WINTER 2007 VOLUME 14 • NO. 1

NATIONAL HIGH MAGNETIC FIELD LABORATORY

MAG LAB REPORTS

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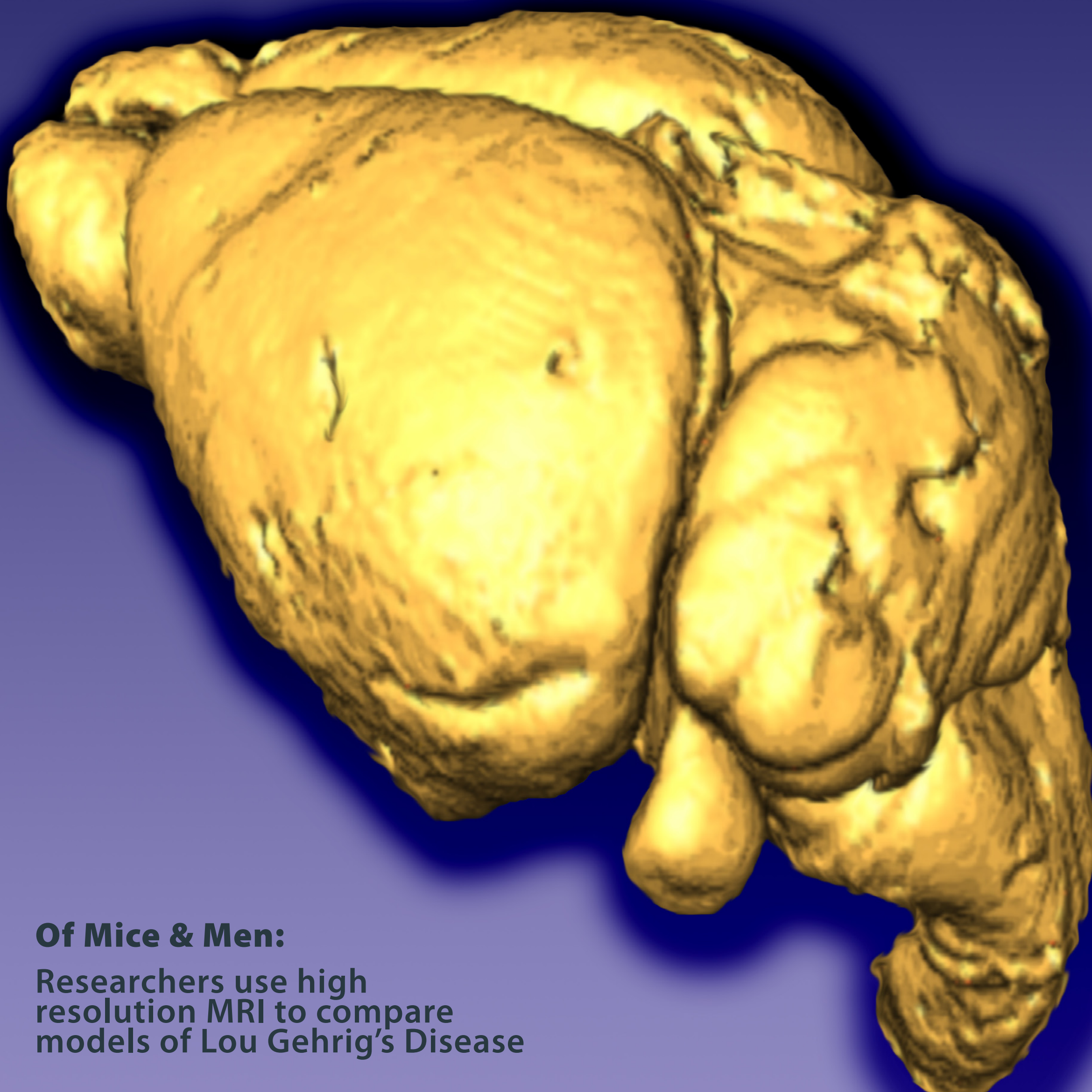

Of Mice & Men:

Researchers use high resolution MRI to compare models of Lou Gehrig's Disease

Page 6

ON THE COVERS:
Mouse brain and spine images like those on the front and back of this issue helped Sam Grant and other researchers to compare models of Lou Gehrig's disease. See page 6 for more.

Published by:
National High Magnetic Field Laboratory
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Tallahassee, Florida 32310-3706

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2007: A Strong Start

GREG BOEBINGER

In September, we submitted our years-in-the-making renewal proposal to the National Science Foundation. But before the champagne could go flat, we had to gear up for the NSF Site Visit … seeking much-appreciated input from the MagLab External Advisory Committee and polishing and practicing talks to a finely tuned, well-honed and inter-connected unified and synergistic message and … you get the point. The NSF Site Visit Committee promptly scrapped the (finely tuned and well-honed) agenda and turned the meeting into a detailed conversation on the science, the vision and the budget requests to realize the vision. It was great.

The hard work appears to have paid off, in the sense that we now enjoy strong support from the MagLab User Committee and External Advisory Committee, our three member institutions (Florida State University, the University of Florida, and Los Alamos National Laboratory) and, based upon their ebullient report, the NSF Site Visit Committee as well.

The MagLab was hailed as "truly a jewel in the crown of U.S. science." Our user programs and scientific staff deserve all the praise. Of course, funding for research is extremely tight. We can only ask to present our case and compete with other national investments in scientific facilities, and we feel we've put forward a great case … a wonderfully interdisciplinary case, too!

We're making good progress on "Big Light," a THz-IR Free Electron Laser project to provide time-resolved pump-probe spectroscopy inside our existing DC magnets. At the recent National Academy of Sciences Workshop on "CMMP 2010," the next decadal vision for condensed matter and materials physics, the MagLab and the "Big Light" project both enjoyed high visibility. But more on "Big Light" in a future issue, and back to the science of today.

A visit to our publications database (*magnet.fsu.edu/usershub/publications/index.aspx*) reveals that already in 2007:

- From AMRIS, the MRI facility at the University of Florida, Yijun Liu, Glenn Walter and colleagues published a paper in the *Proceedings of the National Academy of Sciences* in which they made quantitative studies of skeletal muscle using Phosphorus-31 magnetic resonance spectroscopy, a landmark demonstration that high magnetic fields allow MRI researchers to access nuclei other than hydrogen.
- A publication in the *Journal of Magnetic Resonance* on our 'Low-E' NMR probes demonstrates reduced RF heating during NMR measurements on biological samples. This development is critically important for the increasing use of NMR to solve membrane protein structures (See page 20)
- Bill Halperin, chair of the MagLab's External Advisory Committee, and his colleagues published in *Nature Physics* on work done in the lab's refurbished 30 T NMR magnet.
- Chris Wiebe, assistant professor of physics at Florida State University, and his collaborators also have a *Nature Physics* article. His article further demonstrates the usefulness of neutrons and high magnetic fields as complementary probes in condensed matter physics. (See page 16).
- The first data at 89T has been published in *Applied Physics Letters*, a wonderful demonstration that we have not only built a world-leading magnet, but more-importantly a new scientific tool. (See page 11).

Finally, a word about *Mag Lab Reports*. In addition to the name change (we noticed that *NHMFL Reports* didn't exactly roll off the tongue), we have a new look and a few new features. We will continue to focus on scientific communication, but we'll be opening each issue with "Wavelengths," highlights among recent news items, and closing with "Science starts here," portraits of early career scientists whose paths have been shaped by their experiences at the MagLab.

Rock 'n' Roll,

Greg Boebinger

Wavelengths

Mag Lab partners with Absolute Zero campaign

The Magnet Lab has joined forces with other scientific groups across the country to become a national partner in Absolute Zero, a campaign designed to raise awareness about low temperature physics. The campaign includes educational outreach and a two-part PBS television special that will "demonstrate how civilization has been profoundly affected by the mastery of cold." You can get more information about the campaign at *www.absolutezerocampaign.org.*

The campaign uses an unusual, narrative style to tell the story of the mastery of cold - how scientists came to understand, explore and harness its power for research. The lab joins national partners including the American Physical Society, the Cryogenic Society of America, the Department of Energy, and USA TODAY Education.

The lab's public affairs and education groups will be promoting the TV show and community education outreach guide. Low temperature physicists can become involved by becoming Absolute Zero Experts. The level of participation is up to each individual; experts can do as much or as little as their schedule allows. Information about how to get involved can be found at the Web site.

Lab featured on Florida Crossroads

Without escorting a single extra visitor, Magnet Lab facilities in Tallahassee and Gainesville have allowed thousands of Floridians a glimpse inside their labs this winter as the subject of a new "Florida Crossroads" documentary called "Attracting Science."

"Florida Crossroads" is an award-winning, half-hour documentary series that looks at the people, places and events shaping Florida. Produced by the Florida Channel, it airs on public television affiliates across the state, and is expected to re-air many times over the next few years.

"Attracting Science" examines the pivotal role the Magnet Lab plays in Florida through its cutting edge work, its status as a national facility for visiting researchers, and its efforts to grow the next generation of scientists. Mag Lab staff at both facilities gave the show's producers open access to the people, science, technology and day-to-day workings of the lab.

For more information on the show or to order a copy, visit *http://www.wfsu.org/Florida_Channel/crosroad.htm*.

Ad highlights FSU/UF partnership

Magnet Lab Director Greg Boebinger (pointer) and AMRIS Director Art Edison (pointee) watched the ad's debut at FSU's Doak Campbell Stadium.

Rivals on the field…but on the same team as part of the National High Magnetic Field Laboratory. That was the central message of a 30-second TV spot that was shown on the Doak Campbell Stadium video screen during the University of Florida-Florida State University football game Nov. 25 in Tallahassee.

The spot highlights the two universities' research partnership in the Mag Lab and features the vice presidents for research at each university, Kirby Kemper for FSU and Win Phillips for UF. The idea was the brainchild of Art Edison, the director of lab's Advanced Magnetic Resonance Imaging and Spectroscopy facility at UF, and plans are underway to edit the spot so it can be shown whenever the two teams meet. You can watch for yourself at: *http://vh1.acns.fsu.edu/univcomm/wmv/mag_lab.wmv*

Alumni Village condos readied for user, visitor use

Users and other long-term visitors to the Magnet Lab can now take advantage of the lab's newly renovated and refurbished one-bedroom condos at Alumni Village.

The four units, owned by FSU and leased to the Magnet Lab, have been renovated specifically for the lab's users. They're located around half a mile from the lab itself, an easy walk for most users.

