NATIONAL HIGH MAGNETIC FIELD LABORATORY

REPORTS

Sergei Zvyagin and Jurek Krzystek have recently completed a new facility for spectroscopy between 140 and 700 GHz in a 25 T high homogeneity resistive magnet in the DC High Field Facility of the NHMFL in Tallahassee. This new equipment is complete and has already attracted several users.

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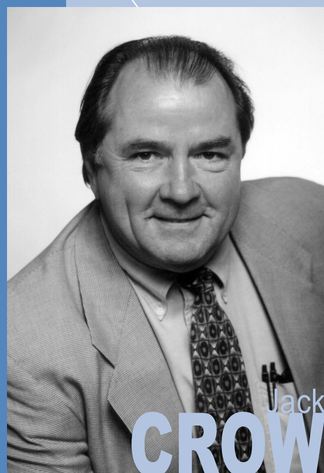

from the Director's Desk

The laboratory recently received the report of the NSF Site Visit Committee, which conducted a review of the NHMFL on May 13-15 in Tallahassee. Before addressing the report itself, I would like to recognize the distinguished members of the committee and thank them for their time, dedication, and service:

- Dr. Miles Klein, Chair, *University of Illinois, Urbana-Champaign*
- Meigan Aronson, *University of Michigan*
- Paul Chaikin, *Princeton University*
- Paul Ellis, *Pacific Northwest National Laboratory*
- Clare Grey, *State University of New York–Stony Brook*
- Michael J. Lamm, *Fermi National Accelerator Laboratory*
- David Larbalestier, *University of Wisconsin*
- Robert Scanlan, *Lawrence Berkeley National Laboratory.*

I am pleased to report that the Committee acknowledged the international stature of the laboratory, and its overall comments were positive and supportive. "The NHMFL is the premier magnet laboratory in the world. Its magnets hold the world records for producing the highest magnetic fields, both continuous and pulsed, representing substantial increases over the prior state of the art." The report continues, "Users at the Lab find excellent support staff and instrumentation to assist in setting up their experiments. Since many of the facilities are state of the art and since the visitors are pushing the scientific state of the art with their investigations, the visitors and the staff often collaborate in the research and publish jointly."

In addition to providing NSF with a "report card" on the laboratory's progress and effectiveness, site reviews and reports provide the laboratory with extremely important insights. The external perspectives of a site review committee, the NHMFL Users' Committee, or an external advisory panel help to guide the management of the laboratory as it sets priorities and makes critical operating and management decisions. Users and friends of the NHMFL may be interested in our response to

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some of the specific Site Review Committee comments and recommendations:

- The 900 MHz project will be brought to closure in April 2003.

- A previous search for a senior NMR spectroscopist was extensive, but unfortunately, unsuccessful. A new search is underway for a solid state spectroscopist, whose interests will be more compatible with the science that directly benefits from the NHMFL's unique facilities.

- The NHMFL will continue to explore opportunities to work with other agencies and international programs to capitalize on the NSF and state investment in the NHMFL's Magnet Science and Technology Program.

- The laboratory will carefully balance work for others with in-house magnet projects. The distinct magnet development groups have been integrated fairly closely over the last two years, and efforts in this regard will continue.

- The NHMFL will implement "Best Practices" management tools for future magnet development projects, which will include a phased development starting with pre-conceptual design, conceptual design, engineering and R&D phase, and finally fabrication and commission phase. This new approach to project management should provide a better basis for managing risk, cost, and schedule.

- The committee recognized the "extremely successful" condensed matter research program and the partnerships formed between internal faculty and external users through the In-House Research Program. Efforts will be made to expand these interactions whenever feasible.

- The NHMFL is proud of its success in growing the user community, both nationally and internationally, and across the various user programs (NMR, ICR, DC Field, Pulsed Field, High B/T capabilities, etc.)

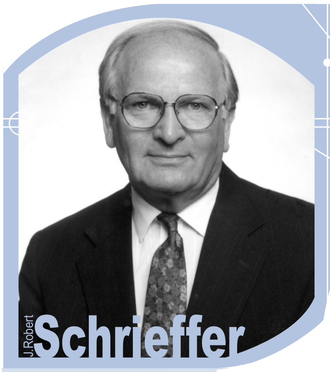
- The NHMFL consults regularly with its Users' Committee, but may have, in the past, not provided sufficient information about financial and work-scheduling constraints and about the technical challenges associated with state-of-the-art magnets under consideration. These factors, in addition to unanticipated costs associated with the repair of the 45 T Hybrid and rebuild of the 60 T Long-Pulse, have resulted in an understandable concern from the user community about the delay of the split-coil magnet. The laboratory will look for new ways to engage and inform the Users' Committee to enlist their guidance and support and to help ensure realistic expectations.

