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NATIONAL HIGH MAGNETIC FIELD LABORATORY

MAG LAB REPORTS

FLORIDA STATE UNIVERSITY • UNIVERSITY OF FLORIDA • LOS ALAMOS LAB

On the cover:
Jim O'Reilly conducts a creative maintenance experiment designed to flawlessly apply a tricky, fast-drying epoxy in the Cell 4 magnet housing. This dry run mimics the delicate, under-30-second process during which the team will apply epoxy to the magnet housing and then blow up the pictured inner tubes to hold it in place as it dries.

— Photo by Larry Gordon

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Monumental work: Mammoth news about a big magnet

Mammoth news – the "new and improved" 45 T Hybrid magnet is up and running. This flagship magnet returned to user service as planned Oct. 15, following monumental work by many, including the Magnet Science & Technology (MS&T) and Instrumentation & Operations groups. Special thanks go to Project Leader Jack Toth and his MS&T team and to John Pucci and his cryogenics team for building us another Big Dog magnet.

GREG BOEBINGER

The new Hybrid's resistive insert uses only three power supplies instead of four, so the new system allows the possibility to host two experiments simultaneously when the hybrid is running. This means more users and more science, which always will be the top priority at the MagLab.

What's more, the upgraded Hybrid allows us to more easily test the cable-in-conduit-conductors needed for the Series Connected Hybrid, as well as to assist partners such as the International Thermonuclear Experimental Reactor (ITER) with their conductor testing. In the longer-term MagLab vision, the Hybrid upgrade is a necessary step on the road to running the future Series Connected Hybrid in parallel with the existing 45 T Hybrid.

We've also passed a key milestone toward the user-requested split helix magnet for rotation and optical scattering experiments. You can read the latest developments on page 4.

GIANT MAGNETORESISTANCE: A HUMONGOUS LEAP FOR THE MICRO-MAGNETICS AGE

"GMR" is front page news thanks to the Royal Swedish Academy of Science, who in October awarded the Nobel Prize in Physics for 2007 jointly to Albert Fert and Peter Grünberg for the discovery of giant magneto-resistance (GMR) in 1988. Less than 10 years after its discovery, a GMR-based computer hard drive made its debut and immediately became the new standard technology.

The success of GMR further demonstrates the importance of magnetism in the "Micro-electronics Age"… and how basic research can fuel new technologies worth billions. We, the public and the Federal policy makers must all understand that the economic benefits of GMR would not be realized without flexible basic research funding on thin magnetic films in the 1970s, much of it provided by corporate research laboratories that no longer exist.

There are many physical systems that display large and tunable magnetoresistance…colossal MR and Kondo-rific MR come immediately to mind (Alas, I could never get "KMR" accepted as a description of the magnetoresistance upon closing the Kondo Insulating Gap). In this issue, we present a transitional metal oxide system, the cobaltites, in which high field NMR maps the internal magnetic field distribution. Although the underlying physics is not yet known, the data imply that a large magnetoresistance results from nano-scale phase separation into magnetic polaron clusters (Page 7).

THE REALLY, REALLY BIG CHALLENGE OF DIVERSITY

The MagLab is serious about becoming a nationally recognized leader in improving diversity by expanding the diversity of our user programs and our scientific, technical and engineering staff.

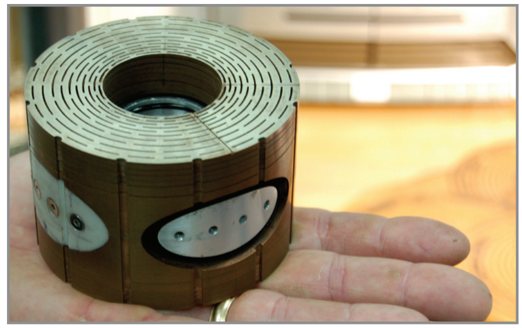
This isn't an easy problem to solve in the physical sciences, as statistics and several decades of efforts have shown, so we have our work cut out for us. Nevertheless, because our educational programs have received national attention, we feel that we can build upon and extend that success. You can read more about the scope of the problem and our plans to address it on page 13.

A completely new diversity initiative comes to the MagLab with Eric Hellstrom, who recently joined the rest of his Applied Superconductivity Center colleagues in Tallahassee. Hellstrom is a principal investigator on a "PREM Grant" (Partnerships for Research and Education in Materials) with the University of Puerto Rico-Mayaguez campus to work on magnetic materials. The program now includes mentoring students and working with undergraduates in research experiences during the summer months…and we anticipate new and fruitful collaborations with MagLab scientists and engineers in the years to come.

Rock n' Roll,

Gregory S. Boebinger

New magnet's mid-plane split will allow unprecedented experimental access



By Jack Toth and Mark Bird

INTRODUCTION

The National High Magnetic Field Laboratory operates a powered magnet facility in Tallahassee providing DC solenoids with a variety of fields, bores and homogeneity levels. In recent years we have started to develop high-field powered magnets with configurations other than simple solenoids. Specifically, a preliminary design of a resistive magnet with a mid-plane split for use in far-infrared photon scattering experiments was completed at the conceptual level. This user magnet, to be operated at our own facility, should provide a flux-density in the range of 25-30 tesla depending on the final gap dimensions using less than 28 megawatts of DC power.

RESULTS AND DISCUSSION

The user magnet requires a traditional bore tube as well as four large scattering ports of elliptical shape to provide adequate experimental space at the mid-plane (each with an opening angle: horizontal=45°/ vertical=11.4°). While the mid-plane of a traditional solenoid typically consists of high current-density conductor, the mid-plane of this split magnet will be more than 50 percent vacuum space. A significant fraction of the mid-plane also will be steel to isolate the vacuum from the cooling water. The remaining space is further compromised to provide sufficient room for cooling-water passages. Eventually, there needs to be adequate coil structure to not only carry the current, but also to react the clamping forces and the torque pulling and twisting the two halves of the magnet together. These unique design challenges are especially severe for the windings in the mid-plane region of the innermost coils. Consequently, the Magnet Lab developed a new technology called Split Florida Helix, a modification of the previously described Florida Helix technology[1].

To demonstrate the technology suitable for a 30 T split magnet, we have designed and built model coils. The model coils have been designed to match or exceed the critical design parameters of the conceptual design of the user magnet. The working model[2] consists of two coils, and only the innermost coil includes a mid-plane gap. The Split Florida Helix is employed near the mid-plane and Florida Bitter technology elsewhere. As in most of our other high-performance solenoids, we incorporated axial current grading including a different cooling hole pattern for the end turns.

Two model coil tests (with different coil lengths to consider varying coil clamping forces) were conducted at the appropriate level of current-density, power-density, stress, and field by inserting them in the existing 20-T, 200-mm bore resistive magnet (Large Bore Magnet). While designed for 15.6kA, we eventually increased the current in the working model up to 18.0 kA, tested a range of different cooling water flow rates (+/- 7%), and cycled the magnet at least 20 times. The measurements confirmed a center field of 32.1 T while the resistance of the split resistive insert coil never increased by more than 2.1%.

CONCLUSIONS

A working model for a large split resistive magnet was designed, built, and successfully tested at a high magnetic field above 32 T at the Magnet Lab. The test results fell well within the expectations and confirmed the design assumptions. Complex and sophisticated FEA proved to be fundamental for the implementation of the new technology called Split Florida Helix.

ACKNOWLEDGEMENTS

This work was supported by the State of Florida and the National Science Foundation through NSF Cooperative Grant No. DMR 9016241.

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Streak camera to expand experimental possibilities

By Stephen McGill

Over the past year, the ultrafast optics facility in Tallahassee has made several powerful capabilities available to the user community. In May of 2007, SCM3, an optics-dedicated high-field (17.5 tesla) superconducting magnet went into service. It allows convenient access to high magnetic fields for optical spectroscopy that can, if necessary, be used for extended periods of data collection. This magnet is available in addition to an already existing 31 T resistive magnet located in an adjacent cell. A new regeneratively amplified Ti:Sapphire ultrafast laser was installed, capable of delivering 2.5 millijoule, 130 femtosecond duration pulses and coupled with an optical parametric amplifier extending the tuning range of ultrafast light from the ultraviolet to the mid-infrared.