"We think that lodging space close to the Lab will be more attractive to certain users who may have concerns about daily transportation or commuting distances," explained Clyde Rea, assistant director of the lab's Accounting and Business Administration Program.

The 40-year-old units feature totally renovated interiors, including new furniture and appliances. Each unit features the full complement of amenities available in a typical furnished studio apartment, as well as Internet service.

The renovation's total cost came to around $100,000, and the Magnet Lab's lease agreement began at the first of the year. Users and visitors can call Merry Ann Johnson to reserve a room at $45 a night.

Questions about the renovated condos? Contact Rea at rea@magnet.fsu.edu or Merry Ann Johnson at *johnson@magnet.fsu.edu.*

Date set for annual Open House

The Magnet Lab will open its doors to thousands of curiosity seekers and returning guests Feb. 24 when it hosts the annual Open House. For 13 years running, the lab has invited the public – young, old and in between – to spend the day touring the world-class research facility. Look for Open House coverage in the next issue of MagLab Reports.

MR microscopy of the central nervous system of a mutant SOD model of ALS

Petrik MS[1, 2], Wilson JMB[1, 2], Grant SC[3], Blackband SJ[4], Tabata RC[7], Shan X[5], Krieger C[5], and Shaw CA[1, 2, 6, 7]

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INTRODUCTION

Amyotrophic lateral sclerosis (ALS) is a chronic neurodegenerative disorder characterized by progressive degeneration of the motor neurons (Eisen and Krieger, 1998). In humans, researchers have categorized several forms of ALS: nearly 90% of all cases correspond to a sporadic form (Maruyama *et al.*, 1999) for which the cause of the disease is unknown; a familial form (fALS) seen in 5-10% of all ALS cases for which an autosomal dominant transmission appears causative; and a variant seen in the Western Pacific (ALS-parkinsonism-dementia complex (ALS-PDC), Hirano *et al.*, 1966; Kurland, 1988). For approximately 20% of fALS cases, there exists a mutation in the gene coding for the antioxidant enzyme superoxide dismutase (SOD) (Armani *et al*., 1987). Meanwhile, ALS-PDC is associated with the ingestion of a neurotoxin found in the seed of a cycad (Cycas micronesica K.D. Hill). In recent years, animal models of the different forms of ALS have been developed and characterized.

In this study, which was recently accepted for publication in *NeuroMolecular Medicine*, measurements of volumetric changes in the brains and spinal cords of mutant SOD (mSOD) mice were compared with neuronanatomical deficits previously identified in mice fed a diet of cycad flour, which induced ALS-PDC associated symptoms (Wilson *et al*., 2004). In both cases, neurodegeneration was assessed through Magnetic Resonance Microscopy (MRM) at 17.6 T and immunohistology. Dissimilarities between the two models may suggest that the mSOD mutation and cycad neurotoxins may not target identical cell death pathways in these two forms of ALS.

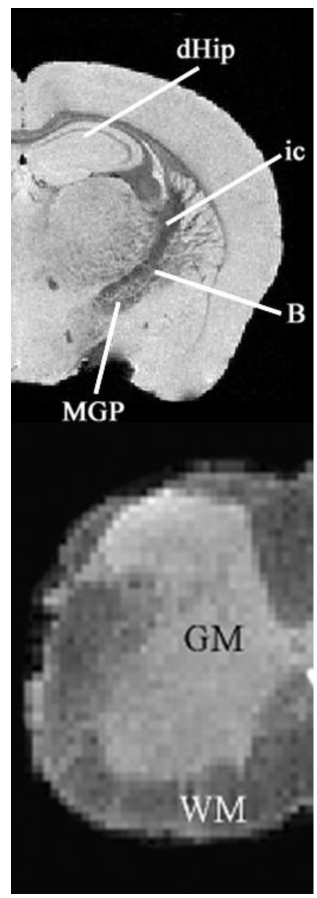

Figure 1.
MR Microscopy (MRM) images of mSOD CNS tissue.
Top: mSOD lumbar segment from a 3D dataset displaying areas of white (WM) and grey (GM) matter.
Bottom: mSOD slice of the brain from a 3D dataset displaying some of the CNS structures that were segmented: dorsal hippocampus (dHip), internal capsule (ic), nucleus basalis (B) and medial global pallidus (MGP).

MATERIAL AND METHODS

Perfusion-fixed brains and spinal cords of hemizygous transgenic mice overexpressing human mutant SOD1 protein (G93A mSOD) and wild type control mice were transported to the Advanced Magnetic Resonance Imaging and Spectroscopy Facility (AMRIS) of the National High Magnetic Field Laboratory at the University of Florida. Specimens were scanned using the 17.6-T widebore magnet equipped with a Bruker (Billerica, MA, USA) Avance console, Micro2.5 microimaging gradients and homebuilt RF coils optimized to accommodate these samples. For brain samples, 3D gradient recalled echo MRM datasets were acquired at an isotropic resolution of 40 µm. For spinal cords, T_2*-weighted 3D images were acquired similarly but at a resolution of at least 39x31x31 µm. For the brain, anatomical segmentation included the substantia nigra (pars compacta) (SNpc), striatum, cortex, hippocampus and internal capsule (including nucleus basalis). Additionally, cortical thickness measurements were made from the MRM images. For the spinal cord, anatomical segmentation included the total grey and white matter volumes and the ventral, dorsal and lateral subregions. To correlate MRM findings, immunohistochemistry was performed on the same specimens that were scanned via MRI. Samples were stained for apoptosis (rabbit polyclonal antibody against activated caspase-3), reactive astrocytes (rat polyclonal antibody) and microglia (rabbit polyclonal antibody).

RESULTS

As shown previously with cycad-fed mice (Wilson *et al*., 2004), analysis of brain tissue from mSOD and control brain revealed a significant reduction in overall brain volume in mSOD mice compared to controls. Significant reductions in cortical thickness were present in mSOD mice within the primary motor cortex region and primary somatosensory barrel field cortex. Volume reductions also were identified within the striatum, internal capsule including the nucleus basalis, SNpc and hippocampus. mSOD mice showed significantly decreased volumes of total grey and white matter in lumbar spinal cord segments compared to controls. Dorsal horn white matter volumes showed a statistically significant decrease in mSOD mice compared to controls.

With regard to histological analysis, brain sections from the SNpc, motor cortex and striatum showed increased immunoreactivity in mSOD mice compared to controls. GFAP labeling in the primary motor cortex also demonstrated a significant trend toward increased astrocyte proliferation in the striatum and SNpc of mSOD mice compared to controls. Additionally, the striatum, primary motor cortex and regions in the lumbar spinal cord of mSOD mice showed increased microglia activity compared to controls.

DISCUSSION

A unique aspect of the study is the determination of grey and white matter volumes by MRM in the lumbosacral spinal cord. Significant reductions of grey and white matter volumes in lumbosacral spinal cord in mSOD mice were identified. Indeed, there also was a trend towards a reduction in the ventral horn volume in mSOD mice without losses in the dorsal horn, which may point to the loss of motoneurons and ventral horn interneurons (Hamson *et al*., 2002). The significant reduction in mean white matter volume in mSOD mice supports the view that these mice have significant upper motor neuron lesions in addition to lower motor neuron loss. In cycad-fed mice, decreased volumes in the ventral horn grey matter also were identified, but with no changes in the

Table 1. Summary of CNS volume changes in genetic and environmental models of ALS.

MRM volumes by CNS structure	mSOD mice	Cycad-fed mice†
Total SC grey matter volume	-16%*	-21%*
Total SC white matter volume	-20%*	0%
SNpc	-23%*	-25%*
Striatum	-16%*	-25%*
Hippocampus	-17%*	-20%
Internal capsule including nucleus basalis	-24%*	-39%*
Total brain volume	-9%*	-17%

†Wilson *et al*., 2004
*Indicates percentages with statistical significance ($p<0.05$) when compared to controls.

white matter volume. Although the two models of ALS share similar inflammatory responses, the difference in white matter involvement is potential evidence that the genetic and environmental forms of ALS may have different origins or disease progressions.

Another important finding of this work is the apparent impact of these two models on areas outside the traditionally accepted sites of neurodegeneration common to ALS. As shown previously, the cycad model presents neuronal losses outside of the spinal cord, mirroring the human disease of ALS-PDC. This study also identified more widespread neuronal pathology for the mSOD model, which traditionally is considered to mimic pure motor neuron involvement. As such, it is tempting to consider that ALS-PDC may reflect a broader range of motor neuropathologies, for which traditional ALS is only one component.

CONCLUSIONS

In summary, this study compared environmentally and genetically-induced models of ALS to show a differential volume loss in spinal cord white matter, but very similar volume losses in other neuroanatomical structures. This loss of white matter volume may explain the significantly different behavioural phenotypes of these ALS models. Furthermore, data suggest that neurodegeneration in both models extends beyond the traditional boundaries associated with ALS, providing evidence of involvement outside of the spinal cord and motor.

ACKNOWLEDGMENTS

This work was supported by grants from the US Army Medical Research and Materiel Command (#DAMD17-02-1-0678) Scottish Rite Charitable Foundation of Canada and the Natural Science and Engineering Research Council of Canada (NSERC) to CAS, and by an NSERC grant to CK. MRM studies were made possible through the support of the National High Magnetic Field Laboratory (NSF-0084173) and NCRR/NIH (P41-RR016105) (SB). All MR data were obtained at the Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) facility in the McKnight Brain Institute of the University of Florida.

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A novel diffusion method for generating contrast in MRI

E. Ozarslan and PJ Basser of the National Institutes of Health, PE Thelwall of Newcastle University, England, and TM Shepherd, B Vemuri, and SJ Blackband of the University of Florida contributed to this piece.

INTRODUCTION

Diffusion magnetic resonance imaging techniques and applications have grown dramatically over the last decade, providing a new way to probe the microstructure of biological tissues. Most prevalent are studies that use anisotropic water diffusion in tissues to generate nerve fiber track maps that are being evaluated both clinically and in animal studies. However, water diffusion has also been shown to be sensitive to changes in cellular compartmentation, and has so far been exploited mostly in brain and spinal cord tissue.

The development of ever stronger magnets and sensitive RF coil technologies has facilitated further advances in this area since the increased signal to noise generated can be exploited to probe tissue at ever higher levels. This is particularly true on small samples at very high fields, such as excised brain and spinal cord tissue studies at 750MHZ at the Magnet Lab. In this short report we summarize how diffusion can be exploited to generate a new form of contrast in MRI. A full account of the diffusion methodology and theory has been published (1,2) and is summarized in Experiment and Theory below.

