation. He joined the Los Alamos explosives pulsed power research group in 1985 and conducted work in high-energy microwave devices, high-current sources, and high-magnetic-field generation.

With the National Science Foundation award of the National High Magnetic Field Laboratory, Rickel assumed the project leadership of the pulsed magnet installation at

Los Alamos. In the years following, he built the laboratory into an internationally recognized leader in pulsed magnetic field research. He also served as the Deputy Center Leader for the organization for four years. In the past few years he has been involved in nanotechnology; engaged in studies of spin noise in atomic gases and two dimensional semiconductors, and pulsed ultrasound; and the project leadership for the construction of the 60 and 100 T large magnets.

Rickel has received two Laboratory Distinguished Performance awards, authored and co-authored over 200 articles in a variety of scientific areas, and is a past chairman of the American Physical Society topical group, *Instrument and Measurement Sciences*.

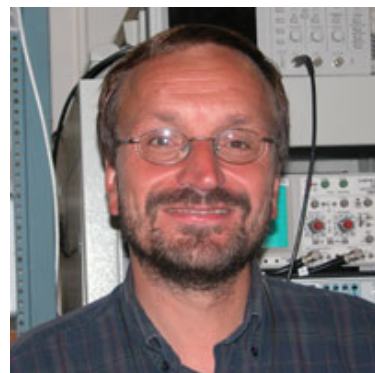
drickel@lanl.gov



PAT RUMINER

Pat Ruminer has over 20 years experience as a technician at Los Alamos National Laboratory. He supports users with cryogenics, instrumentation, and general experimental setup. Ruminer is the primary interface for users of the pulsed magnetic field facility. It is important that scheduled users contact Pat prior to their visit to coordinate liquid helium and any other special experimental need.

pruminer@lanl.gov



JOHN SINGLETON

John Singleton's interests include actinides, alloys, magnetic-field-induced phase transitions, unusual superconductivity, organic metals, and relativistic electrodynamics. He works with magnetotransport (2-axis rotators are a specialty); magnetization (pulsed-field and cantilever); magneto-optical techniques (cyclotron resonance, EPR); heat capacity and high-frequency conductivity to characterize some of these phenomena. He was elected as a Fellow of American Physical Society in 2004 and a LANL Fellow in 2005. He also has over 360 publications (citation count greater than 4,500), many of which concern GHz and THz spectroscopy and the use of very high magnetic fields, including pulsed and single-turn-coil systems. In addition, Singleton has written an undergraduate text on electronic bandstructure.

jsingle@lanl.gov

Vivien Zapf received her Ph.D. from the University of California in San Diego with Brian Maple working on heavy fermion systems. She is interested in the interplay between magnetism and superconductivity, and their role in driving unconventional behavior such as non-Fermi liquids and quantum criticality. She went on to become a Millikan postdoc at Caltech working on high temperature superconductivity, and then became a director-funded postdoc at LANL.

Zapf is now a permanent staff member of the Magnet Lab at LANL. Since joining the NHMFL, she has been drawn into the field of quantum magnets and the phenomenon of Bose-Einstein condensation of magnons. She has developed a calorimeter for the 20 T magnet and dilution refrigerator at LANL and performs specific heat, magnetic, and transport measurements at millikelvin temperatures. She has also worked with magnetic and TDO measurements in pulsed fields. She plans to continue developing low temperature measurement techniques including force magnetometry for the 20 T dilution refrigerator.

vzapf@lanl.gov



VIVIEN ZAPF

BIG PULSED MAGNETS NEARING COMPLETION



Pulsed magnet engineers and technicians are poised to deliver the 60 T Controlled Waveform magnet this summer—and the long-anticipated 100 T Multi-Shot is not far behind.

By the time this issue of *NHMFL Reports* hits the street, it's probable that the 60 T has already been pulsed, and if everything goes as expected, it should be available to users this summer. The 60 T will allow for a customized magnetic field waveform that can be designed to suit the experiment.

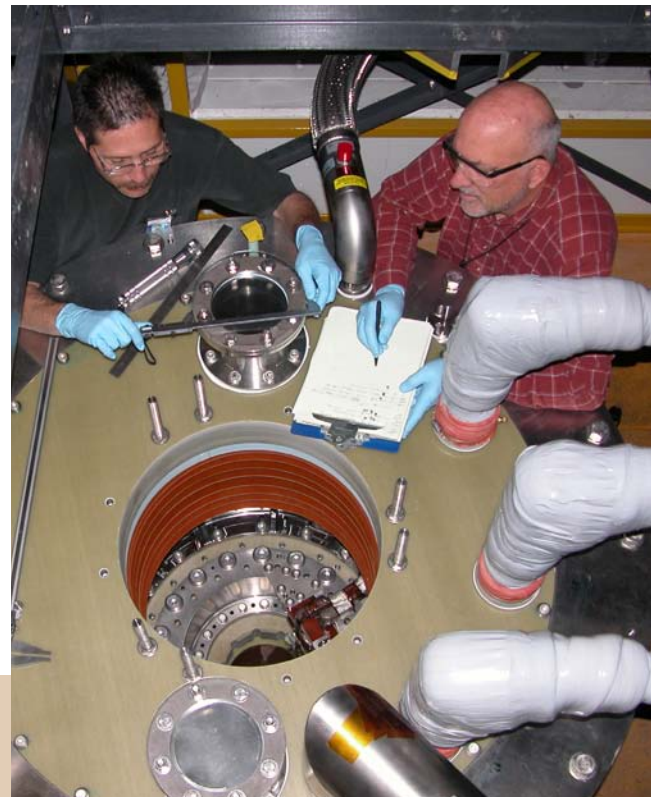
“What the engineers and technicians learned during design and assembly of the 60 T helped pave the way for the eventual completion of the 100 T,” said Chuck Mielke, head of the Pulsed Field Facility users program. “The 100 T will take us places science has never been before; and thanks to established techniques we’ve built up over the years, we expect to hit the ground running after it’s commissioned.”