Perhaps the most exciting of these user capabilities, however, is a streak camera that is operable over a wide wavelength range of 300 nm to 1600 nm and measures the relative intensity and duration of optical pulses. The high sensitivity of the instrument makes measuring even very weak optical pulses possible, without which capability the difficulty of aligning and collecting optical emissions in high magnetic fields would greatly limit these experiments. In addition, the streak camera is housed within a custom-designed magnetic shield, where the camera has successfully been used to measure photoluminescence (PL) lifetimes at full magnetic field in SCM3. Using graded-index fiber optics to couple a sample's PL into the streak camera, a minimum time-resolution of 6 picoseconds has been attained, as illustrated in Figures 1 and 2. As a result of these achievements SCM3 is being subscribed, and research time can currently be requested by proposal submission via the Users Hub online.

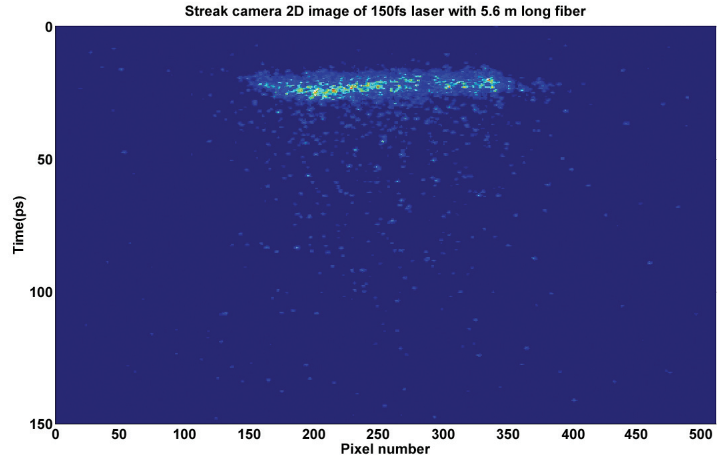


Figure 1.
2-D streak image of the laser excitation pulse traveling through the optical fibers used to couple PL into the streak camera. The width of the image shown is the spatial map of the pulse onto the detector. The vertical dimension represents the time axis, with earliest times at the top and latest times at the bottom.

Optical spectroscopy encompasses a broad range of techniques that provide a wealth of insight into the structure and dynamics of materials. These spectroscopies are especially robust for high-magnetic-field research as they are non-invasive and contactless remote measurements. In time-resolved optical spectroscopy, changes in the intensity, polarization and energy of light transmitted, reflected, or emitted from a sample can be measured as a function of time, typically with ps to sub-ps resolution. Time-resolved changes in absorption and transmission reveal transient redistributions of optical spectral weight as well as phase-space relaxation. Similarly, modifications of polarization can convey the switching rate of magnetic moments, the extent of spin-lattice coupling, and even the dynamics of structural changes within a crystal. In addition, the intensities and lifetimes of optical emissions, such as PL, give insight into the symmetry of optical states, their mixing or separation in an applied magnetic field, electron-hole pairing (e.g. exciton formation and recombination), and electron-hole interactions with other excitations such as phonons and magnons just to identify a few possibilities.

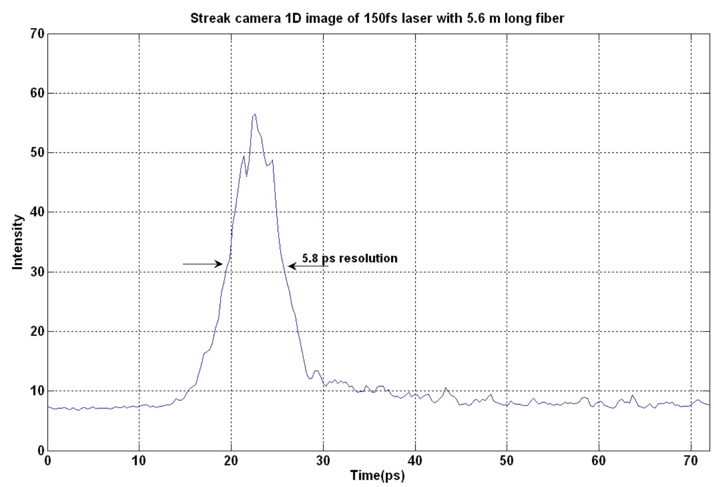
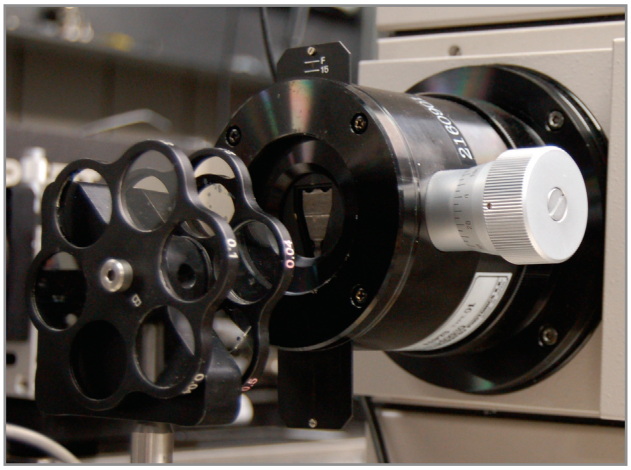


Figure 2.
This 1-D image represents the streak signal integrated over the spatial width of the detector. As demonstrated, a minimum resolution of 6 ps was obtained. The resolution limit of the instrument is 2 ps.

One important justification for combining ultrafast measurements with high magnetic fields lies in the fact that though magnetic energies are small and may produce indiscernible optical changes in the steady-state, the same applied fields can result in dramatically different dynamics that can identify the observed physics.

Examples of the advantages gained by performing ultrafast spectroscopy in high magnetic fields are found in current user research involving the streak camera. One project being performed by David Reitze's group from University of Florida in collaboration with Junichiro Kono of Rice University is investigating quantum optical phenomena in semiconductor quantum wells. This research combines optical pumping with high magnetic fields to create a dense electron-hole plasma in the semicondector's Landau levels. The high magnetic field increases the density of states so that the carrier density may achieve a cooperative recombination regime.[1] If the coherance buildup time becomes short enough, then it may be possible to make novel observations of quantum optical phenomena, such as superflourescence emission, in semiconductors. In this particular case, measuring changes in the dynamics of fluorescence emission with increasing magnetic field is imperative to identifying and understanding the physical processes creating these novel states.


The streak camera is now available to users.

Another ultrafast project endeavors to study magnetically induced brightening of PL emission from carbon nanotubes. This work is being performed by Kono's group. The brightening has been proposed to result from a mixing of bright and dark exciton states caused by application of a magnetic field.[2] The magnetic flux contained within the nanotube lifts the valley degeneracy of +k and –k permitted momentum states on the circumference of the nanotube as a manifestation of the Aharonov-Bohm effect. Within this model, as the magnetic field breaks this inherent symmetry, the PL intensity should increase. Since nanotube diameters are typically on the order of 1 nm, high magnetic fields are required to provide enough enclosed flux to observe these behaviors. Studying the evolution of PL lifetimes in carbon nanotubes at high magnetic fields will provide further evidence for and a deeper understanding of the state mixing that occurs. Additionally, these measurements are also fundamental to understanding electron-phonon interactions in carbon nanotubes as well as for evaluating their potential use as optical components in nanoscale electro-optical devices.[3]

A final example of current research involving the streak camera comes from within the field of spintronics, which attempts to incorporate control over an electron's magnetic moment (i.e. spin) into electronics. Magnetically doped semiconductor nanocrystals hold important promise as components of spintronic devices that have been proposed for quantum computing, for example.[4,5] Though the sp-d exchange that occurs in bulk dilute magnetic semiconductors has been shown to result in giant Zeeman splittings and carrier-mediated ferromagnetism,[6] understanding the modifications to sp-d coupling due to quantum confinement at the nanoscale is an important challenge. Geoffrey Strouse's group at Florida State University has made important contributions in the synthesis of semiconductor nanocrystals doped with magnetic impurities and is also studying PL lifetimes of both doped and undoped nanocrystals of varying size in an attempt to decipher the electronic structure and interactions regulating magnetic correlations at the nanoscale.