In short, the diffusion of water in tissues can vary depending on how far the water can travel before hitting boundaries, thus providing a way of probing the sizes of structures in the tissues. It is recognized that the structures have similar properties at different length scales, i.e. appear self similar, and thus can be modeled in terms of fractals. By using a fractal data analysis, indices can be generated that characterize the transition between different length scales that make up the fractals. These indices can then be used to provide "weighting" of the MR signal or image contrast that will vary depending on the diffusion properties of the sample. In effect this thus provides a new contrast mechanism for MRI. To investigate the feasibility of this approach, we have performed experiments on excised rat brain slices.

METHODS

Theory summary: Many biological tissues including the neural tissue have a hierarchical structure that exhibits significant self-similarity. Sensitizing the MR signal to random movements of the molecules makes it possible to probe length scales that can not be resolved by conventional MR imaging methods. Varying the diffusion time provides a means to observe water diffusion at different temporal or spatial scales. A nonlinear dependence of the mean-square-displacements (MSDs) on the diffusion time gives rise to anomalous diffusion, which occurs

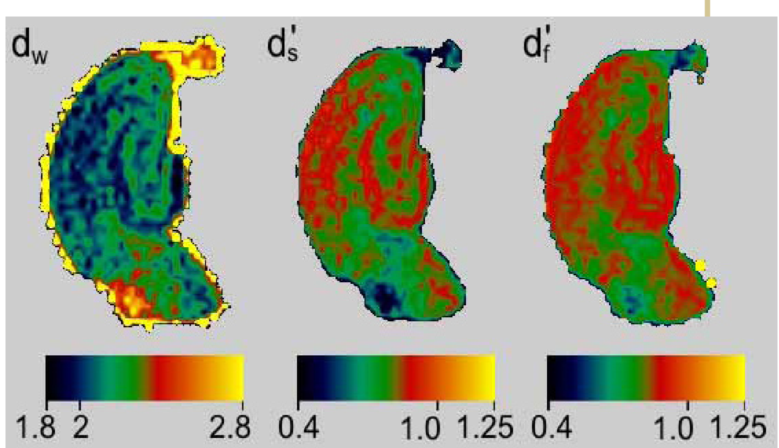

Figure 1.
Scaling exponent maps of isolated hippocampi.

in systems exhibiting fractal behavior. In fractal environments, Brownian motion of particles are restricted in all length scales giving rise to the scaling relations $<r2> \alpha\ t^{2/dw}$, and $P(r = 0,t)\ \alpha\ \ t^{-ds/2}$ where $<r2>$ is the mean square displacement and $P(r=0,t)$ is the return to origin probabilities for the water molecules undergoing diffusion during time t. The scaling exponents dw and ds are called the fractal dimension of the random walk and the spectral (fracton) dimension respectively. The diffusion process is called "normal" if $dw=2$, where the cases $dw>2$ and $dw<2$ correspond to sub- and super-diffusion regimes (anomalous diffusion) respectively. These two scaling exponents are related to the fractal dimension, df, through the relationship $df=dw\ ds/2$. In one-dimensional q-space measurements, the projection of the propagator onto one axis is measured. Thus we have a one-dimensional space that can be quantified by the indices ds' and df'.

Experimental: A series of diffusion-weighted MR images were acquired from three excised rat hippocampi with varying diffusion gradient strengths and diffusion times. The imaging parameters were: B0=14.1T, TR=1000ms, TE=12.6ms, resolution = (78x78x500)μm^3, matrix size=(64x64x3), δ=2ms. The diffusion gradient strength varied between 0 to 2935mT/m while the q-space acquisition was repeated 10 times with Δ values ranging from 12 to 300ms on a logarithmic scale.

RESULTS AND DISCUSSION

The functional fits (data not shown, see (1,2) were very satisfactory indicating the appropriateness of the approach. Figure 1 then shows images generated of the scaling exponents as color coded maps. Different scaling behavior is observed in regions of the hippocampus (i.e. there is image heterogeneity), indicating that a unique contrast method has been developed that may provide information about tissue substructure. Contrast appears to be influenced by unique cytoarchitectural features of different hippocampal regions. For instance, the densely packed myelinated regions like the fimbria and the dorsal hippocampal commissure appear to be in the subdiffusive regime where the characteristic lengths associated with the diffusion process scales slowly in time.

CONCLUSIONS

We have shown that diffusion may be exploited to generate a new form of contrast in neural tissue. The formalism was developed to characterize diffusional processes in fractal environments and was applied to MRI data collected from excised neural tissue. This method can be used to understand the variability of data acquired with different values for diffusion time. The method also provides a novel contrast mechanism that may enhance the utility and specificity of diffusion weighted MRI/S to better assess the structural changes that occur during development and various neuropathologies. Our goal is to now investigate the utility of this contrast method as a function of tissue perturbations that simulate pathological conditions (e.g. by making the brain tissue ischemic to represent a stroke) and to determine its utility in non-neural tissue. Further, we will exploit the higher field of the 900MHz ultra-wide bore to improve the sensitivity of these experiments.

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ACKNOWLEDGEMENTS

Support was provided by NIH grant P41 RR 16105 and the National High Magnetic Field Laboratory.

Science approaching 100 tesla

By Neil Harrison and Scott Crooker

Scientists have long been able to subject materials to the extremes of magnetic field beyond 100 tesla (T), utilizing explosive flux compression or single-turn coil techniques. Such an undertaking is of little consequence for insulators. For conductors, however, the rapid rates of change of magnetic flux brought on by the magnets' microsecond duration proves disastrous — vaporizing the conductor long before the peak magnetic field is reached, after which all is lost in the ensuing fireball, prohibiting any chance of experimental reproducibility.

To counteract these problems, high magnetic field scientists around the world have for the past two decades been attempting to generate magnetic fields approaching 100 T in a controlled fashion non-destructively. The demands on material strength and electrical energy have proven to be a far greater challenge than previously anticipated. Only recently have teams reached controlled magnetic fields anywhere near 100 T.

A team of scientists and engineers at the Los Alamos branch of the Magnet Lab are now in the final stages of commissioning a 100 T Multi-Shot magnet that will provide slightly reduced magnetic fields of ~90 T for experimental use in an interim period before the frontiers are finally pushed back to their ultimate goal a year or so down the road [1]. Even these relatively modest fields reach approximately 30 tesla beyond what was previously available for experiments in pulsed magnetic field laboratories— opening the door for countless new opportunities. Below, we present the first two examples where this magnet is already proving its success with low temperature experiments.

In the first experiments performed in the 100 T Multi-Shot magnet, we studied the field-tunable alloy disorder potential in a single diluted magnetic semiconductor (DMS) quantum well (shown in Fig. 1). As a measure of disorder and crystal quality in compound semiconductors such as $Al_xGa_{1-x}As$ or $Zn_xCd_{1-x}Te$, the linewidth of band-

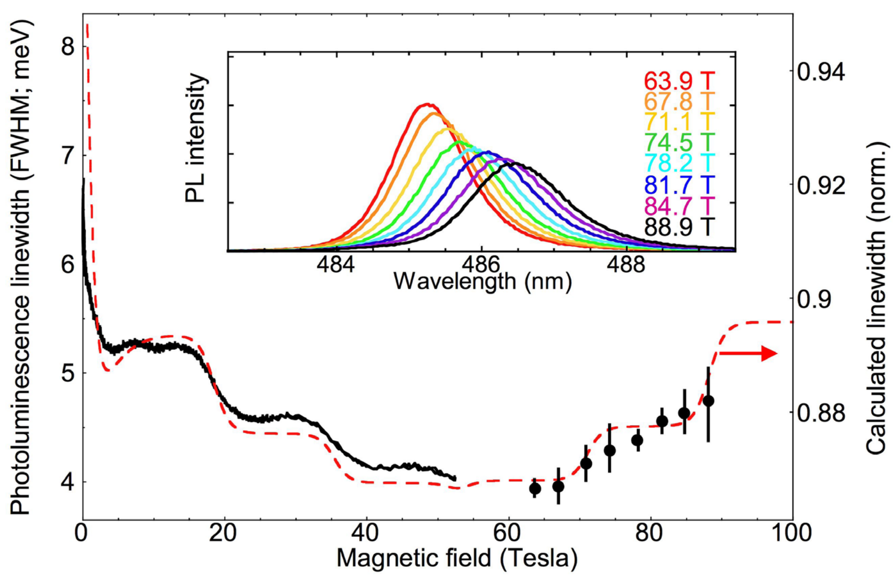

Figure 1.

edge photoluminescence (PL) is a powerful and widely employed diagnostic. Even the cleanest of these materials, however, necessarily possess some degree of intrinsic compositional alloy disorder due to the random placement of cation (or anion) species.

This alloy disorder presents an inherent and microscopic fluctuation potential that can be directly inferred from the PL linewidth, Γ. In DMS materials, the alloy disorder potential within a *given sample* can be tuned as the magnetic cations (usually spin-5/2 Mn) align in an applied magnetic field. DMSs therefore provide a flexible material system against which to benchmark models of alloy disorder. Experiments in DMS to date have observed that Γ decreases as local Mn spins align in low fields, and as Mn spin clusters begin to align in high magnetic fields to 60 T, in approximate agreement with models. However, a critical and as-yet-unverified aspect of current models is the expectation [2] that alloy disorder in many DMS materials should *increase* again as antiferromagnetically-bound clusters of Mn spins achieve full alignment at very high magnetic fields. This field scale is typically quite large, of order 50-100 T.

To this end we measured Γ from a single $Zn_{.70}Cd_{.22}Mn_{.08}Se$ quantum well to 88.9 T at 1.5 K. The 100 T magnet allows non-destructive access to this ultrahigh field regime and —importantly — sufficiently long pulse duration to permit collection of high-resolution PL data. Above 70 T, we observe that Γ markedly increases, in qualitative agreement with a simple "local-bandgap" model of compositional alloy disorder (dotted line shows the calculated linewidth). These data further validate current models of field-tunable alloy disorder in DMS materials, and support "local-bandgap" approaches to alloy disorder in general.