The nondestructive 100 T magnet is a joint project between the National Science Foundation (through the Magnet Lab) and the U.S. Department of Energy. Ultimately, it will produce 100 T pulses for periods of milliseconds, which is approximately two thousand times longer than what is presently available at this field level.

The 100 T project continues to mark important assembly milestones. Engineers have now operated magnets at mechanical and thermal conditions comparable to 100 T operations, and in April, the nine-ton outsert magnet was successfully nestled into its cryostat. The insert is in the final stages of development in Tallahassee and is expected to be delivered to Los Alamos this summer.

The commissioning of the 100 T Multi-Shot will come in stages. Later this year, users should look forward to their first access to milliseconds above 80 teslas, and then higher as engineers get a sense for how the magnet and its component materials will function in this new and extreme regime.

Check www.magnet.fsu.edu for updates and additional information about the pulsed magnet projects and their specs.



Mike Pacheco and Dwight Rickel of the Pulsed Field Facility make final safety checks on the 100 T “burst disk.”



NEWS from the DC Field Facility

Bruce Brandt, Director

Graphene, a two-dimensional sheet of rings of carbon atoms, has become a very hot topic in recent months. Work on graphene has been published in the usual general interest and specialty journals, but is also discussed excitedly in conference halls and the news pages of *Physics Today*, *Nature*, *Science*, *APS News*, and on the Web. The Magnet Lab's involvement in graphene research began when Professor Philip Kim of Columbia University requested magnet time to look for quantum transport effects in May, 2005. His subsequent work, in collaboration with Columbia University colleagues Yuanbo Zhang and Yan-Wen Tan (graduate students), Zhigang Jiang (postdoc), and Horst Störmer (professor), is described in the following article.

Quantum Hall Effect in Graphene at High Magnetic Fields

P. Kim, Y. Zhang, Y.-W. Tan, H. Störmer,
Columbia University
Z. Jiang, NHMFL/Columbia University

Graphene is a single atomic sheet of graphitic carbon atoms that are arranged into a honeycomb lattice. It can be viewed as a giant two-dimensional (2D) fullerene molecule, an unrolled single wall carbon nanotube, or simply a single layer of lamellar graphite crystal. There are two carbon atoms in one unit cell where each carbon atom sits on two interpenetrated triangular lattices with inversion symmetry between them. This unique topology of hexagonal arrangement of carbon atom creates an unusual energy dispersion relation at the Fermi energy in graphene. Figure 1 displays the energy band structure of graphene obtained from a simple tight binding model calculation. There are two bands: the valence band ($E < 0$) and the conduction band ($E > 0$) touching at six points at the Brillouin zone corners of which only two sets of points are inequivalent. These two points in reciprocal lattice (K and K') represent different linear superposition of Bloch wave functions in the two real space sublattices mentioned above. The energy dispersion near these points is particularly interesting, since the 2D energy spectrum is linear, and thus the electrons always move at a constant speed v_F . Such a dispersion relation has an analogy to a

relativistic massless particle, e.g. photons and massless neutrinos. Therefore the electron dynamics in graphene are effectively "relativistic," where the speed of light is substituted by the Fermi velocity v_F . This distinct energy dispersion with an unusual Fermi surface topology creates a non-trivial Berry's phase, the effective chirality of the Bloch wave function in two sublattices. In fact, this chiral nature of carriers in graphene has been speculated to have an important implication in the electronic transport in graphitic materials including single walled carbon nanotubes.¹

In the past two years, graphene has attracted a sudden burst of attention ever since an efficient experimental method of extracting single atomic layers of graphite via mechanical extractions was developed.² At Columbia, and independently at the University of Manchester, we have investigated electron transport in graphene,

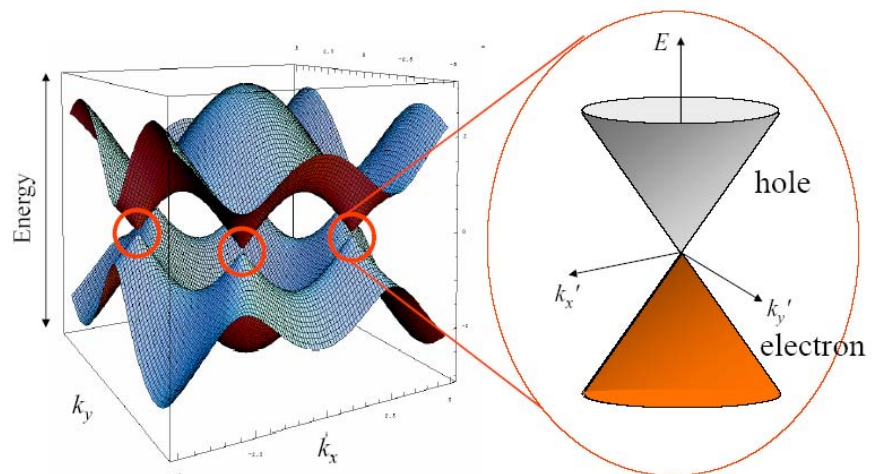


Figure 1. Energy band structure of graphene. The valence band (lower band) and conduction band (upper band) touch at the Brillouin zone corners where the Fermi level is located. In the vicinity of these points, the energy dispersion relation is linear.

The recent discovery of an experimental method to separate out a single layer of atomically thin graphite layers ignited an intense experimental and theoretical research focus on graphene. An unusual half-integer shifted integer quantum Hall effect and a non-trivial Berry's phase have been experimentally observed owing to the effectively relativistic nature of the carrier dynamics in this novel 2-dimensional system. At the NHMFL, researchers from Columbia University investigate transport properties in graphene in the extreme quantum limit, pursuing strongly correlated Dirac fermions in this novel system.

and discovered a variety of new phenomena that stem from the “relativistic” nature of the electron dynamics in graphene.^{3,4} In particular, we have experimentally discovered an unusual quantum Hall effect in high quality graphene samples. Different from conventional 2D systems, the observed quantization condition in graphene is described by half integer rather than integer values. The half-integer shifted integer QHE, as well as the measured phase shift in magneto-oscillation, can be attributed to the peculiar topology of the graphene band structure with a linear dispersion relation and vanishing mass near the Dirac point, which is described in terms of (2+1)-dimensional quantum electrodynamics analogy with non-zero Berry's phase. This system may also provide the basis for novel carbon-based electric and magnetic field effect device applications, such as ballistic metallic/ semiconducting graphene ribbon devices and electric field tunable spin transport devices utilizing spin-polarized edge state.