The ultrafast facility is looking for users and all of the instruments mentioned here and more are available for use.

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Phase separation and giant magnetoresistance in a perovskite oxide

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The transition metal oxides with their very wide range of properties, from colossal magnetoresistance to superconductivity, provide fertile ground for the discovery of new physics and applications. In spite of extensive investigations in recent years, the unusual and interesting properties of these materials are still not well understood and much more needs to be done to clearly identify the mechanisms driving their behavior. The properties of the oxides may be tuned by doping with holes or electrons. Over a range of doping levels and sample temperatures, nanoscale phase separation occurs with the coexisting phases exhibiting different physical properties that determine the macroscopic properties. Competing interactions underlying the phase separation are delicately balanced, giving rise to what has been termed electronic soft matter for which the macroscopic behavior can be readily altered by applying external fields. The cobaltites, such as $La_{1-x}Sr_xCoO_3$ (LSCO), are examples of such systems. The present experiments have used nuclear magnetic resonance to determine the hyperfine field distribution and to identify the inhomogeneous coexisting phases, leading to a modified understanding of the phase diagram.

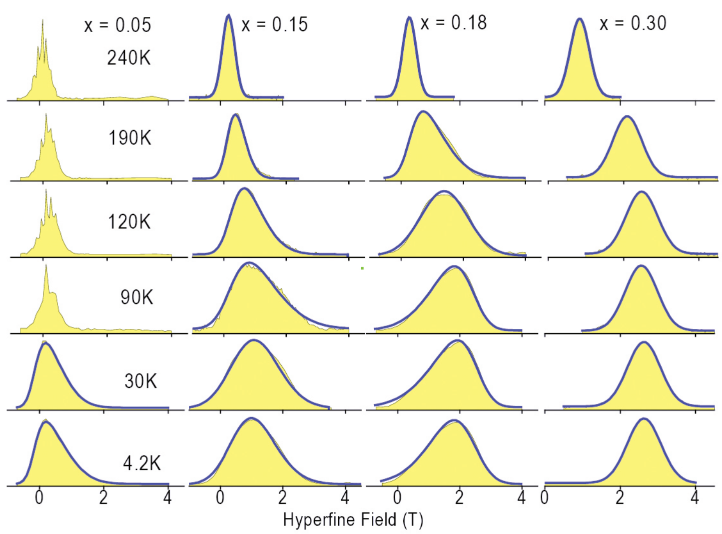

Figure 1.
^{139}La NMR field-sweep spectra for single crystal LSCO at 84.2 MHz showing the internal hyperfine field distribution at La sites as a function of *x* and *T*. The spectra are fitted with a skew-normal distribution.

The thermodynamic phase diagram for LSCO has a metal-insulator transition at $x_C = 0.17$, with long-range ferromagnetism occurring in the metallic phase below the Curie temperature T_C. Nanoscale phase separation has been shown to occur for $x < x_C$ and a droplet model involving small magnetic clusters in a non-ferromagnetic matrix has been proposed to account for the large magnetoresistance and other properties. In the low temperature ferromagnetic phase ($x > 0.17$), coupling between pairs of Co ions in different valence states is due to the double exchange mechanism in the hole-doped regions. The driving mechanism for phase separation in the cobaltites is not clear but involves a number of competing effects, including double exchange interactions, the Coulomb energy of clusters and disordering Jahn-Teller distortions, correlated either locally or over an extended range.

NMR provides a powerful means for detecting inhomogeneities in magnetic materials from the measured local hyperfine field distribution. The present work has applied in-field NMR to a set of floating-zone-furnace grown single crystal LSCO samples from Argonne National Laboratory, with *x* values in the range 0.05 to 0.30. ^{139}La NMR spectra in LSCO exhibit down-field shifts from the bare nucleus value, proportional to the local magnetization, thus mapping the internal field distribution. Figure 1 shows the ^{139}La spectra for four of the samples as a function of *T*. The spectra for the other samples showed similar behavior with a gradual evolution in shape and average field shift with increasing *x*. Resolved spectral features and large shifts corresponding to FM regions at $x<0.17$ observed previously in sintered powder samples are not found in the single crystal spectra.

The single crystal NMR lines are broad and in general asymmetric, with a wide distribution of hyperfine fields at the La sites. A skewed Gaussian (skew-normal) function with three independent fitting parameters, (center field, width and skewness) provides excellent fits to the spectra in Figure 1. Using a color display for the skewness parameter and a curve based on the center field behavior with *x* and *T* as a boundary between paramagnetic and more strongly magnetic regions, we show in Figure 2 the behavior of two of the experimental fit parameters as an overlay on the thermodynamic phase diagram for LSCO. As can be seen regions exhibit phase inhomogeneity over a broad region in the *x*-*T* plane. Phase separation into ferromagnetic and nonferromagnetic regions is found for a small range of *x* values from 0.17 to 0.25 but the inhomogeneous nature of the material extends over a much wider range as shown in Figure 2.

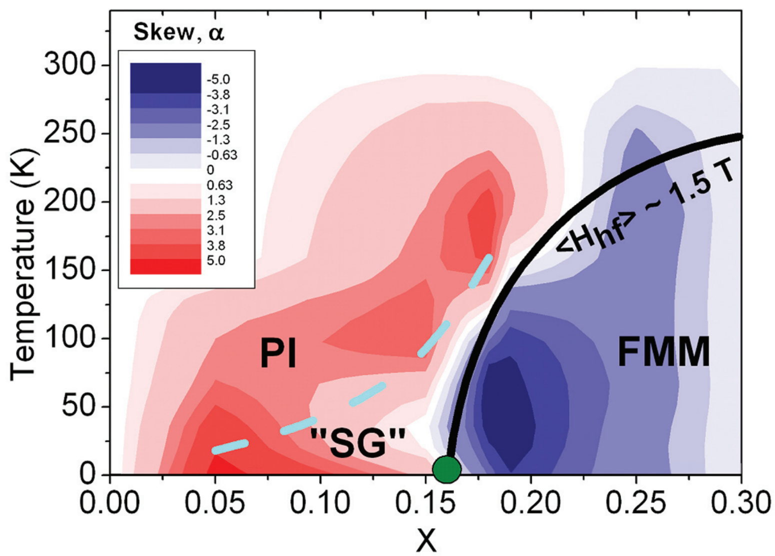

Figure 2.
Contour plot of the skewness of the ^{139}La NMR spectral fit parameter overlaid on the thermodynamic phase diagram. The solid line marks the boundary where we find $\langle H_{hf} \rangle \approx 1.5$ T, which closely matches the transition to a ferromagnetic metal (FMM) found in transport and magnetization measurements [1]. The green dot is the 0 K insulator – metal transition, and the dashed line is the spin glass (SG) region from Ref. 1, which we argue is rather an expected region of glassy behavior in our polaron model. The dark red and blue regions denote the inhomogeneous region around the FMM transition at which the NMR spectra exhibit a large skewness parameter $|\alpha| > 2.5$ ascribed to the coexistence of PI and FMM phases over a large region of the temperature-doping phase diagram.