- The NHMFL has a number of international agreements in place and will continue to use every opportunity to pursue mutually beneficial international collaborations.

- The NHMFL's educational outreach program continues to enjoy enormous success and is making a national impact. At the suggestion of the Committee, the NHMFL Center for Integrating Research and Learning will submit a proposal to NSF to secure separate funding for the Research Experience for Undergraduates program. With additional independent funding, the NHMFL REU program will be able to offer a more competitive stipend and expand the number of students it can support from 15 to perhaps 20.

Following an intensive site review like the one in May, there is a brief quiet period around the lab. Before long, however, discussions among the leadership, faculty, and staff begin to focus on and incorporate the fresh ideas of the review and the guidance gleaned from the report. The laboratory is very pleased and proud of the progress that has been made over the last two years, and we will continue to strive to provide the finest high magnetic field user facilities and support in the world.

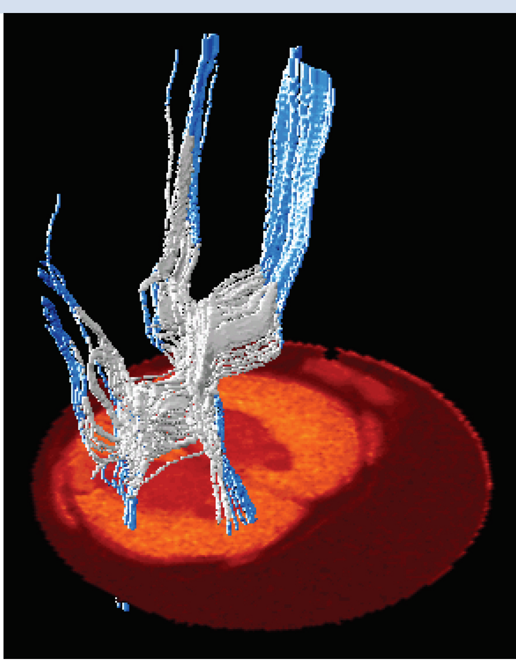
Jack Crow



from the Chief Scientist's Desk

J.Robert Schrieffer

In this issue, Tom Mareci and coworkers discuss the remarkably detailed information that can be achieved concerning multiple rates of water self-diffusion and diffusion anisotropy in biological tissue. Using very high magnetic field, 14.1 and 17.6 T, they find in spinal cord tissue that there are important differences in the fast and slow diffusion tensors. The white matter margins around the gray matter exhibit the slowest average diffusivity in the white matter. They suggest that this is due to a higher packing density of microtubules in these axons compared to other axons in the white matter. In brain slices, the bi-exponential analysis of water diffusion giving the diffusion rates and volume fractions involved. To simulate the effect of ischemia, the slices were perfused with a Na+/K+ ATPase inhibitor that caused cell swelling. The diffusion rates did not change but the volume fractions did. These measurements clearly show how detailed information can be obtained in the spatially resolved diffusion of water in important biological material.



Experimental Observations of Multiple Rates of Water Self-Diffusion and Diffusion Anisotropy in Tissue, Intact Isolated Cells, and Cell Phantoms

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Introduction: Water in biological tissue diffuses within cells, in extracellular spaces, and crosses membranes. NMR imaging can be used to measure the translational diffusion of water using pulse-field-gradient spin echo methods. Using these results, the rate and direction of diffusion can be quantified. If the water is diffusing in a structured environment, like nerve fibers, this can be used to visualize the tissue structure. For example, we have used NMR measures of water translational diffusion to create a map of the nerve fibers (colored gray-blue) within a spinal cord (representative slice in orange) shown in Fig. 1.