Continuing our initial efforts at Columbia, the accessibility of high magnetic fields up to 45 Tesla at NHMFL now allows us to study the magneto-transport in graphene in the extreme quantum limit.⁵ Under such condition, we discovered a new set of quantum Hall (QH) states at filling factors $\nu = 0; \pm 1; \pm 4$, indicating the lifting of the four-fold degeneracy of the previously observed QH states at $\nu = \pm 4(|n| + 1/2)$, where n is the Landau level (LL) index (Figure 2). In particular, the presence of the $\nu = 0; \pm 1$ QH states indicates that the LL at the charge neutral Dirac point splits into four sub-levels, lifting both sublattice and spin degeneracy and potentially indicating a many-body correlation in this LL. The QH effect at $\nu = \pm 4$ is investigated in tilted magnetic field and is attributed to the lifting of the spin-degeneracy of the $n = \pm 1$ LL. We also map

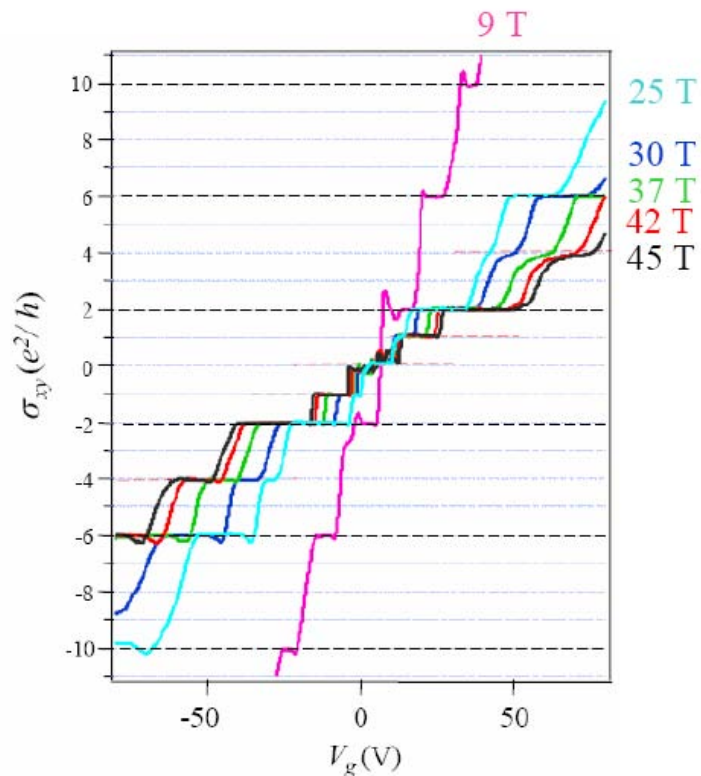


Figure 2. Quantized Hall conductivity measured in graphene at various magnetic fields as a function of gate voltage (V_g) that modulates the carrier density. While integer Hall plateaus, shifted by a half-integer, are observed at lower fields (< 10 T), new quantum Hall plateaus appear at higher magnetic fields.

out the sequence of the Landau level splitting when the magnetic field increases. The $\nu = 0$ state appears at a rather low field ($B \sim 11$ T). Then appear the $\nu = \pm 1$ and $\nu = \pm 4$ states at about the same field ($B \sim 17$ T). The fact that $\nu = \pm 1$ and $\nu = \pm 4$ start to develop at the same field suggests that they may have the same origin. Since $\nu = \pm 4$ has been found to originate from spin-splitting, the $\nu = \pm 1$ features are very likely due to spin-splitting, too. Therefore, this experiment strongly suggested the existence of interesting many-body correlated states in graphene near the Dirac points, which makes us confident that we can observe the fractional quantum Hall effect in the presence of a non-trivial Berry's phase. We now focus our efforts to increase the mobility of graphene samples in order to experimentally access this strong quantum regime directly.

¹ McEuen, P.L., *et al.*, *Phys. Rev. Lett.* **83**, 5098 (1999).

² Novoselov, K.S., *et al.*, *Science* **306**, 666-669 (2004).

³ Zhang, Y.; Tan, Y.-W.; Störmer, H.L. and Kim, P., *Nature*, **438**, 201 (2005).

⁴ Novoselov, K.S., *et al.*, *Nature*, **438**, 197 (2005).

⁵ Zhang, Y., *et al.*, *Phys. Rev. Lett.*, **96**, 136806 (2006).



NEWS from AMRIS

Art Edison, Director

This research highlight from AMRIS (the Advanced Magnetic Resonance Imaging and Spectroscopy Facility) demonstrates the unique capabilities that *in vivo* NMR and MRI can provide. Prof. Constantinidis and his research team are developing an artificial pancreas that one day might be useful to implant into humans to treat type-I diabetes. The beauty of their approach is in the combination of tissue engineering, cell biology, biochemistry, physiology, and imaging technologies. As with most magnetic resonance studies, signal-to-noise is a limiting factor in this work. To address this, the Constantinidis group has developed an inductively coupled implanted coil for measurements on the AMRIS 11.1 T/40 cm system that is capable of increasing S/N by up to 17x over conventional technology. This is a great example of the importance of high fields in biomedical sciences. Very recently, the Constantinidis group scored in the top 0.5% for an RO1 grant at the NIH to continue this work. Clearly, this research has the possibility of making a major impact in human health.