Computer simulations that we have made using a statistical model show that, for *x* values near x_C, departures from local random fluctuations in Sr^{2+} concentration occur with hole-rich regions growing at the expense of hole-poor regions. Correspondingly, phase separation into distinct long-range ferromagnetic and non-ferromagnetic phases occurs over only a small range of *x* close to x_C. For $x< x_C$ the data analysis suggests that a model involving magnetic polarons, with a distribution of cluster sizes, can describe the inhomogeneous non-ferromagnetic phase. Large clusters grow into connected ferromagnetic regions as *x* is increased above x_C and for $x = 0.3$ the sample appears to be single phase. This new information on the inhomogeneous nature of the metallic and non-metallic phases for a range of *x* values will assist in understanding the properties of LSCO including the large magnetoresistance and the spin-glass-like properties that are found.

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New Web tools for automated analysis of metabolite mixtures by NMR spectroscopy

Fengli Zhang[1], Steven L. Robinette[3], Aaron T. Dossey[3], Cherian Zachariah[3], Lei Bruschweiler-Li[2], Arthur S. Edison[1,3], and Rafael Bruschweiler[1,2]

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Comprehensive identification and quantification of different chemicals in biological mixtures is a key aspect of the emerging field of "metabolomics." Metabolomics, which is an integral part of systems biology, aims at the systematic study of the unique chemical fingerprints that specific cellular processes leave behind, specifically the study of their small-molecule (< 1000 Da) metabolite profiles. Due to the inherent complexity of most biological mixtures, reliable and efficient methods are needed to identify the components that are suitable for automation. Frequently, the chemical components occur at low concentrations and can undergo isomerization, which makes their isolation and identification notably hard. Nuclear magnetic resonance (NMR) spectroscopy has a unique potential for this task as it (a) does not *a priori* require potentially labor-intensive and costly physical separation of the components prior to measurements and (b) can provide quantitative concentrations of the different metabolites.[1]

Table 1. Covariance NMR Metabolomics Web Portals

http://spinportal.magnet.fsu.edu/covariance/covariance.html
- Automatically generates a covariance NMR spectrum using Bruker, Varian, or NMRPipe data as input

http://spinportal.magnet.fsu.edu/demixC/demixC.html
- Identifies NMR traces of individual components of metabolomic mixtures
- Accepts NMRPipe or covariance Web server data as input

http://spinportal.magnet.fsu.edu/webquery/webquery.html
- Automatically searches DemixC results (above) against NMR databases
- Can also be used as a standalone tool to search NMR databases using chemical shift information of query spectra

Biologically active molecules are often produced in small quantities creating a challenge for NMR sample preparation and detection. Higher magnetic field (such as the Magnet Lab's 900 MHz Ultra Wide Bore spectrometer[2]) and better probes (such as the Magnet Lab's 1-mm high-temperature superconducting, HTS, probe[3]) help to overcome some of these issues. The HTS probe proved essential to recent studies of defensive secretions from a single insect.[4,5]

We have recently developed three interrelated covariance-based NMR metabolomics Web servers or Web portals (see Table 1). Covariance NMR[6,7] processing has been made available previously using NMRPipe and Topspin software (which can be downloaded from http://spin.magnet.fsu.edu/). Now, users can conveniently perform covariance NMR through our Web portal. In a next step, the DemixC part of the Web portal accepts TOCSY-type spectra of the mixture as input, and returns traces (spin systems) of individual components of the mixture. In the last step, the Web query part of the Web portal searches the DemixC results against NMR spectral databases. The three parts of the portal can be used together or separately, depending on the specific needs.

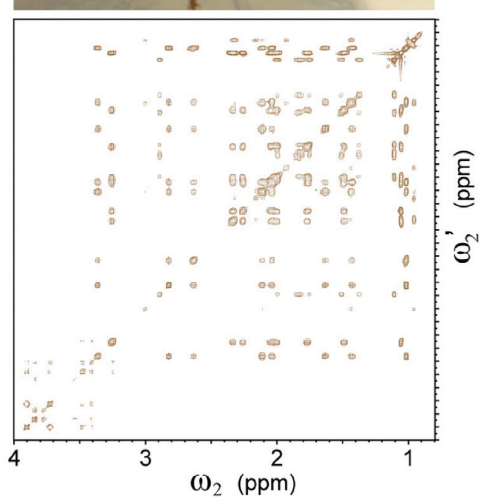

Figure 1.
Covariance NMR result for aliphatic section of TOCSY spectrum of defensive secretion of a single walking stick insect.

Figure 1 shows the covariance NMR spectrum of the aliphatic section of the TOCSY spectrum of defensive secretion of a single walking stick insect. The sample of a single defensive spray milking from a single adult female *Anisomorpha buprestoides* was collected in the field from the University of Florida Natural Area (exact position 29º 38′ 1″ N, 82º 22′ 11″ W) and immediately frozen. Prior to NMR analysis, the sample was thawed and dissolved in D_2O, and a 10 µL sample was transferred to a 1-mm NMR tube. The covariance TOCSY spectrum (**C**) of the mixture was obtained from the standard 2D Fourier transform NMR spectrum (**F**) by the matrix square root

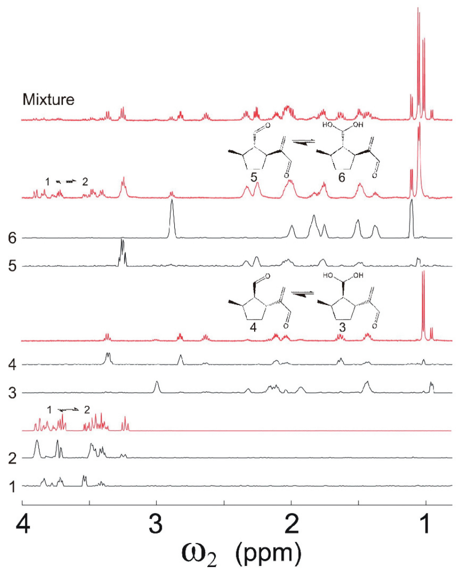

Figure 2.
DemixC result: top spectrum: 1D ^{1}H NMR spectrum of the mixture. Six black spectra: covariance TOCSY traces picked by DemixC. The bottom three red spectra are reference 1D spectra of purified components.

operation $\mathbf{C} = (\mathbf{F}^T \mathbf{F})^{1/2}$.[6,7] Because of its inherent symmetry, **C** displays the same high spectral resolution along both dimensions.

In the DemixC analysis,[8] for each trace (row) of matrix **C** the importance index is calculated as the sum of all elements of the corresponding row of $\mathbf{C}^2$, which is a measure of the cumulative overlap of this trace with all other traces of **C**.[8] Based on the importance index profile, a subset of traces of **C** are selected and clustered according to the agglomerative clustering algorithm. For each cluster a representative trace is identified as the one with minimal overlap. In this way, the likelihood is optimized that the selected traces reflect individual components free of spurious contributions from other spin systems. The DemixC result for defensive secretion of a single walking stick insect is shown in Figure 2. Traces 1 and 2 are readily assigned to α-glucose and β-glucose, which are present in slow equilibrium. Traces 4 and 5 correspond to anisomorphal and peruphasmal (see insets), respectively, which are two monoterpene dialdehyde stereoisomers that are components of the defensive secretions of *A. buprestoides*. In aqueous solution, each monoterpene dialdehyde is in chemical equilibrium with a geminal diol form, and the diols from anisomorphal and peruphasmal correspond to traces 3 and 6, respectively. These components have been independently confirmed by gas chromatography, mass spectrometry, and traditional NMR.[4]

A promising and highly efficient approach to assign these traces to their underlying compounds screens the traces against a NMR spectral database. Several spectral databases are available in the public domain, such as the metabolomics/metabonomics database of the Biological Magnetic Resonance Data Bank (BMRB) (http://www.bmrb.wisc.edu) and the Human Metabolome database (http://www.hmdb.ca). The Web query part of the Web portal presently searches the DemixC traces against the BMRB database. Figure 3 shows the result of a Web query for a DemixC trace (top spectrum, red) that serves as an input. The top three scoring compounds returned by the Web server are shown in blue. The Web query correctly identifies the trace as belonging to myo-inositol (top return).