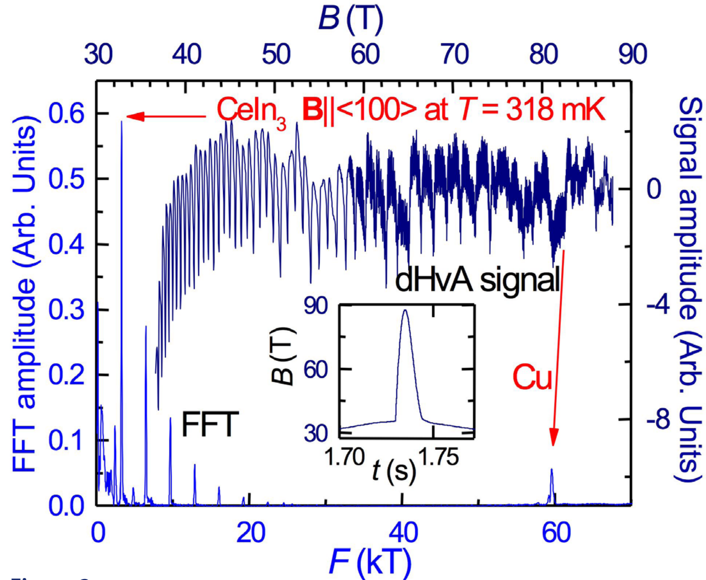

Figure 2.

One essential benefit of a slowly varying 90 T magnetic field is that the temperature of a metallic sample can remain cold throughout the pulse, enabling low temperature quantum phenomena to be observed (shown in Fig. 2). $CeIn_3$ provides the first example of a system, in which temperatures of ~318 mK (3/10 of a degree above absolute zero) enable observation of the quantum oscillations in the magnetization, better known as the de Haas van Alphen (dHvA) effect.

Fig. 2 shows an example of raw data of such oscillations measured in a pulse extending to 88 T. The Fourier transform of the oscillations in Fig. 2 (done in reciprocal magnetic field) provides a reliable in-situ calibration of the magnetic field; the fundamental dHvA frequency F ~ 59.5 kT of Cu originates from the windings of the detection coil while that of F ~ 3.22 kT corresponds to a sample of $CeIn_3$ aligned with the field parallel to its <100> axis.

$CeIn_3$ is of interest because it belongs to a small family of Ce-based antiferromagnets that become superconducting under the application of hydrostatic pressure, just at the point where antiferromagnetic order is suppressed [3]. Knowledge on the degree to which the f-electrons contribute to the electrical properties throughout is an essential prerequisite for understanding the origin of unconventional superconductivity. Strong magnetic fields assist in our pursuit of this understanding by changing the extent to which the f-electrons contribute to electrical conduction by polarizing their spin degrees of freedom.

This polarization depletes the system of available spin degrees of freedom for ordering, causing the antiferromagnetic order to be suppressed (as under pressure). This then manifests itself by way of subtle changes in the electronic structure that can be observed as field-induced changes in the dHvA Fourier spectrum.

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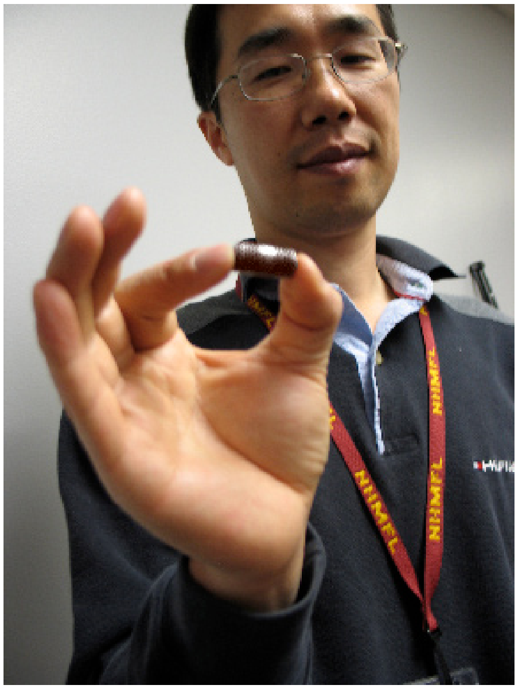
Magnetization measurements at high pressures fine-tuned

Robert P. Guertin, Tufts University
Eun Sang Choi, Mag Lab

Reports of experiments on materials under the influence of high hydrostatic pressure are not uncommon. Surprisingly, however, reports are rare of fundamental bulk magnetization measurements on materials under the simultaneous influence of high hydrostatic pressure and controlled external magnetic fields.

At the Mag Lab, we have successfully developed a technique for making high precision magnetic moment measurements on bulk materials in hydrostatic pressures to about 1 GPa (~10^4 atm) in external fields (to 9 tesla) and over a range of temperature (from pumped liquid helium (~2 K) to room temperature). Though this method for determining M(H,T,P) was first described in 1974 [1] by one of the authors, use of a specially designed high homogeneity superconducting magnet, updated fast data acquisition, and modern temperature and magnetic field control allow measurements to be made much more rapidly and with higher precision.

Samples are immersed in a liquid medium at room temperature inside a beryllium copper pressure clamp device to which external pressure is applied and locked in. A typical pressure clamp device is shown



with Eun Sang Choi in the accompanying photograph. The clamp is 0.8" long and 0.44" in diameter and aside from the Teflon capsule holding the sample and pressure transmitting fluid (not shown), it is made entirely of hardened high purity (Co-free) beryllium copper. The clamp is affixed to the end of the drive rod of a conventional commercial vibrating sample magnetometer (VSM). VSM magnetometry is one of the few methods for determining absolute values for sample magnetization, M. VSM magnetometry also allows continuous measurement of M(H,T) as a function of temperature at fixed applied field or as a function of swept (reversible) field at fixed temperature.

Thus with our system, continuous rapid accumulation of M(H,T,P) can be achieved for fixed pressures. Detection of the oscillating (~87 Hz) magnetic dipole moment of the sample/clamp ensemble in our system is through normal pickup coils. There is no

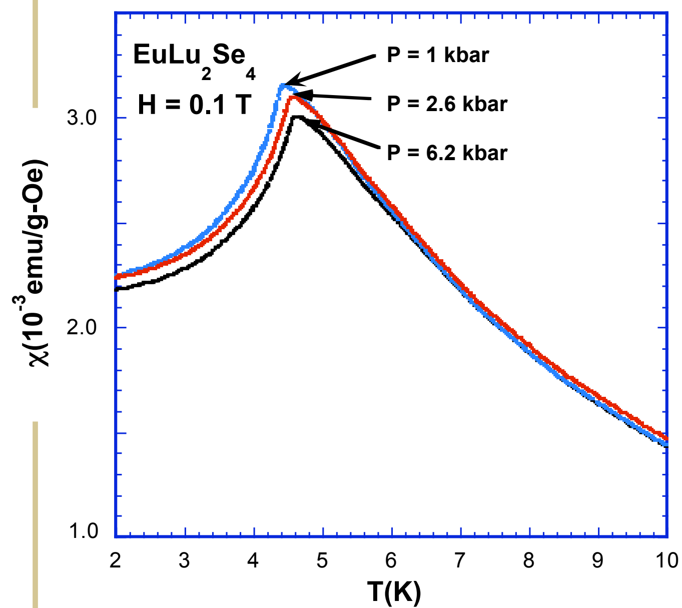


Figure 1.

limit to the magnetic field that can be applied, which is a limitation of SQUID magnetometry. This method can be readily adapted for use in higher field Bitter solenoids.

Though in our system the clamp (~13 g) typically outweighs the sample (~10 mg) by more than 1000:1, only a fraction of the clamp moment is detected, but 100% of the sample moment is measured. With closely spaced pickup coils, much of the (diamagnetic) clamp moment is self-canceling. Furthermore, the high homogeneity 9 T superconducting magnet (~1:10^4 in 1 cubic inch) greatly reduces the effects of eddy current interference from the pressure clamp itself. The noise level and ultimate sensitivity of the sample/clamp system is about 1×10^{-5} emu, less than SQUID magnetometer sensitivity for sample-only detection, but adequate for most magnetic and superconducting samples. Typical sample size is around 1 mm^3, and samples can be oriented inside the clamp relative to the field for magnetocrystalline anisotropy determinations under pressure. The low temperature pressure determination is made by measuring the differential in the superconducting transitions, T_c, of a sliver of Pb inside the clamp vs. T_c of a Pb sample outside the clamp.

Magnetization data are shown in the accompanying figures for a powdered polycrystalline sample of $EuLu_2Se_4$, which is antiferromagnetic below T_N =4.45 K. (The group of Prof. Thomas Albrecht-Schmitt of Auburn University provided this sample.) The first figure shows M vs. T at three different pressures in an applied field of 0.1 T. The data illustrate that the shift in T_N can be determined to high precision (~20 mK) and, in addition, because there is no detectable broadening of the transition, the pressure appears highly hydrostatic. The second figure shows M vs. H at fixed temperature (2 K) to 9 T. Though the data shown are for a very small hydrostatic pressure, there is no additional noise at higher pressures.

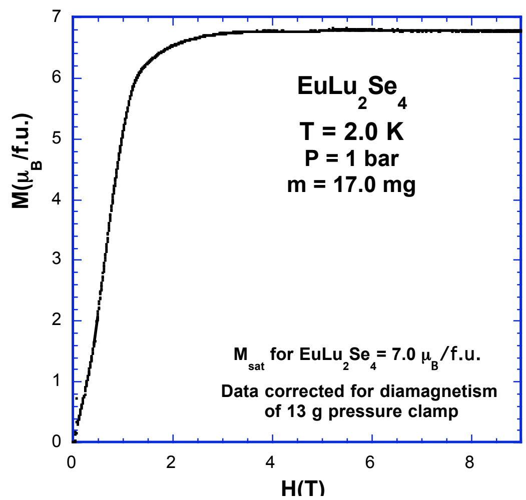


Figure 2.

The data have been corrected for the diamagnetism of the clamp body, which in this case amounts to about 20% of the signal at maximum field. Unlike any other method for determining magnetization under pressure, this method provides hundreds of data points continuously in a few minutes as a function of applied field. It is particularly useful in detecting pressure induced or pressure altered field-induced magnetic transitions. In addition to its unique capability of providing high pressure magnetization measurements, the Magnet Lab VSM system has been used as a staging area for ambient pressure higher field Bitter solenoid magnetometry [2] and for sample magnetic characterization of numerous superconducting and normal magnetic materials.

We welcome use of the system for indigenous and outside investigators, particularly those with materials in which new physics can be revealed in high pressures and in high magnetic fields.

Robert P. Guertin is a professor of physics at Tufts University who was a Visiting Scientist at the lab in 2005. Eun Sang Choi is a scholar scientist in the lab's instrumentation and operations user support group.