A Study of Model β -Cells in Diabetes Treatment

I. Constantinidis, N. Simpson, T. Mareci, University of Florida
A. Sambanis, Georgia Institute of Technology

It is estimated that 6.3% of the U.S. population (18.2 million people) has diabetes.¹ Currently, the standard treatment for Type-1 diabetes consists of insulin delivery either through multiple daily injections or an insulin pump supplemented by injections. Although these treatment strategies have afforded patients a near normal life, they require constant vigilance. Pancreas or islets transplantations have shown considerable promise,^{2,3} however, the continuous administration of immunosuppressive medication and the shortage of donor tissue limit their broad utility. Therefore, there is still a great need for an efficacious treatment that provides physiologic blood glucose regulation without the need for immunosuppressive medication. A treatment that can fulfill these requirements is the tissue-engineered pancreatic substitute.^{4,5} Tissue engineering combines the principles of engineering and the life sciences towards the development of substitutes that can restore, maintain, or improve tissue function.⁶ Pancreatic substitutes often consist of cells encapsulated in hydrogels, such as agarose, or alginate. The main criterion in assessing the therapeutic

efficacy of any tissue engineered construct is the successful restoration of the host's physiology. Direct, non-invasive, monitoring of a construct subsequent to its implantation is of great importance in managing the welfare of the recipient. Nuclear magnetic resonance (NMR) is uniquely suited for this task because it can provide information about both the structural integrity of the construct and the intracellular metabolism of its cells.

The overall objective of our research is to generate a clinically-relevant bioartificial pancreas and develop the noninvasive methodology to monitor it *in vivo* in an effort to predict its failure ahead of the end-point effect. Our current model consists of murine insulinoma cells or islets encapsulated in alginate/poly-L-lysine/alginate microbeads and contained in an agarose disc.

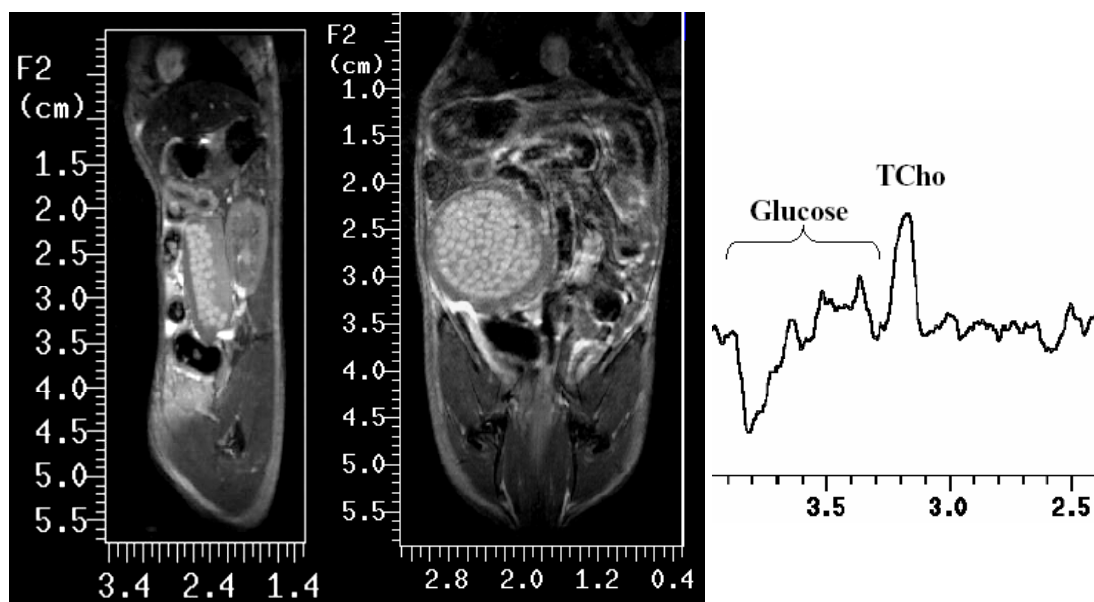


Figure 1. T₂ weighted images of a mouse showing the location of a construct.

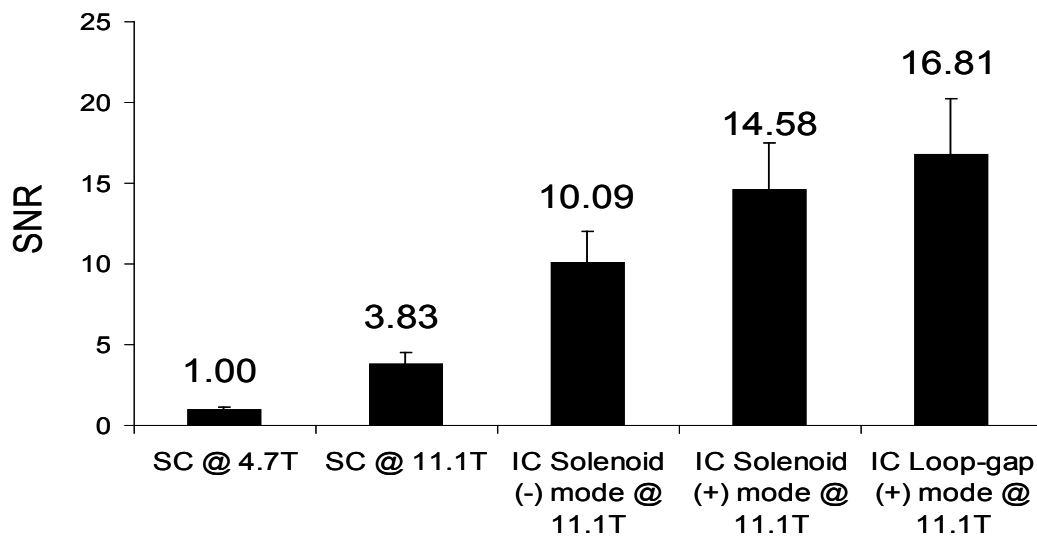


Figure 2. SNR measurements in water at 4.7 and 11.1 T. SC: surface coil; IC: inductively coupled coil; (+) co-rotating mode and (-) counter-rotating mode. Two inductively coupled coil designs were tested: a two-turn solenoid and a loop-gap.