In summary, we have described here the three parts of the recent Covariance NMR Metabolomics Web Portal consisting of (i) a covariance NMR server, (ii) the DemixC server and (iii) the web query server, which aid the identification and quantification of chemical components of metabolomics mixtures without requiring physical separation of individual components. This Web portal, which allows users easy uploading and downloading of NMR data, should significantly facilitate the analysis of a wide range of biological mixtures.

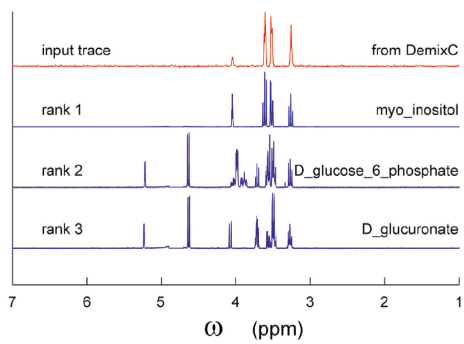

Figure 3.
Web query result. Top spectrum: DemixC trace used as input. Bottom three spectra: top three returns of web query against BMRB database, which shows the correct component (myo-inositol) as the top return.

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The Long Road to Tambopata: How the 1-mm HTS NMR probe is creating new international opportunities in natural products

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2 Center for Rhizosphere Biology, Colorado State University
3 Departamento De Ciencias Sección Química, Pontificia Universidad Católica Del Perú

In several previous issues of *Mag Lab Reports*, we have described some of the technical details and great capabilities of the Magnet Lab 1-mm HTS NMR probe. Bill Brey and his outstanding RF engineering team at the Magnet Lab designed the probe, which was constructed by our commercial partner in the project, Bruker Biospin. With a sample volume of just 5-8 µL, we think the probe has greater mass sensitivity *at any field strength* than any other probe in the world (Brey, 2006 #6). In this issue of *Mag Lab Reports*, you can read about how the 1-mm HTS probe has contributed to exciting work in complex biological mixtures with Fengli Zhang and Rafael Brüschweiler. This short article outlines some of the interesting and unanticipated new directions and opportunities that have developed as a result of this new bit of Magnet Lab technology.

The journey started after Jorge Vivanco, director of the Center for Rhizosphere Biology at Colorado State University, read a paper by Aaron Dossey and coworkers describing the analysis of the defensive secretion of a single walkingstick insect (Dossey, 2006 #2273). Although Jorge is not an entomologist, he works on several projects that involve characterizing very small quantities of secreted material from the roots of plants. Jorge invited Art Edison to CSU last April to give a seminar on the 1-mm HTS technology and applications. This was a productive trip, and the Vivanco lab has become a new external user group of the Magnet Lab/AMRIS facility to analyze *Arabidopsis* root secretions; the Edison lab has also sent secreted material from *Caenorhabditis elegans*, a small soil-dwelling nematode, to the Vivanco lab for biological characterization. We hope to report outcomes of both of these collaborative projects in the near future.

However, the most interesting part of the CSU visit began when Jorge, a native of Peru, described his upcoming sabbatical in Eric Cosio's chemistry laboratory at Pontificia Universidad Católica Del Perú (PUCP). Jorge and Eric have established a collaboration to investigate several interesting chemical ecology projects in the Tambopata National Reserve (TNR), part of a vast 2.5 million acre protected natural preserve in Peru's Amazon basin. This preserved area of tropical rainforest is larger than Yellowstone National Park and is considered by many to be the most biodiverse region on earth. TNR is home to 17% of all known species of birds, about 15,000 species of plants, and several exotic large predators including jaguar, anaconda, caiman, and giant otter.

It took very little effort for Jorge to convince Art that there are some very exciting new chemical and biological opportunities in the TNR. Of course, Art also pointed out the necessity of having an NMR expert help with sample collection, and so our adventure began...

PUCP is one of the best universities in Peru. Students at PUCP have great opportunities to participate in chemical biology projects in the TNR under Eric Cosio's supervision. However, Peru is lacking in major analytical instrumentation, and PUCP has the only NMR spectrometer in the entire country: a 300 MHz Bruker instrument. Therefore, Eric, Jorge, and Art decided that as part of any efforts collecting samples in the TNR, we would also try to provide new educational opportunities and access to high-field NMR to students in Peru.

As part of the Magnet Lab diversity program, Art recently traveled to Lima and gave a seminar that showed research opportunities at the Magnet Lab to chemistry students at PUCP. We hope to recruit one or two students who can work with students in the summer Research Experiences for Undergraduates (REU) program. Students who were interested in chemical biology could learn the basics of NMR data collection and analysis with free or inexpensive computer software. In the future, samples that are obtained in the TNR or other natural preserves in Peru could be sent to the Magnet Lab for data collection, and experienced students could interpret NMR spectra in Peru.

We have also planned our first collecting trip to the TNR in early December. Aaron Dossey, the walkingstick secretion expert in the Edison laboratory, and Art will join Jorge, Eric, and other colleagues from Peru on a field trip to collect insect secretions and explore new chemical ecology problems such as the chemical composition of a clay lick used by parrots and macaws, and several interesting observations of specific plant/ant or ant/frog interactions. We hope that this visit is the start of a new long-term relationship between PUCP, CSU, and the Magnet Lab.

Jorge Vivanco (left), Art Edison (center), and Eric Cosio (right) visiting the Pachacamac ruins near Lima. This site has structures from much of the past 2000 years, culminating with the Inca Sun Temple (1400-1500 C.E.). This photo was taken by Tiffany Weir on the Sun Temple and shows the Pacific Ocean in the background.

While our initial plans were being developed, we learned about an exciting new funding opportunity called an International Cooperative Biodiversity Group (ICBG). These groups are funded by the NIH International Fogarty Center with financial input from other NIH institutes, the NSF, DoE, and USDA. ICBGs are large collaborative projects between institutions in the USA and an underdeveloped country with rich biological resources. The program has four major goals: 1) discovery of new compounds for human health, agriculture, or energy, 2) conservation and biodiversity inventory, 3) education and training, and 4) partnership and development with the host country. We had many of the required pieces established and have decided to develop an application for a new ICBG based in the Tambopata National Reserve. The overall project will primarily focus on the discovery of novel molecules in the rhizosphere of the TNR. The rhizosphere is the soil that surrounds roots of plants, and it contains numerous interacting microbes, nematodes, and insects. Among other things, we will obtain small molecule extracts of TNR rhizosphere and screen for activity against several diseases with several other collaborators. Active extracts will be fractionated, and fractions will be tested for activity until we have a relatively simple mixture or pure compound. We plan on extensively utilizing the NMR mixture analysis tools from Brüschweiler and Zhang that were described in this *Mag Lab Reports*.

The ICBG proposal is due in December, and we will be very busy putting together this complex document that requires considerable effort for scientific plans but also legal documents that outline very interesting details of permits, royalties, intellectual property, informed consent, and other political/social requirements. Regardless of how we do in the ICBG proposal, we have had a great time getting to this point, and new areas of science have opened up for all of us.

All of these new relationships with Peru have happened because of the development of a new NMR probe developed at the Magnet Lab and UF. Although it is often difficult or impossible to predict how new technology will influence new applications, it is clear that the NMR and RF engineering efforts at the Magnet Lab are creating exciting new opportunities for chemical and biological science.

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Magnet Lab taking bold steps to address lack of diversity in science

By Amy Mast

As many a scientist will tell you, numbers rarely lie. The Magnet Lab boasts many big numbers to be proud of: publications, awards and honors, collaborations, scientific data, and grant money are each trumpeted, impressive numbers all.