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With move, Korea Basic Science Institute researchers and equipment head home

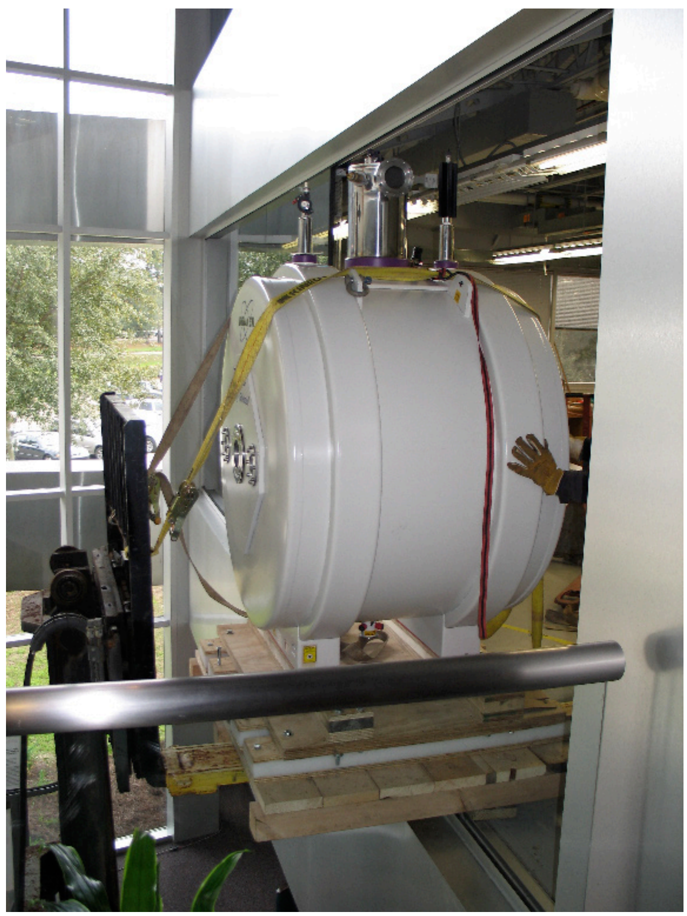
Wrapping up a two year partnership, the Korea Basic Science Institute moved its Asia-bound Ion Cyclotron Resonance equipment out the same way it came in – through the second story window of the Magnet Lab's B-wing.

In January, Korean scientists watched from the lab's Atrium as the equipment was lowered from the window via a forklift. One scientist held his hand over his mouth as the magnet slid from the window, suspended 20 feet over the Magnet Lab's main lobby. Another researcher leaned over the balcony, grinning. "It will be fine," he said. "It's insured for $700,000."

The converted office space of the B-wing has played host to KBSI scientists and their Magnet Lab staff support team for more than two years. The group of scientists engaged in a magnet and instrument building and maintenance crash course of sorts, preparing to run an independent lab back in Korea.

The Magnet Lab's role, explained Chris Hendrickson, Ion Cyclotron Resonance group associate scholar/scientist, was to ensure that KBSI left for Asia with the equipment necessary to upgrade a magnet they'd already purchased – a project that will result in the world's second 15-tesla superconducting magnet. (The first and now only is located at the Magnet Lab.)

"KBSI wanted to get into the field of magnet research," said Hendrickson. "They are a fairly new lab and they wanted to advance pretty quickly. So they bought a commercially available system but then improved it in various ways that we could help them with."



KBSI and the Magnet Lab completed the Institute's two main goals: preparing an upgraded, customized data system for the Korean magnet and creating "guts" superior to those of the stock magnet.

KBSI's contract financed their own supplies and equipment, as well as support staff time for three Magnet Lab researchers.

Despite some linguistic challenges among staff members, Hendrickson said the lab's experience was overwhelmingly positive. "This was a great partnership and its part of our mission, to improve our instruments and the application of those instruments, and to educate people on what they can do with them. It's all part of what we do and it helps drive the field to bigger and better things," he said.

Neutrons find missing entropy in a superconductor

By Chris Wiebe

It is rare when a single material in physics commands the attention of the condensed matter community for several decades, but the intermetallic compound URu_2Si_2 has done just that. Discovered in the mid 1980s, URu_2Si_2 belongs to a class known as "heavy fermion materials," since the electrons themselves within the metal are strongly interacting with one another, and as a result they behave as if they have larger effective masses. This typically appears as an enhanced electronic portion of the specific heat at low temperatures.

There are dozens of these materials that have been synthesized by various research groups around the world, but URu_2Si_2 stands out for two reasons: (1) it is a superconductor at around 1 K, and (2) there is a magnetic transition at 17.5 K that physicists still do not understand. In the early 1990s, neutron scattering experiments showed that a very small ordered moment appears below 17.5 K, but the size of the moment could not explain the large anomalies noted by other experiments, such as the specific heat.

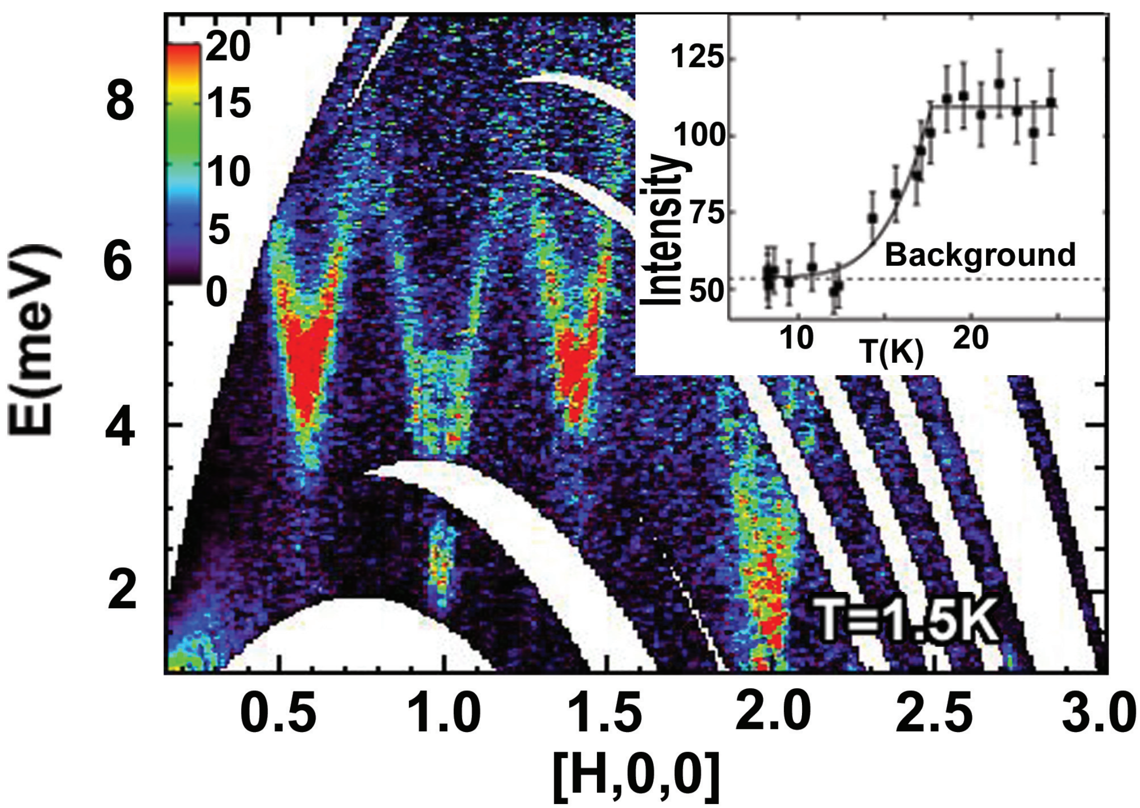


Figure 1.
Inelastic neutron scattering dispersion curve of spin excitations in URu_2S_{i2} at 1.5 K. The gaps at ~ 3.5 meV and ~ 2 meV give rise to the change in electronic heat capacity through the transition. The inset shows the development of the gap at (0.6,0,0).

Various theories have been postulated over the years to explain this transition since it is not a conventional magnetic ordering – orbital currents, quadrupolar ordering, and other exotic ground states have been suggested to form beneath 17.5 K. This represents a major gap in our understanding of the interactions between the electrons in these strange metals (and how the superconducting state develops).

Recent measurements by myself and John Janik of the Magnet Lab's Quantum Materials Group have shed some new light on this problem. State-of-the-art neutron scattering experiments have unveiled the source of the change in the electronic heat capacity at the transition. The results have been published in Nature Physics.

Above 17.5 K, very fast gapless spin excitations were observed that are typical of excitations within itinerant electron systems (ie. systems that have delocalized electrons). Below the transition, these modes become gapped and thermally inaccessible. Therefore, the reason for the change in the electronic specific heat capacity is due to this gap opening in the itinerant spin excitations, and not due to many of the unusual order parameters previous suggested. The change in entropy through the transition, which appears as a change in the electronic specific heat, can be completely accounted for through the gapping of these spin excitations, and other theories to explain the transition now have to be abandoned.

Even though the change in the electronic heat capacity can be accounted for, the identity of the ground state is still unknown in this material. The situation is reminiscent of the early days of the superfluid transition in liquid helium – there is an anomaly in the specific heat, but no positional long range order as noted through neutron scattering. The electrons themselves with URu_2Si_2 could be forming a new kind of condensate analogous to the atoms within superfluid helium, but only time will tell what new mysteries will be uncovered in this fascinating material.

A portion of this work was completed at the NIST neutron center in Gaithersburg, Maryland using the Disk Chopper Spectrometer.

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SEE IT ON THE WEB

Read more about Wiebe's research, *Gapped itinerant spin excitations account for missing entropy in the hidden-order state of URu_2Si_2*, online at *www.nature.com/nphys/index/html*

Resistivity measurements at low temperatures require extreme care

By Eric Palm and Tim Murphy

An experiment that is frequently performed in the dilution refrigerators in the Magnet Lab's DC Field Facility is measuring resistivity as a function of temperature and magnetic field. On occasion a user has run enough current through the sample to increase the temperature of the mixing chamber. We were curious as to what the internal temperature of the sample may have been as it was heating the entire mixing chamber, so we devised and performed the following simple experiment.