In experiments performed thus far, we have demonstrated that acquisition of ^1H NMR images and localized spectra from within an implanted construct can provide information about the viability of the construct. Figure 1 shows two T_2 weighted NMR images of a C57BL/6J mouse abdomen with the location and make-up of the implanted construct. The square drawn on the construct identifies a volume of $192\ \mu\text{l}$ ($8 \times 8 \times 3\ \text{mm}^3$) from within which we acquired the ^1H NMR spectrum shown on the right. The TCho resonance at 3.2 ppm corresponds to trimethylamine protons of choline related metabolites: glycerolphosphorylcholine, phosphorylcholine and choline. These data were obtained at 4.7 T and the spectrum was acquired within 13 min. The dots and connecting dashed line outside the animal on the sagittal image represent the location and size of the surface coil used to acquire the spectrum. The data show a strong correlation ($R^2=0.87$) between the TCho resonance area and the number of viable cells within the construct,^{7,8} however, the lowest number of viable cells that can yield a quantifiable TCho resonance is 1×10^6 cells/ml. This limit was determined under ideal *in vitro* conditions, and it is expected to be higher *in vivo*.

To improve the sensitivity of our NMR measurements, and thus be able to acquire spectra from smaller number of cells, we transferred our experiments to a stronger magnetic field (11.1 T) and developed an inductively coupled RF probe that can be incorporated within the construct. Specifically, inductively coupled probes consist of two coils working together as a single unit; one coil is implanted as part of the construct while the other is extracorporeal and receives signal from the implanted coil. The implanted coil can match the geometry of the construct thus improving spatial localization and SNR. To quantify the improvement afforded by these changes, we performed a SNR analysis of a water phantom at 4.7 T and 11.1 T. SNR was determined by subtracting the noise average from the signal average and dividing by the noise standard deviation as it was described by Henkelman.⁹ Figure 2 is a bar graph illustrating the SNR improvement for the proposed changes normalized to the SNR obtained with a surface coil at 4.7 T. Our data show that by switching to an 11.1 T instrument and using inductively coupled

coils we can improve our NMR sensitivity by approximately 17x. Although under *in vivo* conditions the maximum improvement in SNR is predicted to be lower due to dielectric losses despite the insulation of all implanted probe components, we anticipate that the improvement in SNR will enable us to lower the cell density within our construct as well as permit the acquisition of NMR spectra from other biologically relevant nuclei, such as ^{31}P .

Overall, our research will add valuable new insight into the metabolic activity of encapsulated cell implants. Furthermore, the development of a non-invasive methodology to monitor pancreatic constructs *in vivo* can lead to the identification of biological markers that can predict their failure ahead of their end physiologic effect (i.e. reinstatement of hyperglycemia).

Acknowledgements: The authors would like to acknowledge Dr. Cheryl Stabler, Dr. Robert Long, Jr., and Nelly Volland for their assistance. This work was supported by grants from the NIH (DK56890, DK47858). All NMR data acquired at 11 T were obtained at the AMRIS facility.

- Services, U.S.D.o.H.a.H., Diabetes statistics, in NIH Publication No. 04-3892. 2004, NIDDK: Washington, D.C.
- Shapiro, A.M.; Lakey, J.R.T.; Ryan, E.; Korbitt, G.; Toth, E.; Warnock, G.L.; Kneteman, N.M. and Rajotte, R.V., *New England Journal of Medicine*, **343**, 230-238 (2000).
- Ryan, E.A.; Lakey, J.R.T.; Paty, B.W.; Imes, S.; Korbitt, G.S.; Kneteman, N.M.; Bigam, D.; Rajotte, R.V. and Shapiro, A.M.J., *Diabetes*, **51**, 2148-2157 (2002).
- Lim, F. and Sun, A.M., *Science*, **210**, 908-910 (1980).
- Sun, A.M.; Parisius, W.; Macmorine, H.; Sefton, M.V., and Stone, R., *Artif. Organs*, **4**, 275-278 (1980).
- Nerem, R.M. and Sambanis, A., *Tissue Engin.*, **1**, 3-13 (1995).
- Stabler, C.L.; Long, R.C. Jr.; Constantinidis, I. and Sambanis, A., *Tissue Engin.*, **11**, 404-414 (2005).
- Stabler, C.L.; Long, R.C., Jr.; Constantinidis, I. and Sambanis, A., *Cell Transplantation*, **14**, 139-149 (2005).
- Henkelman, R.M., *Medical Physics*, **12**, 232-233 (1985).

EDUCATION and OUTREACH Thrive at the Magnet Lab

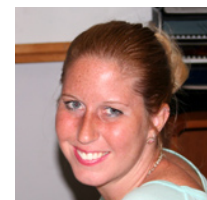
Pat Dixon, Director of the NHMFL Center for Integrating Research and Learning (CIRL)

As the Center for Integrating Research and Learning gears up for an exciting summer working with K12 students, undergraduates, and teachers, we welcome several new members of the Center's team. This is the first summer for the new assistant director and for our program assistant. This is a good time to introduce the people who make sure that educational programs at the Magnet Lab continually grow in depth and breadth.

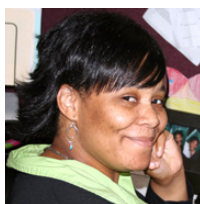
Jose Sanchez assumed the duties and responsibilities of assistant director of CIRL in September 2005. A Research Experiences for Teachers (RET) alumnus (1999, 2005), Jose brings a unique perspective to the position. He received his B.S. in physics education and an M.S. in science education at Florida State University. Jose taught physics and mathematics in Dade County, Florida, for six years before coming to the laboratory. He has rejuvenated the Research Experiences for Undergraduates (REU) program by close attention to detail, recruiting new mentors, and actively recruiting REU students. Jose has also identified research projects for teachers in the RET program by working closely with mentor scientists at the lab soon after coming here. On top of these duties, Jose is liaison for the Girls in Science Camp and will assist in facilitating a four-day summer physics institute for teachers.