This view of water translational diffusion in tissue, however, is simplistic. NMR imaging and spectroscopic studies at high diffusion-weighting ($b > 1500$ s/mm^2) have shown that cells and tissues exhibit exponential signal loss described by two or more rates of decay. These rates may reflect diffusion in extracellular and intracellular water compartments,[25, 19, 21, 10, 20, 23, 2, 18, 4] but the volume fractions do not appear to agree with those determined by other methods so the interpretation of these results is unclear. In order to better understand the

Figure 1. A map of the nerve fibers (colored gray-blue) within a spinal cord (representative slice in orange) created by NMR measures of water translational diffusion. (see *www.magnet.fsu.edu* for color presentation.)

physical meaning of the measured diffusion, we have been investigating multiple-component diffusion within intact whole tissue,[14] tissue slices,[6, 4] single isolated cells,[12, 7, 8, 22] and cell phantoms.[24] In the following, we will discuss our findings concerning the origins of the fast and slow components of a two-component fit to diffusion measurements.

Methods: We used the Kärger[15] model of two-component diffusion in the slow compartment-exchange limit for the analysis of our measurements. In the limit where the diffusion time, τ, is short compared to the life-time, $\tau_{1(2)}$, of water in either compartment 1 (extracellular?) or compartment 2 (intracellular?), i.e., $\tau << \tau_{1(2)}$, a two-rate decay will be observed with the following functional form,

$$S(b)/S_0 = f_1 \exp(-bD_1) + f_2 \exp(-bD_2) \quad , \quad [1]$$

where b represents the pulse-field-gradient diffusion weighting applied by the NMR measurement method.

Conversely, in the long diffusion-time limit, i.e., $\tau >> \tau_{1(2)}$, water in compartment 1 and compartment 2 will have mixed and a single effective rate of diffusion, D_{eff}, will be observed, which is an average of the rates of the two compartments weighted by the volume fractions of each compartment. In the intermediate time limit, i.e., $\tau \approx \tau_{1(2)}$, the signal decay is bi-exponential in character but has a more complex dependence on rates and times.[15] This model is valid for spatial compartments, such as intracellular and extracellular spaces, but the model also fits for compartments representing the local environment of the water.

Also, we extended the diffusion tensor imaging (DTI) formalism of Basser *et al.*[17] to account specifically for bi-exponential diffusion.[14] For mono-exponential diffusion, a series of diffusion-weighted images may be used to compute a single-rate DTI by fitting to:

$$\ln(S/S_0) = -\Sigma_{ij} b_{ij} D_{ij} \; , \quad [2]$$

where b is the diffusion weighting factor, S is the diffusion-dependent signal intensity, S_0 is the (T_2-weighted) signal intensity in the absence of diffusion weighting gradients, b_{ij} is the i,jth element of the matrix of diffusion weighting terms,[17] D_{ij} is the i,jth element of the DTI, and i,j = x,y,z. For a two-compartment model under the assumption of slow exchange (i.e., minimal water exchanges between compartments during diffusion time), Eq. [2] may be expanded to a linear combination of observable signal components:[15]

$$S_{ij} = S_{0f} \exp\left(-\Sigma_{ij} b_{ij} D_{ijf}\right) + S_{0s} \exp\left(-\Sigma_{ij} b_{ij} D_{ijs}\right), \; [3]$$

where S_{0f} and S_{0s} are the (T_2-weighted) signal intensities in the absence of diffusion weighting gradients and the subscripts f and s denote fast and slow components of diffusion, respectively.

Samples: Diffusion tensor images of the excised fixed rat spinal cords in phosphate buffered saline solution were measured at 14.1 T.[13, 14] For isolated single cells, the L7 neuron from the abdominal ganglion of *Aplysia californica* was extracted and maintained in artificial seawater.[22] NMR measurements were performed at very high magnetic fields (14.1 and 17.6 T) using small diameter solenoidal RF coils.[26] For perfused brain slices, NMR measurements at 14.1 T were obtained from 500-μm-thick coronal slices from the rat hippocampus using a standard 10 mm RF coil in a specially constructed slice holder.[3] For erythrocyte ghosts,[24] human blood was collected from a volunteer, and ghosts were prepared by gel filtration with hemolysis induced in a hypotonic solution. Diffusion-weighted MR spectra of the erythrocyte ghosts were measured at 17.6 T.

Results: Using multiple diffusion-weightings, we have quantified multiple-component diffusion rates in whole fixed tissue (intact fixed spinal cord), perfused tissue slices (rat hippocampus), perfused single cells (*Aplysia* neurons), and cell phantoms (blood cell ghosts). In addition, we have examined diffusion anisotropy in these whole fixed tissue samples and single cells. The measurements are summarized below.