We used a calibrated, 1 kΩ, RuO_2 sensor, 2 mm x 1.3 mm, as our test sample. It was mounted in the field center position (labeled "sample space" in Fig. 2) of the portable dilution refrigerator in order to measure the increase in its internal temperature as the applied power was increased while simultaneously monitoring the permanently mounted probe thermometer. The geometry of the

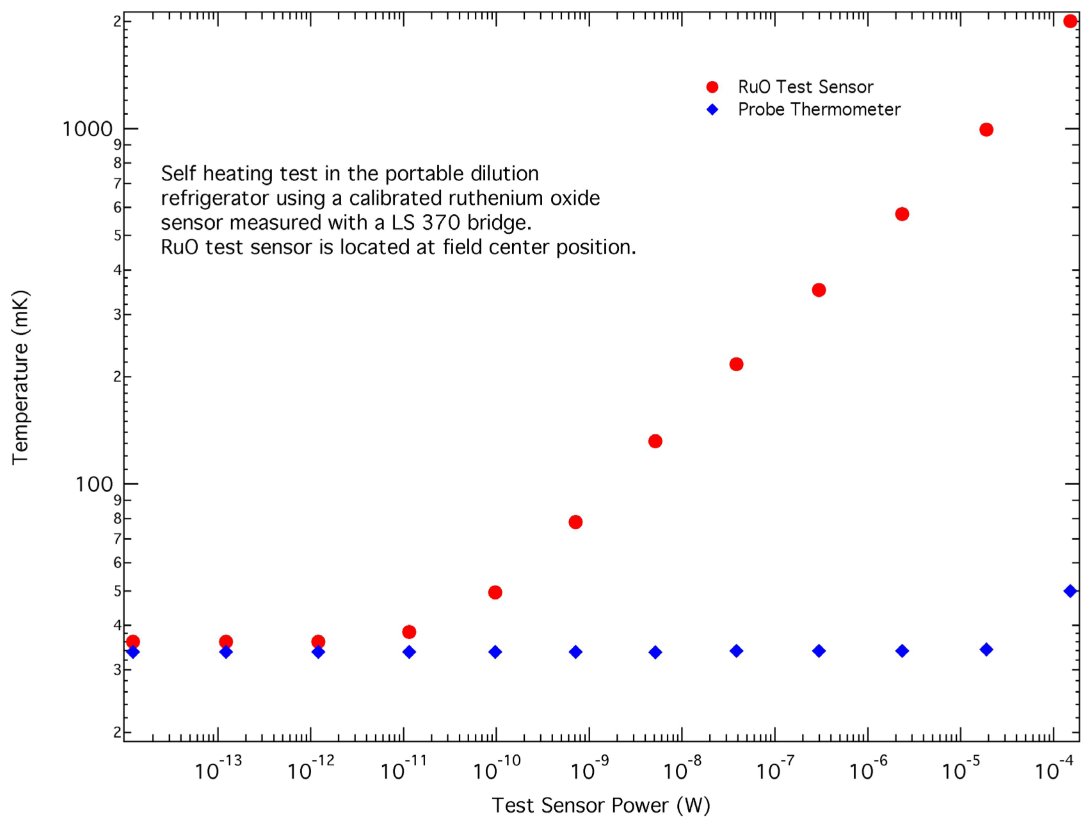

Figure 1.
Self-heating of a model sample in a dilution refrigerator. Sample temperature is plotted as a function of the power generated by the sample current.

sensor locations is shown in Fig. 2. Using a Lake Shore 370 AC resistance bridge, we measured the temperature of the test sensor as a function of current (power) with the results displayed in Fig.1. When the power dissipated in the test sample rises above ~ 6 pW, self heating begins to occur. The most dramatic result of this test was that a temperature of 1K can be achieved in the test sample before any heating begins to show on the probe thermometer. Going to the maximum current output on the 370 yielded an internal temperature of 2 K in the test sample with only 50 mK showing on the probe thermometer.

Does mounting a temperature sensor close to the sample solve the problem? To answer this question we located a ¼ W metal film resistor inside the sample space ~ 3 mm away from the test sensor. We generated 10 μW in the metal film resistor, and monitored the temperatures of the two sensors. From Figure 1 we estimate that the metal film resistor was at ~500 mK. Both the probe thermometer and the test sensor registered ~34 mK .

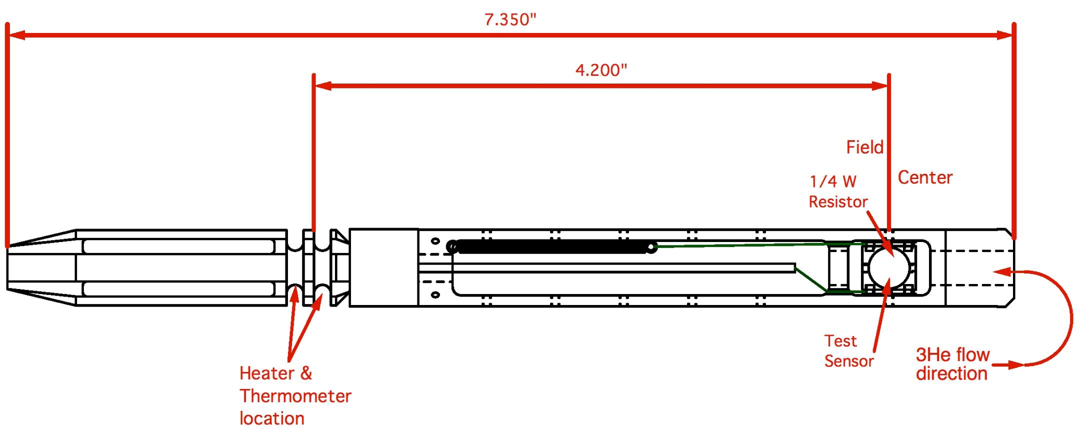

Figure 2.

It is clear from these measurements that users should be extremely careful when making resistivity measurements at low temperatures. The sample resistance may be quite low, in the milli-ohm or even micro-ohm regime, but the resistance of the contacts is usually at least an ohm, often much more. Since the transfer of thermal energy from the sample to the temperature sensor(s) via the mixture is extremely poor, the sample can heat significantly before a thermometer in the liquid senses the heat at all. As this experiment shows, as little as 20 μW heated the sample to more than 1K, which certainly defeats the purpose of the dilution refrigerator! Since making good measurements on low resistivity samples at low temperatures can be difficult, we stand ready to assist users in obtaining error-free data.

New 'Low-E' probes available for biological solid state NMR

By William W. Brey and Peter L. Gor'kov

Solid state nuclear magnetic resonance (NMR) spectroscopy at high magnetic fields is rapidly developing into an important technique for protein structure determination. It is especially valuable since it can be applied to a vast array of insoluble proteins for which neither solution NMR nor X-ray crystallography is appropriate. However, the high radio-frequency (RF) fields needed for solid state NMR techniques can very easily heat the protein samples, distorting the spectra and even destroying the samples.

To solve this problem, we have developed new "Low-E" RF probes at the Magnet Lab to minimize these sample heating effects. Probes for PISEMA spectroscopy of mechanically aligned samples at 600 and 900 MHz are now available through the Magnet Lab user program. A ^{19}F–^{1}H probe for aligned samples at 600 MHz, a bicelle probe for 600 MHz, and a low-E ^{1}H–X magic angle spinning (MAS) probe for 4 mm samples at 750 MHz have also been constructed and will soon be available to users.

THE DILEMMA OF SAMPLE HEATING

An RF electromagnetic excitation field is an essential part of the NMR experiment. The RF magnetic field B_1 interacts with the nuclear spin magnetic moments, flipping them back and forth as needed for a given experiment. However, any time-varying magnetic field carries with it an electric field, as described by Faraday's law $\nabla \times E_1 = -dB_1/dt$. In an aqueous sample, charge carriers respond according to Ohm's law to form a current distribution $J = \sigma(\omega)\, E_1$, where $\sigma(\omega)$ is the frequency dependent conductivity of the sample. These currents circle around the parallel lines of magnetic induction B_1 and cause "inductive loss" that can be represented as an effective series resistance $R_I \sim \sigma\omega^2$ [1]. A spectroscopist can reduce the heating effects of inductive loss by using the least conductive sample possible, either by reducing its hydration or salt concentration. However, there is not much that an RF probe can do to reduce this E_1 field without changing B_1 as well.

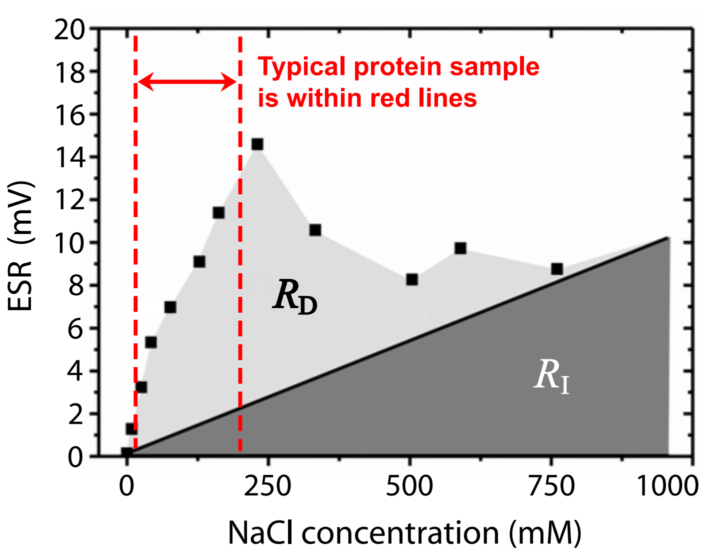

Figure 1.
Effective Series Resistance (ESR) of saline sample in solenoid at 400 MHz [2].

As if inductive loss were not bad enough, solenoidal sample coils also create a strong electric field along their principal axis. This field is due to the large voltage, up to several kilovolts, required to force sufficient current through the large inductance of a multi-turn solenoid. This axial field is often described as conservative, meaning that the motion of a charge in this field conserves energy, so we give it the symbol E_C. The loss R_D associated with E_C depends upon the distributed capacitance between the coil and the sample. Unlike R_1, R_0 does not generally have a simple dependence on conductivity and frequency. To determine the relative inductive and dielectric loss, the total ESR of a series of samples, identical except for their salinity, was measured in an NMR probe at 400 MHz. Figure 1 illustrates that, for samples with salinity in the typical range, dielectric loss R_D dominated inductive loss was the dominant effect [2]. Fortunately, the conservative field is not tied to the magnetic field, and there are a number of ways to suppress it and its associated dielectric loss. Faraday shields inside a solenoid can be used at lower frequencies, but since they tend to reduce the self-resonance of the solenoid they are not really appropriate for high frequencies. Directly reducing the inductance will reduce heating, but may also reduce the sensitivity for the ^{15}N and ^{13}C channels. Another approach is needed to reduce heating while preserving sensitivity.