But seven is a small number. Seven is the number of postdoctoral and senior-level African-American scientists currently employed at the lab. Eleven isn't such a large number either; that's the percentage of female senior scientific staff at the lab.

In the "open door lab," graduate research assistant Kenny Purcell and postdoc Tesfaye Gebre check O-rings on the gas handling panel used for crystal growth operations.

As bleak as those numbers appear, the lab's diversity statistics are better than national averages of similar institutions. The lack of diversity is prevalent across the scientific community, and is most keenly felt in physics, the core of the Magnet Lab's research program.

"The problem is huge," said Mag Lab Director Greg Boebinger. "And despite several decades of honest attempts, very few universities have been successful in making big changes," he said. "But we as a nation simply have to succeed."

The Magnet Lab intends to become a nationally recognized leader in the diversity of its scientific, technical and engineering staff, and with its Diversity and Inclusion Action Plan in place, the lab is demonstrating its commitment to finding innovative ways to increase the diversity of its staff.

TAKING ACTION

Magnet Lab founding director Jack Crow launched the lab's diversity initiative in 2004. His chosen head of the diversity committee was Dragana Popovic, a Mag Lab physicist who, when asked about the diversity initiative, pulls out a manila folder as thick as an arm.

"I don't think diversity has changed dramatically here since I started in 1995," said Popovic, "but the willingness to improve it certainly has."

Central to the lab's diversity initiative is the Diversity & Inclusion Action Plan, fueled by several goals with one larger aim: to build diversity permanence into the Magnet Lab scientific population. Expanding advertising strategies to reach women and ethnic minorities, hiring underrepresented groups at a greater percentage than the lab's present diversity statistics, and tracking progress by using three year running averages of diversity statistics to provide annual, concrete feedback fill out the lab's permanence strategy.

The changes are small, but they're happening. Here's a snapshot of diversity statistics in January 2004, the year the diversity action plan was put into place, and in January of this year.

Senior Scientific Staff: 2005	***Senior Scientific Staff: 2007***
*Male 142 (**92%**)*	*Male 166 (**89%**)*
*Female 13 (**8%**)*	*Female 21 (**11%**)*
*White 128 (**83%**)*	*White 151 (**81%**)*
*Black/ African American 1 (**<1%**)*	*Black/ African American 3 (**2%**)*
*Asian 26 (**17%**)*	*Asian 33 (**18%**)*
*Hispanic/ Latino 3 (**2%**)*	*Hispanic/ Latino 5 (**3%**)*

Thinking small, Popovic noted, can yield big results in the long term. "If you look at female grad students, the percentage is about 30 percent. If you look at postdocs, the percentage is about 20 percent. The percentage of female senior scientists is about 11 percent. So clearly, there is a pool. You know, maybe one day we will have 50 percent female scientists, but for now it is important to concentrate on getting the 10 percent up to 20 percent," she said.

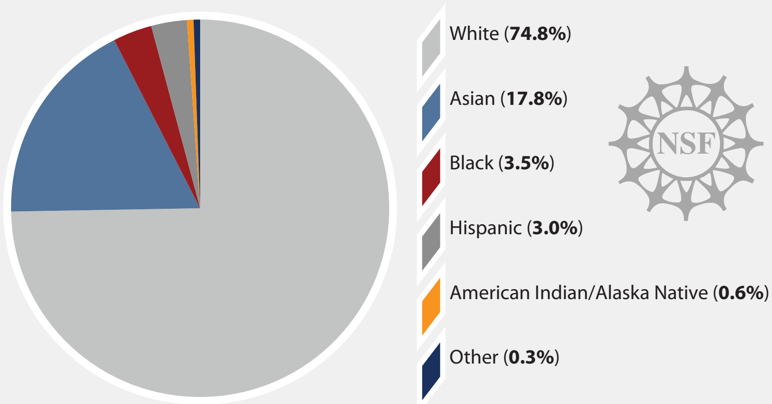
Part of making long-term positions viable for women, said Popovic, is greater flexibility for dual career couples. Before accepting her position at the lab, she explained, "When I would interview for job, I was always asked about my marital status, even though it was against the law to ask such a question. Everyone asked me, everywhere I went. I never knew what to say – should I say anything at all? Everything I did was bad, I felt, unfavorable for me. I think that situation has really changed, and there is more willingness both to accept women in general and to accommodate dual career couples."

OPENING DOORS

One hurdle as students become scientists is that students at smaller, all-female, or historically black colleges and universities may not have access to the resources available at larger research institutions. One of the action plan's most successful initiatives thus far, says Boebinger, is to develop and cultivate individualized early career opportunities for members of underrepresented groups at the undergraduate level and above.

That is done in large part through the lab's successful College Outreach – Workforce Initiative (CO-WIN). The program consists of a series of lectures designed to promote diversity in future generations. Scientists and engineers from the lab's three branches travel to women's colleges, historically black colleges and universities, and other minority-serving institutions to tell undergraduate audiences about the wide range of career development opportunities available at the Magnet Lab and its partner institutions.

US doctoral scientists by race/ethnicity: 2003



SOURCE: Women, Minorities, and Persons With Disabilities in Science and Engineering (December 2006)

The lectures are interdisciplinary and fully funded by the Magnet Lab, with all expenses are paid by the program. The lab's Research Experiences for Undergraduates programs are heavily marketed during these visits.

The single biggest success story in the CO-WIN effort so far is the "open door laboratory," built in the lab's A-Wing. The lab's seed money came from a series of grants to historically black colleges Prairie View A&M and North Carolina A&T, and was paired with Magnet Lab support to refurbish and maintain the lab space.

Traffic in and out of the open door lab has been steady; it's rare to walk by and find it unoccupied. "Professors and students came to spend the entire summer here," said Boebinger, adding, "It's a real way to get people networked right into the heart of the lab."

The lab has also stepped up efforts to recruit visiting scientists, Research Experience for Undergraduates (REU) participants, and postdoctoral associates with diverse backgrounds. Of course, getting a diverse group of students interested in science must take place before college, and the lab's K-12 effort strives to expand opportunities, resources and exposure to science for even the youngest students. (For more about this effort, see "Ground-up outreach jump-starts science education" on page 15.)

NEW ALLIANCES

During the upcoming budget cycle, the Magnet Lab is committing one percent of its National Science Foundation budget to improving lab diversity. Boebinger said that with this funding, the lab will be able to put more muscle into the good intentions behind the Diversity Action Plan.

Said Boebinger, "We're talking about trying to buy release time for professors at undergraduate institutions. They typically have very heavy teaching loads so they just can't do research during the year. In the summer, they don't have any salary, so they typically find whatever job they can. The ones that want to do research, I think we could cover their salaries to come here and do research. That's a very different mode than we'd worked in before, and it's a mode that could work for a more diverse group of academics. I think it's an opportunity for us to create meaningful collaborations."

The diversity plan, said Popovic, had placed a member of the diversity committee on each job search team, and individual scientists are challenged to build relationships with job candidates from underrepresented backgrounds – even if that person may not be interested in a Magnet Lab job for several years.

Qualitative changes like relationship building, outreach programming and cooperative partnerships, said Popovic, should be treated as long-term investments that yield quantitative changes in lab population over time.

Boebinger explained, "This plan represents a big challenge, but the challenges are fine. We get challenged all the time. I'm pretty optimistic. I think we've got programs that are working, but it may take time to see the real change we're putting into motion right now. This is a challenge we can meet in terms of one classroom, one undergrad program, and one new hire at a time."

Ground-up outreach jump-starts science education

By Pat Dixon

A student's decision about his or her vocation can happen as early on as grade school, which is why the Magnet Lab has made outreach programming an integral part of its mission to invite students of all backgrounds to see science as a viable career option. Get children and their teachers excited about science, and it logically follows that those children will be more likely to pursue such careers.