Intact Spinal Cord (fixed): The fast and slow component diffusion tensors exhibit similar gross features, such as fractional anisotropy, in both white and gray matter.[14] There also are important differences, however, that appear to be consistent with differences in intracellular and extracellular structure. In particular, the slow diffusion-component tensor exhibits subtle features that seem to be closely related to the cellular and axonal cytoskeleton. For example, the white matter margins around the gray matter exhibit the slowest average diffusivity in the white matter. This is consistent with a higher packing density of microtubules in the axoplasm of these axons compared to other axons in white matter. But the volume fractions of the fast diffusion component (66 to 80%) and slow diffusion component (20 to 34%) were not consistent with commonly accepted values. These calculated volume fractions appear to be weighted by T_2 relaxation of water with the experimental parameters used in these measurements (i.e. echo time of 36 ms with a diffusion time of 17 ms).

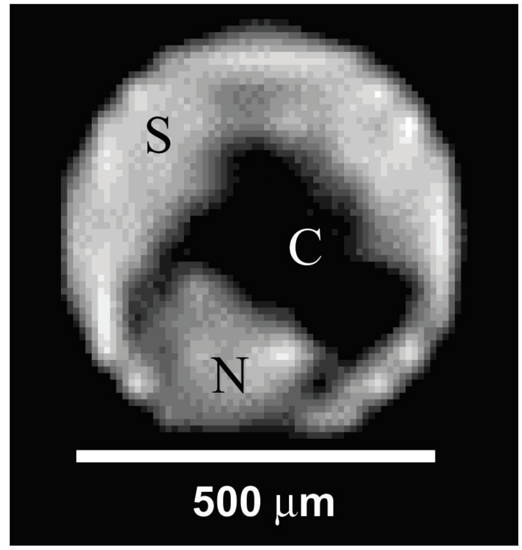
Perfused Brain Slices (Rat Hippocampus): Bi-exponential analysis of water diffusion in hippocampal brain slices[4] yielded a fast component

($1.015 \pm 0.155 \times 10^{-3}$ mm^2 s^{-1}) and a slow component ($0.089 \pm 0.026 \times 10^{-3}$ mm^2 s^{-1}), with a calculated fast-rate volume fraction of 53.3 ± 6.4%. To simulate the effect of ischemia, the slices are perfused with 1 mM ouabain (a Na^+/K^+ ATPase inhibitor) that caused cell swelling. The measured rates of diffusion did not change, but the calculated volume fractions changed. The fast diffusion volume fraction decreased by 10% while the slow diffusion fraction increased by 10. A possible effect of exchange between compartments was investigated by varying the diffusion time. At diffusion times less than 12 ms, the diffusion rates are constant, but at 20 ms the rates appear to become slower, possibly due to exchange between compartments. The effect of T_2 relaxation was investigated by varying the echo time at a constant diffusion weighting time. The measured rate of diffusion appears to increase as the echo time is varied from 24 to 100 ms indicating a differential effect of relaxation in the different compartments.

In further experiments, the cell volume fraction in the hippocampal slices was estimated by adding a paramagnetic contract agent to the slice perfusate.[5] The estimated cell volume fraction was 66 ± 4%. To investigate the effect of cell shrinkage, 60-mM mannitol was added to the perfusate resulting in a 26% decrease in cell volume fraction. Further diffusion measurements[6] were performed on slices perfused with the excitatory amino acid, N-methyl-D-aspartate (NMDA). The two rates of diffusion observed did not change upon addition of NMDA, but the volume fraction of rapidly diffusing water increased by 5%. The effect of NMDA was blocked by pretreatment with its antagonist dizocilpine maleate (MK-801).

Isolated Single Cells (L7 neuron of Aplysia californica): The cytoplasm and nucleus are resolved (see Fig. 2, Part A) and have very different relaxation and diffusion properties.[22,1,11] No diffusion anisotropy was detected in either the cytoplasm or the nucleus.[11] A 20% hypotonic perturbation to these cells[12] resulted in a significant increase in T_2 relaxation time (~20 to 30%) for both the cytoplasm and nucleus. As shown in Fig. 2, Part B, approximately a single rate of water diffusion was observed in the nucleus but the diffusion in the cytoplasm was observed to occur at multiple rates.[8] Cytoplasmic diffusion has a fast component ($0.48 \pm 0.14 \times 10^{-3}$ mm^2 s^{-1}) and a slow component ($0.034 \pm 0.017 \times 10^{-3}$ mm^2 s^{-1}) with calculated volume fractions of 61.3 ± 11.2% and 31.7 ± 11.2%. In localized spectroscopy measurements, the osmolyte, betaine, is observed in only the cytoplasm[7] with single component diffusion.[9]