THE LOW-E APPROACH

In order to preserve sensitivity while reducing sample heating, we have combined an inner solenoid for the ^{13}C or ^{15}N channels with an outer single turn ^{1}H solenoid otherwise known as a loop-gap resonator (LGR). An example of this approach is shown in Figure 2A. This probe allows the study of aligned membrane protein samples in a large 7.5 x 5.5 mm rectangular glass tube at 900 MHz. The inner coil, a five turn rectangular solenoid, is designed to give excellent sensitivity for the 91 MHz ^{15}N detection channel in PISEMA experiments. It can be retuned for other nuclei by replacing the ceramic capacitor shown on the left hand side of the photograph. The solenoid is placed inside a LGR that provides the ^{1}H decoupling field with minimal conservative electric field E_C (hence the name "low-E"). The slot visible on top of the low-E coil has been added to reduce interactions inductive coupling between the LGR and the solenoid. These probes have been fully tested at 600 and 900 MHz and have been shown to reduce sample heating by approximately 10-fold. They are now available through the NMR user program. Recent publications describing the design [3] and applications of these probes to protein structure determination [4-8] will be of interest to potential users. Figure 3 shows a result from a peptide study performed with low E-probes at both 600 and 900 MHz. In this case, the linewidth has been dramatically improved by the higher field [4].

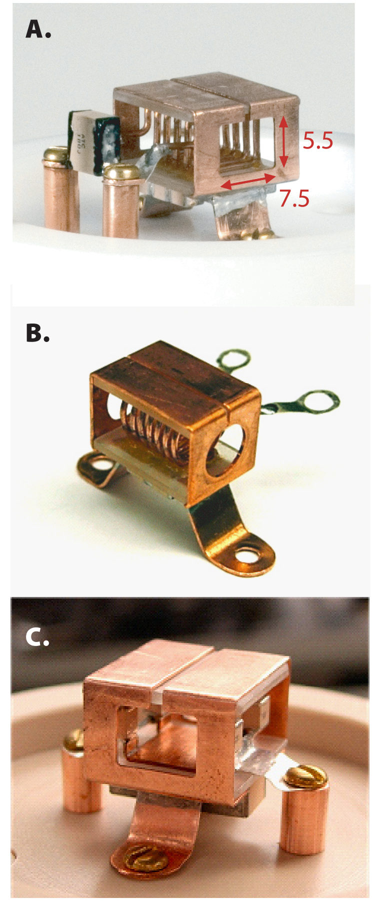

Figure 2.
Low-E cross coil assemblies: (A) 900 MHz ^{15}N–^{1}H flat coil PISEMA probe; (B) 600 MHz ^{15}N–^{1}H probe for 5 mm bicelle samples; (C) 600 MHz ^{19}F–^{1}H flat coil probe for oriented samples.

FLOURINE AND MAS LOW-E PROBES

Other applications for the low-E approach are being explored. In ^{19}F–^{1}H experiments, irradiation on both channels can contribute to sample heating. Since the Larmor frequencies of ^{19}F and ^{1}H are only 6% apart, achieving good isolation of a ^{19}F detection channel from ^{1}H decoupler noise is a common challenge for ^{19}F–^{1}H probes. Some probes utilize a single port for both channels, and then employ an outside splitter and filters to obtain the >80 dB isolation needed. The low mutual inductance of the orthogonal low-E approach has been used to develop a ^{19}F–^{1}H probe for 600 MHz that provides 24 dB of isolation within the probe itself. The probe uses two nested low-E resonators to reduce heating at both frequencies, as shown in Figure 2C. This probe is being tested and is now available for collaborative projects. An example 2D ^{19}F CPMG spectrum is shown in Figure 4. Interested spectroscopists should contact the authors to make arrangements to use this probe.

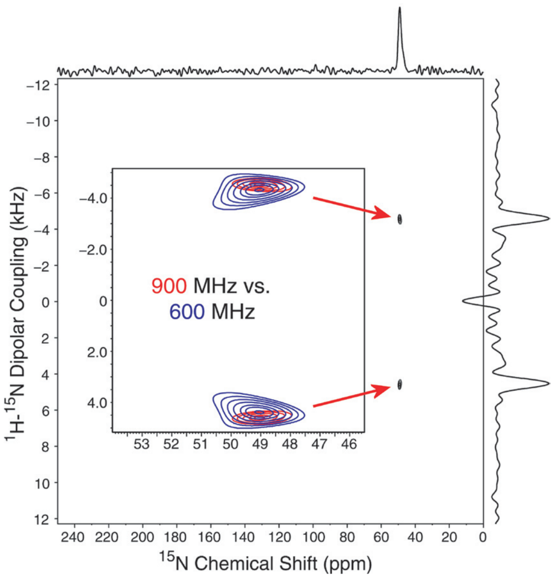

Figure 3.
Comparison of 900 and 600 MHz PISEMA spectrum of piscidin-3 peptide [3]. The slices are from the 900 MHz spectra. The sample was 10 mg of single site ^{15}N-labeled P_3-NH_2 (^{15}N-Leu_{20} amidated piscidin-3 in DMPC/DMPG (1:3), 1:20 peptide to lipid ratio, pH 6. The experiment used 48 t_1 increments with 192 transients each, B_1 (decoupling) ~60 kHz, B_1 (CP) ~45 kHz, 40ºC. Spectrum from E.Y. Chekmenev, *et al.*[4]

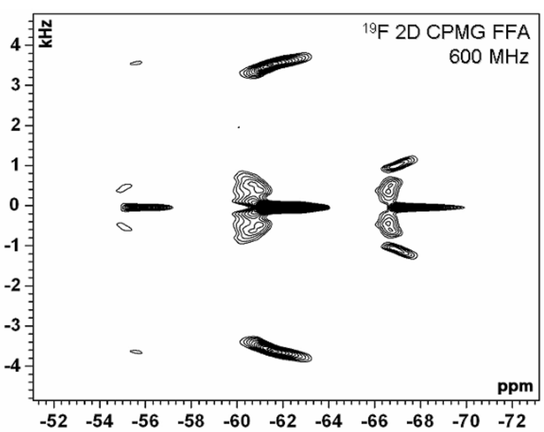

Figure 4.
Two-dimensional ^{19}F-CPMG spectra of Flufenamic acid in DMPC bilayers (1:8, fully hydrated, 35°C) at 600 MHz. 256 t_1 increments with 16 transitions, ^{19}F B_1 = 100 kHz, ^{1}H B_1 (decoupling) = 70 kHz. Spectrum from R. Fu and R. Witter.

Crossed-coil probes with good sample heating characteristics are commercially available for magic angle spinning NMR [9]. However in the commercial probes the order of coils is reversed: the detection solenoid is on the outside and the ^{1}H coil is on the inside. Interchanging the order of the coils may have advantages and disadvantages. In order to explore these, and to provide a probe for users interested in high sensitivity and RF homogeneity, we developed a 4 mm ^{1}H–X MAS probe for the 750 MHz wide bore spectrometer at AMRIS (Figure 5). The project was funded by a Magnet Lab In-House Research Program grant to Joanna Long of the University of Florida. The probe is intended to meet the needs of users with dilute biological samples, and so every effort was made to provide the largest possible sensitive volume. Preliminary measurements of probe RF performance were highly promising, obtaining a nutation rate of 93 kHz at 210 W for ^{1}H and 71 kHz at 107 W for ^{13}C with an excellent RF field homogeneity in both channels. The probe spins at up to 25 kHz. Scientists interested in collaborative projects using this probe should contact Joanna Long at *jrlong@mbi.ufl.edu*.

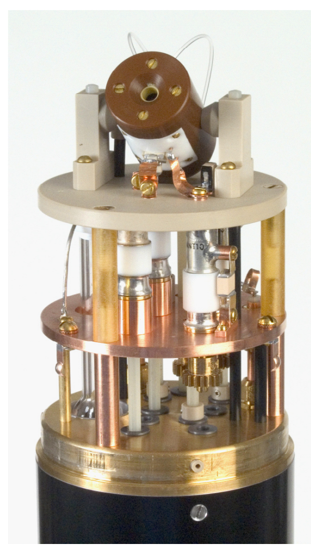

Figure 5.
Low-E MAS probe for 4 mm samples at 750 MHz.

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People

The Straty Adams gauge, developed by Mag Lab affiliate and University of Florida Professor Emeritus of Physics **Dwight Adams** along with his first graduate student, **Gerald Straty**, has been acquired by the Smithsonian Institution. The gauge has expanded the range of low-temperature research, allowing accurate measurement down to 458º below Fahrenheit and enabling Nobel Prize-winning research in the field.

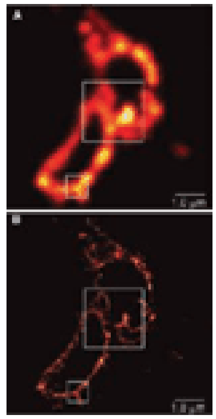
The museum, closed until 2008 for renovations, will eventually display some of Adams' early gauges in a section devoted to the production and study of ultra-low temperatures. Adams, a UF professor for more than 40 years, is planning a visit to the Smithsonian in the fall to provide the museum with video content for the section.

Irinel Chiorescu published a Perspective piece in *Science* magazine. The piece, "Microwave Cooling of an Artificial Atom" was published in the Dec. 8 issue.

"Being asked to write a Perspective is an acknowledgement that you are an expert in the field," said Mag Lab Director Greg Boebinger. "It's acknowledgment that you are able to provide a context and commentary on a submitted paper."

Chiorescu is an assistant professor of physics at Florida State University and the principal investigator of the lab's Quantum Spin Dynamics and Nanotechnologies group.

Michael Davidson and **Scott Olenych** of the Lab's optical microscopy facility recently published an invited review article on fluorescent proteins in the series: "Current Protocols in Cell Biology." The remarkable genetically encoded probes are fast becoming one of the most important tools ever developed for investigation of cellular dynamics and metabolism.



With more than 250 research reports being published each week using fluorescent protein tools, it is of paramount importance for cell biologists to stay abreast of the new technologies discussed in the review article. The article covers the latest developments in the ever-expanding fluorescent protein color palette, tips on imaging the proteins, and introduces optical highlighters or photoconvertible fluorescent proteins.

Davidson and Olenych were also mentioned in Science's December 22 list of 2006's top 10 scientific breakthroughs. The two collaborated with the Howard Hughes Medical Institutes Janelia Farm Research campus in Virginia and the National Institutes of Health to develop "optical highlighters" that would prove a key factor in the successful realization of photoactivated localization microscopy, or PALM. PALM allows researchers to look at the fine structures of cells and proteins with far more detail than other techniques. For more detailed information of PALM, see the Volume 13, Number 4 issue of NHMFL Reports.