One of the challenges of providing outreach to K-12 students and their teachers is finding ways to expand offerings and reaching those who are typically underserved.

There is necessary pressure on national research facilities to reach a broader audience with science outreach and to encourage a more diverse population to pursue careers in science, and it's incumbent upon informal science education centers to develop innovative programming. The Magnet Lab's Center for Integrating Research and Learning is addressing this challenge in the following ways:

MIDDLE SCHOOL PARTNERSHIPS

In 2006-2007, Nims Middle School in Tallahassee, Florida, received an "F" from the Florida Department of Education, as measured by the Florida Comprehensive Achievement Test (FCAT). The school, which serves a predominantly minority student body, has embarked on an ambitious plan to improve its FCAT scores, and is working with the Center to enhance its science instruction. Through the partnership, Magnet Lab scientists and educators will mentor students on Science Fair projects, and provide outreach correlated to required curriculum, fields trips, hands-on experiences for students, and professional development for teachers.

ELEMENTARY SCHOOL PARTNERSHIPS

CIRL is working with area Title I elementary schools by providing professional development for teachers. "First Thursdays" provide quality, content-rich mini-workshops with activities that can be immediately implemented in the next day's classroom.

SCIENCE BUDDIES

Implemented by the Center's Teacher in Residence, almost 30 scientists and researchers from the three Magnet Lab sites have volunteered to work with an elementary, middle or high school teacher. Teachers, who sometimes feel isolated, can e-mail questions about content or process to their assigned scientist and receive expert information in a timely manner. The Science Buddies Program enables the lab to reach schools that typically do not participate in outreach opportunities.

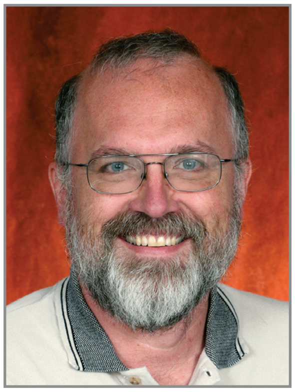
SCIPALS

SciPals is a classroom partnership between the Center and fifth-grade students at Rufus E. Payne Elementary, an inner-city school in Jacksonville, Florida. Students exchange correspondence about science with Center educators, developing their writing skills while reinforcing concepts they are learn in science.

WOMEN IN MATH, SCIENCE AND ENGINEERING (WIMSE)

The Magnet Lab is providing paid internship opportunities for undergraduate women from Florida State University who are involved in the WIMSE program. WIMSE provides support starting in the freshman year for women who are committed to careers in the science, technology, math or engineering.

People in the news



Greg Boebinger

Magnet Lab Director **Greg Boebinger**, a leading researcher in high-temperature superconductivity, has been named a Fellow of the prestigious American Association for the Advancement of Science (AAAS) "for research in high-temperature superconductivity and two-dimensional electron and hole systems, including the development of pulsed magnetic fields as a prominent research tool."

The AAAS awarded the distinction of Fellow to 471 of its members this year. Boebinger and the other new Fellows will be recognized Sat., February 16 at the Fellows Forum during the 2008 AAAS Annual Meeting in Boston.

"I am particularly honored to be named a Fellow in the AAAS because it is a wonderfully cross-disciplinary organization focused on advancing science broadly – much like high-magnetic-field research itself," Boebinger said.

The AAAS is the world's largest general scientific society and publisher of *Science*, which, with an estimated total readership of 1 million, has the largest paid circulation of any peer-reviewed general science journal in the world.

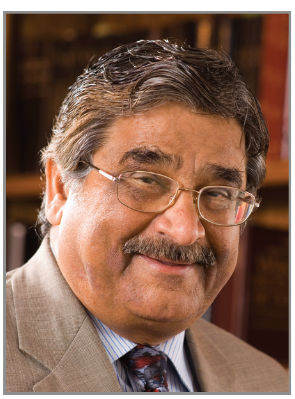
Scott Crooker

Ground-breaking research in the development of novel magneto-optical spectroscopies and their applications has earned **Scott Crooker**, a staff scientist at the Mag Lab's Pulsed Field Facility at Los Alamos National Lab, a 2007 Fellows' Prize for Outstanding Research.

Crooker's work – which employs a variety of magneto-optical spectroscopies to measure the magnetization and spin polarization of both solid-state and atomic systems – has been recognized with highly cited articles in *Nature, Science* and *Physical Review Letters*, as well as with invited and plenary talks at the American Physical Society's annual meetings, the Gordon Conference and several other national and international seminars.

"I'm very fortunate to have colleagues and managers here at Los Alamos and within the Magnet Lab who have always supported the more 'exploratory' aspects of work going on in the optics lab," said Crooker. "From a scientific point of view, it's a terrific environment."

The Los Alamos Fellows' Prize for Outstanding Research recognizes individuals for work performed at the laboratory that was published within the last 10 years and has had significant impact on its discipline or program.



Naresh S. Dalal

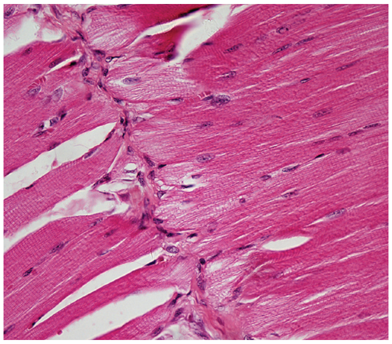
Naresh S. Dalal, a researcher with the Magnet Lab's Electron Magnetic Resonance Group and the Dirac Professor of Chemistry and Biochemistry at Florida State University, has been selected to receive the 2007 Southern Chemist Award from the Memphis Section of the American Chemical Society.

The award honors "an outstanding researcher who has brought recognition to the South," specifically the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee and Virginia. A medal and honorarium will be presented to Dalal at a meeting of the Memphis Section of the American Chemical Society in December.

"It always is a great honor to be recognized by one's peers in such a manner," Dalal said of the award. "I'm particularly pleased because this award recognizes the work I have done since I moved to Florida State in 1995."

Dalal has made notable contributions to spectroscopic techniques spanning frequencies from a few hertz to several terahertz over more than three decades of pioneering research in magnetic resonance spectroscopy, mainly electron magnetic resonance.

Wired magazine wanted to know what a Thanksgiving Day meal looked like up close – really up close. So its editors asked Magnet Lab researcher and microscopist **Michael Davidson** to do what he is perhaps best known for: putting every day items under his high-powered microscopes. The result, a feast for the eyes, appears in Issue 15.11 and online at www.wired.com.



Turkey under the microscope.

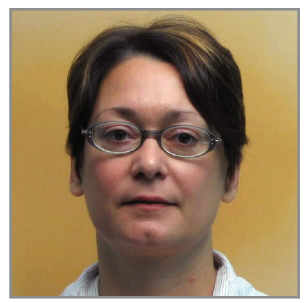
Magnet Lab affiliate and University of Florida Distinguished Professor of Physics **Art Hebard** (together with Jun Akimitsu of Aoyama-Gakuin University and Robert Haddon of the University of California-Riverside) has been selected to receive the 2008 James C. McGroddy Prize for New Materials from the American Physical Society "for the discovery of high temperature superconductivity in non-oxide systems."

Art Hebard

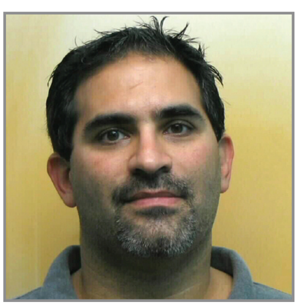
The Prize consists of $5,000 and a certificate, and will be awarded at the 2008 March Meeting of the American Physical Society. The McGroddy prize was established to recognize outstanding achievement in the science and application of new materials. Hebard was one of the co-discoverers of superconductivity in potassium-doped C60; the breakthrough paper, "Superconductivity at 18K in Potassium-doped C60," (A.F. Hebard et al., *Nature* 350, pp 600-601 (1991), has been cited 1,926 times since its publication, according to the Web of Science.