University of North Texas, a Master's degree in interdisciplinary studies with a focus on math and business administration from University of Texas, and is currently working toward a Ph.D. in educational psychology: learning and cognition at Florida State University. Her experience as a classroom teacher as well as her experience as a researcher places Crissie in a unique position to study teacher practice and impact of professional development programs.



Vanessa Shaw joined the lab in October 2005 as program assistant for both the Center and for NHMFL Office of Public Affairs. Vanessa has an associate in science and early childhood development and education degree from Tallahassee Community College and is pursuing an associate in arts degree. She is a veteran of FSU programs and brings knowledge of university systems, policies, and procedures to support the Center's diverse programs. This unique combination of administrative talent and knowledge of education is an asset to the Center's programs.



Stephen Kornbluth recently joined the Center as a graduate research assistant to oversee the new outreach on cosmogeology. In partnership with the geochemistry department, Stephen will be taking the *Comet Tales* curriculum on comets and origins of our solar system to elementary, middle, and high school students and teachers. Stephen is using *Comet Tales* and curriculum developed at the lab to demonstrate the comprehensive nature of science. Stephen received a B.S. degree in biological sciences from Florida State University and is currently working on his master's in science education. Stephen's expertise in the geosciences greatly enhances the Center's programs.



Crissie Grove will take over research projects for the Center, focusing on how teachers change their thinking and planning as a result of participating in the Research Experiences for Teachers program. Crissie has a B.S. in interdisciplinary studies from the

Mischa Draime comes to the Center as a student assistant to help with the REU and RET programs. Mischa is an active participant in all facets of Center activities. She received an A.A. degree at Manatee Community College in Bradenton, Florida, after working at Tropicana Products Inc. as a training facilitator focusing on departmental procedures. Mischa is pursuing a B.S. in science education at Florida State University with a focus on middle school education.



Center Gears Up for Summer Programs

Sixteen talented undergraduates are participating in the summer **2006 Research Experiences for Undergraduates** working with 12 NHMFL scientists.



2006 REUs at Magnet Lab-Tallahassee Research Location

Intern	University	Mentor
Craig Bazil	Prairie View A & M, Webster	Kevin Storr, Condensed Matter Physics
Nicholas Brown	Colorado School of Mines	Tom Painter, Magnet Science & Technology
Xiomaris Cotto	University of Puerto Rico-Cayey	Mike Davidson, Optical Microscopy
Cindy Figueroa	University of Puerto Rico	Roy Odom, Geochemistry
Lyña Fredericks	University of the Virgin Islands	Mike Davidson, Optical Microscopy
Danish Haque	University of Houston	Ke Han, Magnet Science & Technology
Tomi Herceg	Princeton University	Irinel Chiorescu, Condensed Matter Physics
Sheila Jones	Pacific Lutheran University	Bill Brey, NMR
Jose Medina	Universidad Del Turabo	Stan Tozer, Condensed Matter Physics
Eden Steven	University of Wisconsin	Jim Brooks, Condensed Matter Physics
Mark Wartenbe	Florida State University	Jim Cao, Condensed Matter Physics
Dereje Worku	NC A&T State University	Stan Tozer, Condensed Matter Physics

2006 REUs at Magnet Lab-LANL Research Location

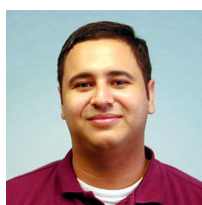
Intern	University	Mentor
Paul Egan	Oklahoma State University	Alex Lacerda, Condensed Matter Physics
Ryan Murphy	Brown University	Chuck Mielke, Condensed Matter Physics
Mack Warren	Colorado State University	Chuck Mielke, Condensed Matter Physics

Fifteen teachers from around the United States are participating in the summer **2006 Research Experiences for Teachers** program working with 8 scientists from the lab.

2006 RETs at Magnet Lab-Tallahassee Research Location

Intern	City/State	Mentor
Jennifer Abrams	Greenville, NC	Alexei Souslov, Condensed Matter Physics
Magen Ballard	Williamsburg, KY	Eric Palm, Condensed Matter Physics
Stephen Clark	Mayo, FL	Alexei Souslov, Condensed Matter Physics
Kelly Dennis	Monticello, FL	Mabry Gaboardi, Geochemistry
Tracy Doyle	Pittsburgh, PA	Bill Brey, NMR
Michelle Ellis	Gastonia, NC	Mabry Gaboardi, Geochemistry
Melvin Figueroa	Fort Lauderdale, FL	Johan van Tol, EMR
Kerry Kittredge	Greenacres, FL	Bob Goddard, Magnet Science & Technology
Tynica Lewis	Greensboro, NC	Mabry Gaboardi, Geochemistry
Ramchand Maharaj	Margate, FL	Bill Brey, NMR
Jeri Martin	Bagdad, FL	Jim Brooks, Condensed Matter Physics
Marcia Martin	Pembroke Pines, FL	Jim Cao, Condensed Matter Physics
Bobby Williams	North Palm Beach, FL	Bob Goddard, Magnet Science & Technology
Amanda Witters	Tallahassee, FL	Mabry Gaboardi, Geochemistry
Marcia Young	Arlington, TX	Johan van Tol, EMR

In addition to the two signature programs, the Center is hosting 25 local teachers for a four-day physics summer institute and six additional teachers who will work with Center educators to develop new programs and curriculum products.



Carlos Villa, outreach coordinator, oversees six high school college bound students in a two-week internship in conjunction with Florida Agricultural and Mechanical University's Regional Institute for Math and Science (RIMS) program. In addition, Carlos is working with secondary educators from Broward County and DeSoto County to develop demonstrations and laboratory activities that represent the research conducted at the lab for middle and high school students and teachers statewide.