David Larbalestier, leader of the lab's Applied Superconductivity Center, together with John Clark, a professor of physics at University of California Berkeley, published a commentary in the December 2006 issue of *Nature Physics*. The piece, "Wired for the future," takes a look at the growing number of successful applications for high-temperature

People continued

superconductors as the 20th anniversary of their discovery approaches.

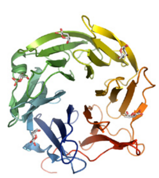
Magnet scientist **Denis Markiewicz** of the lab's Magnet Science and Technology group is the

newest member of the Science Council. Markiewicz was one of the early hires into the lab and has brought experience and a history of success to the high field superconducting magnet program.

Richard McHenry has joined the lab's Center for Integrating Research & Learning as Teacher in Residence. A chemistry teacher on special assignment, Rich will be developing workshops for elementary, middle and high school teachers and will be designing a "Science Coach" program

for the 2007-2008 school year. McHenry, a National Board Certified teacher, has represented the Magnet Lab at national and regional conferences, most recently presenting a poster at the American Geophysical Union annual conference. McHenry was selected as one of three teachers from the United States to attend the European Geophysical Union international conference in 2005. He was also selected as a state finalist for the Teacher of the Year award given by the American Chemical Society and has taught high school science in North Florida for 30 years.

Magnet Lab assistant scholar/scientist **Carol Nilsson** is the editor of "Lectins: Analytical Technologies", due out this July from Elsevier. The comprehensive reference is intended for both novice and advanced researchers. The publisher's description of the text states, "Lectins: Analytical Technologies covers both analytical and biological aspects of lectins (functional carbohydrate (complex sugar) recognition proteins) and provides researchers in the field with a resource containing background information and 'look-up' tables detailing lectin specificity and structures. Also included are methods and practical tips for designing new lectins from existing non-lectin proteins, automated approaches to lectin proteomics and high resolution mass spectrometry techniques." Nilsson directs the lab's Ion Cyclotron Resonance users program.



The Magnet Lab is ramping up its magnet science and technology capabilities with the hire of **Alessandro Bonito Oliva**, a leading expert in the development of large magnet systems. This is Bonito Oliva's second association with the Magnet Lab; in 1993-1995, he assisted with design and technological development of the lab's 45-tesla Hybrid magnet system.

With more than two decades of practical experience developing, designing and fabricating sophisticated superconducting magnets for applications ranging from nuclear fusion to magnetic resonance, Bonito Oliva brings crucial experience to the lab as it prepares to build a first-of-its kind Series Connected Hybrid (SCH) magnet. Once completed, the SCH magnet will have applications in Nuclear Magnetic Resonance, condensed matter physics, biology and chemistry.

"Alessandro is known in the international scientific community for his adept problem solving, troubleshooting and critical thinking - attributes that are all-important as we tackle projects of this size and complexity," said Mark Bird, interim director of the Magnet Science & Technology Group.

Bonito Oliva, who has a Ph.D. in solid state physics as well as a MBA, will play a critical role in the NSF-funded conceptual and engineering study for a similar SCH magnet that would be used for neutron scattering experiments at Oak Ridge National Laboratory's Spallation Neutron Source.

Lab's education efforts enhanced by addition of "Teacher in Residence"

By Pat Dixon

The Center for Integrating Research & Learning starts off 2007 with new partnerships, a Teacher in Residence, and a redesigned Web site. Plans are already underway for our summer Research Experiences programs for both teachers and undergraduates, and also for intensive summer science workshops for 200 area teachers.

Our new Teacher in Residence, Richard McHenry, started his tenure at the Magnet Lab in January on special assignment from Leon County Schools. His job will be to create a "Science Coach" model to provide support for elementary teachers teaching science.

McHenry has worked with the Center during the summer months since 2001 developing workshops and curriculum for secondary teachers, and is an ambassador for at the Magnet Lab at national and international conferences. His current mission is to design and implement summer physical science workshops for 200 teachers in Tallahassee and the surrounding area. McHenry's vast knowledge of science education and ability to design inquiry-based materials for teachers will add a new dimension to educational programs at the lab. (Read more about McHenry in our People section, page 24).

New grant expands reach of *SciGirls*

The continuing partnership with the Tallahassee Museum, WFSU-TV, Florida State University's Marine Laboratory, and the Magnet Lab resulted in a proposal submitted and funded by Dragonfly TV.

As we stated in our proposal, "In an age when more girls look to Britney Spears as a role model than to astronaut Sally Ride, there is a great need to offer these young women additional career options, inspire them to choose a career in science, and feel comfortable with their choice."

Based on the successful *SciGirls* program from summer 2006, we received funding to continue the program and expand it to more middle-school girls. In addition, we will be offering *SciGirlsII*, providing girls who participated last year's camp additional opportunities to pursue more in-depth exploration and teaching them strategies to synthesize scientific experiences.

Teachers at Comet Tales workshop

Partnership with library targets preK-3

Working together with Maria Mena, youth service coordinator at the Leroy Collins Public Library in Tallahassee, the Center has developed a program that targets parents of children preK-3, specifically from underserved schools, and provides strategies for taking everyday occurrences and turning them into science lessons.

We will show parents how to ask and answer questions, and how to listen and talk to their children about what they observe. Parents will leave the sessions confident that they do not have to know all the answers in order to encourage their children in science. Taking a listening walk, for example, encourages children to think about loud and soft sounds, near and far sounds, and whether they were made by something large or small. Picking up leaves, rocks, or shells can lead to classification skills that are basic to the process of science. We are excited about the prospect of offering the program to branch libraries and developing a program that can be posted on the Web site.

Brian McClain, a local high school chemistry teacher, is working with the Center to facilitate a workshop for high school physics teachers that will mark the debut of SuperNet, a Web-based resource. Developed as a result of the BCS at 50 project, the workshop will provide content on nanoscience and inquiry activities that translate the concepts presented for students.

Vladimir Dobrosavljevic, director of the lab's Condensed Matter Science-Theory program, is the driving scientific force behind the series of workshops designed to provide current information to teachers about superconductivity. Lab scientists Irinel Chiorescu, Oskar Vafek, and Chris Wiebe have provided valuable input and made the commitment to enhance education in this area.

Outreach spans many levels

The Center is working with the Center for Intensive English Studies to provide workshops for undergraduates, graduate students, and faculty who are non-native English speakers.

The Center for Intensive English Studies was founded at FSU in 1980 to help students from all over the world improve their language skills to prepare for full-time study at English-speaking universities or for careers that require fluency in English. Fall workshops at the lab focused on writing skills for submitting articles to scientific journals and writing for specific audiences.

The spring schedule includes effective presentation skills, writing grant proposals, and preparing cover letters and resumes. All workshops have been well attended and well received, exceeding initial expectations, and reinforcing the need for such collaborations to support researchers at the lab.

Center Outreach Coordinator Carlos Villa continues to provide quality outreach to area schools and community groups. The entire CIRL staff conducts evening programs for parents and students that highlight research conducted at the lab.

One such outreach at a Tallahassee-area elementary school provided activities for 300 parents and children. It's comments such as the following that keep us motivated:

"Before 7:30a.m. today, I had heard 'Science Night rocked,' 'Science Night was cool,' and 'Are you going to do that next year?' Those comments have continued all day long, so needless to say, last night was a huge success at Gilchrist."

Students and parents investigate "Fingerprints of Light"

Science starts here:

Eduard Y. Chekmenev, 29

POSITION:

Senior Research Scientist

Huntington Medical Research Institutes

Visiting Associate

California Institute of Technology

TIME AND ROLE AT THE MAGNET LAB:

August 2003-December 2005. I worked as a postdoctoral associate with Tim Cross in the NMR program/ CIMAR division.

CURRENT WORK:

I do biomedical research, which utilizes my education and experience of Nuclear Magnetic Resonance (NMR). In particular, we design methods to increase the signal that we can obtain in NMR by several orders of magnitude, using chemical synthesis. Applications of this approach are truly limitless. With the level of sensitivity gained, we are now able to perform metabolic imaging with unpredicted spatial and temporal resolution. Specifically, we are interested in diagnosing cancer. We estimate that we will be able to detect tumors as small as 2x2x2 mm, as well as identify malignancy and track response to treatment. Moreover, this can be done during 1-2 minute scan procedure, which is only a small fraction of time and cost of a typical MRI scan procedure nowadays.

HOW DO YOU THINK YOUR EXPERIENCE AT THE LAB HAS SHAPED YOUR SCIENTIFIC CAREER?

The Magnet Lab shaped my career in many positive ways. I met a good number of interesting scientists and we started several very fruitful collaborations. Besides meeting great people and, obviously, having access to the best instrumentation in the world, experience in the Magnet Lab helped me to learn how the research community works, the importance of publications, funding and the ways to obtain funding from government sources to be successful in science.

WHAT'S THE MOST IMPORTANT LESSON YOU'VE TAKEN AWAY FROM THE MAGNET LAB?

The most important lesson that I learned from the Magnet Lab is how to establish healthy research collaborations and how to avoid traps. Collaborations are very powerful tools in a scientific career, but they can also do a lot of harm if the environment is not right. I will value this lesson in my future scientific career greatly.

DESCRIBE SOMEONE YOU MET AT THE LAB WHO YOU CONSIDER A MENTOR. WHAT IS IT ABOUT HIS OR HER WORK STYLE, APPROACH TO RESEARCH, OR PERSONALITY THAT INSPIRED YOU?

I consider Prof. Timothy Cross my mentor during my time at the Magnet Lab. I really liked his work style and learned a lot from him. The most important value that he inspired was freedom in research, not only with project execution, but also in deciding which topic to work on, making conclusions and publicizing results. He promoted a broader perception of science and how it impacts people's lives. Dr. Cross mentored several scientific publications in premier peer-reviewed journals, where we presented our work and work with our collaborators. The collaborative work was greatly supported and inspired by Dr. Cross and I think we all benefited from this.

HOW DOES THE NHMFL EXPERIENCE DIFFER FROM OTHER EDUCATIONAL/ RESEARCH EXPERIENCES YOU'VE HAD?

The research experience at the Magnet Lab is different from the normal university setting, primarily in terms of much better access to the cutting-edge equipment and technical support. I now work in similar environment, a research institute, with the primary focus on research. The Magnet Lab, in my opinion, is the best of its kind simply because it is not a profit-driven environment. The focus on pure science is very high.

"Science starts here" is a new feature that showcases young scientists whose career paths have been greatly shaped or influenced by their experiences at the Magnet Lab.

MLR

WINTER 2007

VOLUME 14 • NO. 1

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Of Mice & Men:

Researchers use high resolution MRI to compare models of Lou Gehrig's Disease

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