Part A



Part B

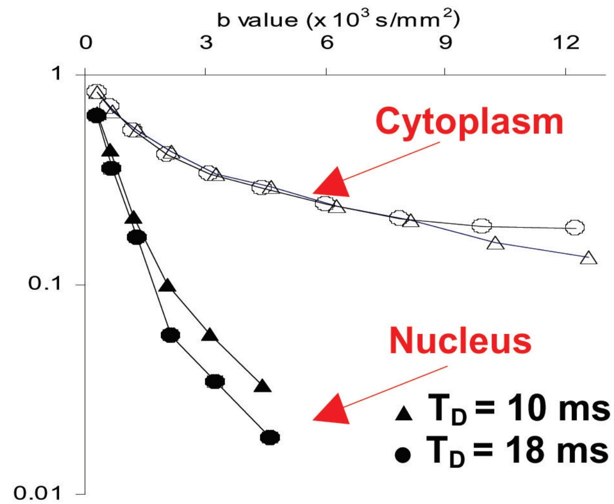


Figure 2A. Different relaxation and diffusion properties are resolved in the cell cytoplasm (C), cell nucleus (N), and artificial seawater (S) surrounding the cell.

Figure 2B. Water diffuses in the nucleus at a single rate, and at multiple

Erythrocyte Ghosts: Multi-component water diffusion was observed in ghost cell suspensions.[24] Data were fitted to a two-compartment model without including exchange as a first approximation to describe the data. The biophysical origins of the components separated by this analysis were investigated by observing the effects of cell density, membrane permeability, and cell size variation. The slow component appears to originate predominately from water molecules remaining in the intracellular compartment for the duration of the diffusion time, whereas the fast component is comprised of water molecules in the extracellular compartment and undergoing transmembrane water exchange. This interpretation allows measurement of average cell dimensions; the apparent restriction demensions of water molecules in the slow component was 1.9 ± 0.2 μm. Additionally, the mean intracellular residence time of water (determined by membrane permeability) was calculated as 21.9 ± 1.3 ms for normal ghosts, and 45 ms after treatment with the aquaporin blocker, pCMBS.

Discussion and Conclusions: In all the tissues studied here, at least two diffusion components were observed (i.e., intermediate to slow exchange). The slow-exchange two-component model of water diffusion has been used to interpret the results of these tissue studies. The hypothesis that the fast component of water is solely extracellular and the slow component is solely intracellular appears to be naive. The two-compartment model in the slow exchange regime has two distinct limitations: (1) no slower diffusion rates are included, and (2) the model does not include exchange. To address the first limitation, slower rates of diffusion may be investigated but will require higher diffusion weighting (>10,000 s/mm^2) and greater signal-to-noise ratio than were available for most of these measurements. The inclusion of exchange in the model requires additional knowledge or the ability to measure exchange. Exchange can be measured in the erythrocyte ghosts so this system represents a simplified yet controllable model to explore the contribution of exchange and other factors. A possible alternative view, however, suggests that the bulk of the slowly diffusing water might be associated with macromolecules and membranes whereas water diffusing around the spaces established by these macromolecules and membranes constitutes the bulk of the rapidly diffusing water. If true, this view may help explain the observation of two-component diffusion in the cytoplasm.

The dependence of the MR measurement on relaxation poses an addition complication for the analysis of results. The choice of pulse sequence parameters (echo time) can lead to the distortion of compartment fractions due to relaxation and exchange effects. Also, the choice of the diffusion time can lead to exchange effects for the long diffusion time acquisitions.