The Center is proud to have expanded programs as well as its research agenda and continues to grow in response to national, regional, and local demands for enhanced science education.



For further information about any of these programs, contact Center Director Pat Dixon, pdixon@magnet.fsu.edu, 850 644-4707.

SAFETY AT THE NHMFL



Working Safely in the Lab

-- Prevent accidents by wearing proper attire!

As temperatures approach 100° in Tallahassee, Gainesville, and Los Alamos, people can be seen wearing shorts, tank tops, and open-toe sandals. This attire is perfect for the outdoors and may be acceptable for office areas, but it is not safe in the labs. In fact, open-toe shoes, sandals, and other casual footwear are not allowed in the following areas of the NHMFL:

- Labs or rooms that contain chemicals, cryogenics, or magnets
- Machine shops
- Plant area
- Electrical rooms

In addition, shorts, miniskirts and tank tops are discouraged in laboratories and areas where hazardous conditions exist. The following references discuss the importance of proper—and safety-conscious—attire in the laboratory.

1. Safety in Academic Chemistry Laboratories for Students. American Chemistry Society. 2004

“Clothing worn in the laboratory should offer protection from splashes and spills; it should be easily removable in case of accident and should be at least fire resistant.”

“In the laboratory, wear shoes with uppers made of leather or polymeric leather substitute. Do not go barefoot or wear sandals. Do not wear shoes that have high heels or open toes, uppers made of cloth, woven leather strips or other woven material. Shorts, cutoffs, and miniskirts unnecessarily expose your skin to potential corrosives and are not safe. Constrain long hair and loose clothing. Do not wear jewelry such as rings, bracelets and wristwatches in the laboratory.”

2. Florida State University Chemical Hygiene Plan

“Confine long hair and loose clothing. Wear close-toed shoes and long pants at all times in the laboratory. Do not wear sandals, perforated shoes, or cloth sneakers.”

3. Prudent Practices in the Laboratory - Handling and Disposing of Chemicals. National Research Council. 1995

“Clothing that leaves large areas of skin exposed is inappropriate in laboratories where hazardous chemicals are used. The worker’s personal clothing should be fully covering. Appropriate laboratory

coats should be worn, buttoned, with the sleeves rolled down.”

“Unrestrained long hair and loose clothing such as neckties, baggy pants and coats are inappropriate in a laboratory where hazardous chemicals are in use. Such items can catch fire, be dipped in chemicals and get caught in equipment. Similarly, rings, bracelets, watches or other jewelry that could be damaged, trap chemicals close to the skin, come in contact with electrical sources or get caught in machinery should not be worn. Leather clothing or accessories should not be worn in situations where chemicals could be absorbed in the leather and held close to the skin.”

4. Biological Safety - Principles and Practices. American Society of Microbiology. 2000

“As a minimum, and with consideration of the risks involved, PPE (personal protective equipment) may include street attire protected by a full length, long-sleeved, fully fastened laboratory coat, gown or smock; closed-toed shoes; eye protection; ear protection; molded “surgical type” masks; appropriate gloves (“examination” or “surgical” type depending on the need for sterile projects); and HEPA filtered respirators.”

5. Biosafety Reference Manual. American Industrial Hygiene Association. 2000

“Sneakers, sandals and open-toe or perforated shoe construction are generally not acceptable in a lab or clinical work setting, as required by 29 CFR 1910.1450. Shoes, boots and shoe covers can track dirt and debris into clean zones or generate unwanted dust particles during traffic movement or during donning or doffing activities.”

In summary, any clothing that exposes large areas of skin should not be worn in laboratories and where hazardous conditions exist. Good laboratory safety begins with the appropriate attire. It is one of the best ways to prevent an exposure to hazardous materials in the laboratory. Please call **Angela Sutton in the NHMFL Safety Office in Tallahassee at 850 644-6955** with questions regarding proper attire in the laboratory.



MS&T Director Accepts Leadership Position with U.S. ITER Project Office



John Miller, director of Magnet Science and Technology (MS&T) at the Magnet Lab, is returning to his Tennessee roots.

The Volunteer State native has accepted a position at the Oak Ridge National Laboratory as the magnet system team leader for the U.S. ITER Project Office. ITER,



which stands for International Thermonuclear Experimental Reactor, is a joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power.

During his almost 15 years of service to the Magnet Lab, Miller's contributions have been invaluable in positioning MS&T as an internationally preeminent organization for state-of-the-art magnet systems. Chief among those contributions is the 45 T Hybrid magnet—the first and still only magnet of its kind in the world.



That tradition of innovation will continue under the leadership of **Interim Director Mark Bird**. During the past 14 years, Bird has been instrumental in creating the resistive magnet group and leading the development of high field resistive magnets and "Florida-Bitter" magnet technology. Many of these world record magnets are now the international standard for high field resistive magnets, in place at four laboratories on three continents.

In his new position, Bird will direct the overall activities of MS&T and be the focal point for coordinating MS&T efforts on several immediate opportunities for the design, development, and manufacture of state-of-the-art magnet systems.

"The lab's users certainly have a friend in Mark Bird," said laboratory **Director Greg Boebinger**. "He is always striving for higher and better fields in response to the needs of the users, and

he is an adept project manager whose abilities will now benefit the lab to an even greater extent."

Miller leaves a group that he molded to be flexible.

"One of the greatest tributes to John's tenure as director of MS&T is that he provided opportunities for individual career growth and mentoring," said **Brian Fairhurst, NHMFL associate director for management and administration**. "That helped foster an environment that will provide smooth and seamless transition to new leadership."

Miller was born and raised in Tennessee, and received both his undergraduate and master's degrees in physics from East Tennessee State University. He received his Ph.D. in physics from the University of Virginia. From 1974 to 1983, he was a research scientist at Oak Ridge in the Fusion Energy Division, where he worked on the development of superconducting magnets.