Brian McClain has joined the lab's Center for Integrating Research and Learning as the lead teacher for the Magnet Lab-coordinated SuperNet program. McClain, a science teacher at Godby High School in Tallahassee, will be working on expanding the condensed matter educational outreach offerings to teachers through workshops and Web-based support. McClain – who was named Outstanding High School Science Teacher for 2006 by the Florida Association of Science Teachers – recently presented SuperNet sessions at the Summer Meeting of the American Association of Physics Teachers and the BCS@50 Conference.

Carol Nilsson, an associate scholar/scientist in the lab's Ion Cyclotron Resonance group for more than three years, has been recruited by Pfizer Global Research and Development to direct bioanalytical research in its newly formed Oncology Pathways Platform. The research group, based on La Jolla, California, is dedicated to finding new treatments for cancer. Said ICR Director Alan Marshall of her departure, "For the past three years, Carol Nilsson has directed the Ion Cyclotron Resonance user's program. She and Scholar-Scientist Mark Emmett, in collaboration with Dr. Charles Conrad at M.D. Anderson Cancer Center, have pioneered mass analysis of the role of lipids in cancer and its treatment. Carol has provided yeoman service in recruiting, organizing, and documenting ICR users, and in guiding graduate and postdoctoral researchers. She will be sorely missed, and we wish her the best in her new job in seeking new routes to cancer treatment based on improved understanding of its fundamental biology and chemistry."

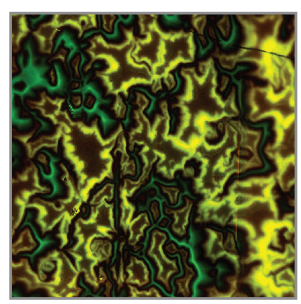


Carol Nilsson



Justin Schwartz

The American Physical Society recently featured work done at the Mag Lab in the "Images in Physics" rotation on its Web site, http://aps.org/. The magneto-optical image of magnetic fields within a YBCO superconductor shows electrically connected grains and grain boundaries that form barriers to superconducting currents. The image was created by the Magnet Lab's **Justin Schwartz** and by Ph.D. student **D.C. van der Laan**, who is now with the National Institute of Standards and Technology. For more information on the science, visit the Images in Physics section at aps.org.



YBCO

Do you have coming and goings, awards, new collaborations or Mag Lab alumni news to report? Send it to Amy Mast at winters@magnet.fsu.edu.

TV special highlights race for absolute zero

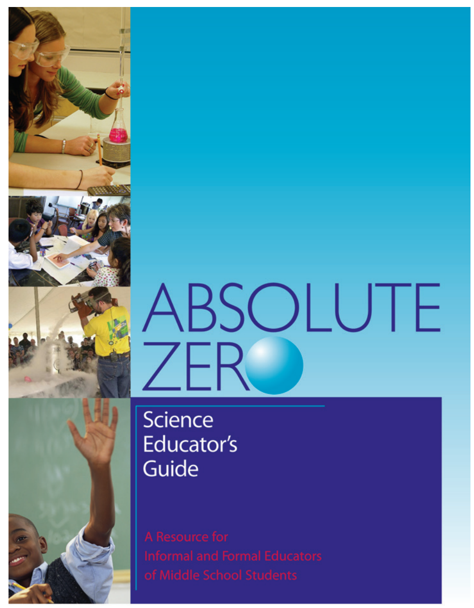
ABSOLUTE ZERO and the Conquest of Cold

Though many of us at the Magnet Lab know plenty about low-temperature physics, have a conversation with a non-scientist and you'll likely draw a blank stare. Absolute Zero is aiming to change that.

The Magnet Lab is a national partner in the Absolute Zero campaign to raise awareness about low-temperature physics. The campaign culminates in January of 2008 with a two-part NOVA special demonstrating how civilization has been profoundly affected by the mastery of cold.

Based on the book, "Absolute Zero and the Conquest of Cold," the NOVA special will be presented as two hour-long programs scheduled to air Jan. 8 and Jan. 15 at 8 p.m. on Public Broadcasting Service stations (check local listings).

Absolute Zero highlights the four-century struggle to understand the nature of cold, from dark beginnings to an ultra-cold end point. Along the way, scientists created cold technologies that have transformed the way we live, and gained insights into the nature of matter itself. NOVA brings this subject to life using a combination of colorful historic recreations and insightful interviews with science historians and Nobel Prize winners.



Part 1, "Absolute Zero: The Conquest of Cold," begins with 17th century court magician Cornelius Drebbel, who successfully created the world's first air-conditioning system. Other memorable characters include Daniel Fahrenheit and Anders Celsius who created the first thermometers; Frederic Tudor who became one of the richest men in America simply deciding to sell ice; and Clarence Birdseye who made his name with frozen food.

Part 2, "Absolute Zero: The Race for Absolute Zero," tells the gripping story of the decades-long scientific race between Scottish physicist James Dewar and Dutch physicist Heike Kamerlingh Onnes, as the two men fought to reach the coldest temperature. Their discoveries opened the door to the modern era of refrigeration and air conditioning. Absolute Zero's final chapter climaxes in the Nobel-winning breakthrough, the production of a new form of matter that Albert Einstein predicted would exist within a few billionths of a degree above absolute zero. This is a temperature so cold that the physical world as we know it transforms completely, electricity and fluids flow without resistance, and the speed of light can be reduced to 38 miles per hour. Three men, in two different labs, were awarded the Nobel Prize for being the first to see the peculiar state of matter that occurs near absolute zero.

The Absolute Zero Web site provides a variety of downloadable resources for science educators, including this Science Educators Guide.

In addition to the TV special, the Absolute Zero campaign includes an educator's guide and a Web site. For more information, visit http://www.absolutezerocampaign.org, which provides a variety of resources and downloadable materials, including a Community Education Outreach Guide and a Science Educator's Guide.

Absolute Zero was made possible by grants from the National Science Foundation and the Alfred P. Sloan foundation.

MLR

Science starts here

James Leif Smith

POSITION

Assistant Professor, Department of Biological Sciences
Mississippi State University

TIME AND ROLE AT THE MAGNET LAB

1997-2002, graduate research assistant in Dr. Arthur Edison's lab, University of Florida branch, Advanced Magnetic Resonance Imaging and Spectroscopy program

CURRENT WORK

Smith's research interests lie in characterizing the dynamic three-dimensional structure of lantibiotics utilizing NMR experiments and molecular modeling applications. The main reason that very little is known about the pharmaceutical potential of many of these antibiotics is due to the difficulty in producing them in sufficient quantity and purity for preclinical and clinical tests. These structures will be used to better understand their interaction and function in bacterial membranes and in the design of mimetic lantibiotic compounds. Mimetic lantibiotics that retain bioactivity will further be explored for their potential pharmaceutical applications.

MOST IMPORTANT LESSON LEARNED AT THE MAGNET LAB

Patience. Discovery is a slow and gradual process, but richly rewarding.

IN HIS OWN WORDS

"My experience at the lab differentiated me from the rest of the horde that was working towards their PhD. Most laboratories now utilize molecular biology techniques, but very few are familiar with structural biology techniques. The use of structural biology along with a proper understanding of the experiments involved is by far the most important aspect of my experience at the lab that has shaped my scientific career. My experiences at the NHMFL have equipped me with the knowledge and tools that honed my research endeavors and still continues to help facilitate my academic collaborations."

HOW MENTORS MAKES A DIFFERENCE

"(Dr. Edison) has an enormous amount of enthusiasm for NMR and academic research. His positive energy and true concern for others was inviting. My experiences with Dr. Edison and with others in his lab molded me into the scientist that I am today."

I believe my NHMFL experience is unique to my other experiences. It creates an "alumni association" mind-set. For instance, I have established collaborations with other scientists based on their association with NHMFL.

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