Fusion energy has always been one of Miller's greatest professional interests, and this is not his first experience with ITER. Between 1988 and 1990, he led the magnet design unit during the conceptual design phase of ITER. In his new role, Miller will have responsibility for delivering the ITER Central Solenoid, a 6.4-Giga-Joule, 800-metric-ton magnet at the center of the ITER Tokamak (reactor) that helps drive and control the plasma.

Miller, who will leave at the end of June, said he will greatly miss the people with whom he worked at the Magnet Lab.

"Their spirit and 'can do' attitude have made 15 years fly by," said Miller. "They made the opportunities to create nearly boundless and they will certainly be missed."



Right to left John Miller, Hans Schneider-Muntau, and the late Jack Crow at the first NHMFL cement pour in 1992.

PEOPLE IN THE NEWS



Rafael P. Brüschweiler, associate director for biophysics at the Magnet Lab and a professor of chemistry and biochemistry at Florida State University, has been awarded a share of the prestigious Laukien Prize in NMR Spectroscopy. The award, presented at the Experimental Nuclear Magnetic Resonance Conference, recognizes cutting-edge nuclear magnetic resonance (NMR) research that is expected to lead to new applications of NMR technology. The prize is shared with Thomas Szyperki, Eriks Kupce, and Ray Freeman. Brüschweiler was honored for his development of covariance NMR, which shortens the NMR measurement time for multi-dimensional spectra and facilitates their analysis and interpretation. The method can be applied to both solution and solid-state NMR.

Greg Boebinger, director of the Magnet Lab, praised Brüschweiler. "Rafael's award is another example of the growing visibility and prestige of the Magnet Lab's NMR program," Boebinger said. "His in-house expertise directly strengthens the lab's NMR user program." Much of the applications for covariance NMR were done in collaboration with Fengli Zhang, a scholar/scientist for liquid-state NMR at the laboratory.

The award is named for Günther Laukien, a co-founder of Bruker-BioSpin Corp., one of the world's leading producers of spectrometers. The award carries with it a \$5,000 award funded by the company. The Laukien Prize was presented at the 47th Experimental Nuclear Magnetic Resonance Conference (ENC), which ran April 24 to 28 in Pacific Grove, California. The ENC is the world's largest scientific conference on NMR, attracting more than 1,200 specialists from around the world.

Layla Hormozi, a graduate research assistant in the Condensed Matter Science group, received the Dirac Hellman Award for Theoretical Physics from the FSU Department of Physics for her work in topological quantum computing. Hormozi works with Nick Bonesteel, professor of physics in the Condensed Matter Science group. Previous recipients of this award include Eddy Yusef, who worked with Kun Yang, and Dimitrije Stepanenko, who also worked with Bonesteel.

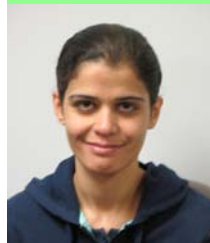
Alan G. Marshall was awarded Florida State University's highest faculty honor at spring commencement ceremonies when he was named the 2006-2007 Robert O. Lawton Distinguished Professor. Marshall is the director of the NHMFL Ion Cyclotron Resonance Program and the university's Kasha Professor of Chemistry and Biochemistry.

"Needless to say, this is a daunting honor," Marshall said. "As I look over the names of previous Lawton professors, I see that some of the most highly regarded scholars in their fields are represented—including Michael Kasha, for whom my own professorship is named. To be considered worthy of inclusion in such an accomplished group is both thrilling and humbling."

Marshall is widely known throughout the world's scientific community as the co-inventor of Fourier transform ICR mass spectrometry, one of the most informative methods available for chemical analysis.



**Rafael
Brüschweiler**



**Layla
Hormozi**



**Alan
Marshall**



**Steven
Van Sciver**

The technique, which allows researchers to simultaneously separate and identify more than 10,000 separate chemical constituents within a single sample, has had a tremendous impact on research in areas as diverse as biomedicine, chemistry, and petroleum analysis.

"Alan's research group is moving into so many exciting directions that they are one of the biggest highlights of the Magnet Lab's research program," said laboratory Director Greg Boebinger. "He is a great ambassador for the critical role that high magnetic fields play in modern research and the world-class chemical research taking place at Florida State University."

During his 13 years at FSU and the lab, Marshall has been accorded 10 national and international awards. He has brought in more than \$17 million in external funding to FSU and the Magnet Lab as a principal investigator, another \$8.5 million as a contributor to grants for other FSU investigators, and is one of the NHMFL's co-principal investigators.

The Robert O. Lawton Distinguished Professor award is the highest honor that FSU faculty can bestow on a colleague. It is named in honor of the late Vice President for Academic Affairs Robert O. Lawton—a longtime and highly esteemed member of the faculty who died in 1980.

Steven Van Sciver, professor of mechanical engineering at the FAMU-FSU College of Engineering and head of the cryogenics research group at the lab, has been awarded a named professorship: John H. Gorrie Professor of Mechanical Engineering. Named professorships recognize and honor outstanding faculty who exemplify standards of excellence in teaching and research. "In addition to his contributions in establishing the Magnet Lab, Steve has been instrumental in the development of the research and educational program in the FAMU-FSU College of Engineering in the area of cryogenics and applied superconductivity," said Chiang Shih, chair of the school's department of mechanical engineering.

The honor was bestowed on Van Sciver by his FSU colleagues, who select recipients from a pool of nominated and highly ranked professors. The appointment consists of a title, selected by the recipient as a tribute to past faculty or administrators, and an annual salary supplement, which professors hold until they retire or resign.

National High Magnetic Field Laboratory

1800 East Paul Dirac Drive
Tallahassee, FL 32310-3706
Tel: 850 644-0311
Fax: 850 644-8350
www.magnet.fsu.edu



Non-Profit
Organization
U.S. Postage
PAID
Tallahassee, FL
Permit No. 55