The origin of diffusion anisotropy must be examined with care. Water diffusion in the *Aplysia* neurons was shown to be isotropic, but this may not be true for cells with extremely anisotropic membrane and/or cytoskeletal structure (e.g. axons). The fast and slow components of diffusion in the spinal cord were shown to be anisotropic with the slow component suggestive of intracellular processes. As stated above, however, a possible alternative view suggests another role for the bulk of the slowly diffusion water. Clearly, the results of compartmental modeling applied to tissue must be interpreted with great care and may be illuminated by the further development of tissue models.[23, 16]

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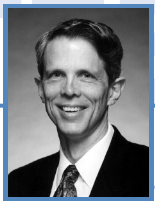


Attention Users

Bruce Brandt
Director, NHMFL DC Field User Program

Sergei Zvyagin and Jurek Krzystek have recently completed a new facility for spectroscopy between 140 and 700 GHz in a 25 T high homogeneity resistive magnet in the DC High Field Facility of the NHMFL in Tallahassee. This new equipment is complete and has already attracted several users. It is described in detail in the article below.

Sergei Zvyagin

Features of and First Results from a New Submillimeter/Millimeter Wave Spectroscopy Facility at the DC Facility in Tallahassee

Sergei Zvyagin, NHMFL/FSU
Jurek Krzystek, NHMFL/FSU

Millimeter and submillimeter (hereafter combined as submillimeter/millimeter) wave spectroscopy plays an important role connecting far-infrared and conventional microwave[1] spectral methods. It covers the frequency range of 30 to 3000 GHz, which spans the energy, temperature, and magnetic field scales relevant to numerous fascinating phenomena in condensed matter science, chemistry, and biology. It is an extremely powerful tool to study magnetic excitation spectra in solids, liquids, and gases, providing very valuable information concerning magnetic structure and interactions in many substances.

Traditional (or multi-frequency) electron-spin resonance (ESR) spectroscopy employs one constant frequency (or a set of frequencies). The spectrometer that we recently built at the NHMFL's DC High Field Facility in Tallahassee, allows for operation in a very wide, quasi-continuously covered, frequency range of 140 to 700 GHz (wavelength range of ~2.1 to 0.43 mm). This range can be expanded by buying more sources. The frequency resolution is remarkable—better than 0.05 GHz *in the entire frequency range*! A key feature of the spectrometer is the set of easily-tunable, highly-monochromatic, stable, relatively powerful microwave sources, *Backward Wave Oscillators* (BWOs). These radiation sources in combination with the highly-homogeneous (better than 10^{-5}/cm) magnetic field provided by a 25 T resistive magnet (built with financial assistance from the W.M. Keck Foundation) makes the facility in Tallahassee *unique* in solving a large number of scientific problems in this frequency-field range. Some examples of measurements that may be done include the study of elementary excitation spectra in highly-correlated electron systems; spin dynamics in quantum low-dimensional and spin-ordered materials; single-molecule magnetism; electron and magnetic structure of solids; ferromagnetic, antiferromagnetic, and cyclotron resonance phenomena; physics of field-induced and spontaneous phase transitions; high-resolution ESR spectroscopy of transition metal ions (which is of great importance in chemistry, biochemistry, and structural biology); and ESR on paramagnetic ions with large zero-field splitting.

Backward wave oscillators appeared as a result of intensive work by scientists and engineers shortly after

World War II. The development of microwave electronics towards the short-wavelength part of the electromagnetic spectrum was extremely important for improvements to radar and high bandwidth communications. A set of short-length BWOs was developed and brought to industrial production in the 1960s in France and the U.S.S.R. In the 1970s, solid-state generators (based on IMPATT and Gunn diodes) began to replace BWOs for most applications because of their lighter weight, smaller size, and so forth. Industrial production of short-wave BWOs was significantly reduced, and seems to have survived only in Russia.

A BWO (Fig. 1) is a classic vacuum-tube microwave device similar to a klystron, magnetron, or a traveling wave oscillator. It possesses an important distinguishing characteristic: it is tunable over a very wide frequency range—up to ±30% from its central frequency. The main part of a BWO is a corrugated comb-like electrode called a slowing system. Interaction of the electron beam and the variable potential of the slowing system results in velocity/phase modulation of the electrons. The periodically grouped electron bunches continue to interact with the variable potential, producing an electromagnetic wave traveling in the opposite direction (backward wave). The velocity of the electrons and, thus, the radiation frequency are determined by the magnitude of the accelerating field. The BWO needs to be adjusted in the high magnetic field by rotating it around two axes. BWO is highly sophisticated device, working in an extremely intensive mode (at high voltage - up to 5-6 kV, high temperature of cathode—up to 1200°C, with high electron beam current density—up to 150 A/cm^2).

The present configuration of the submillimeter/millimeter spectrometer includes a set of four BWOs,

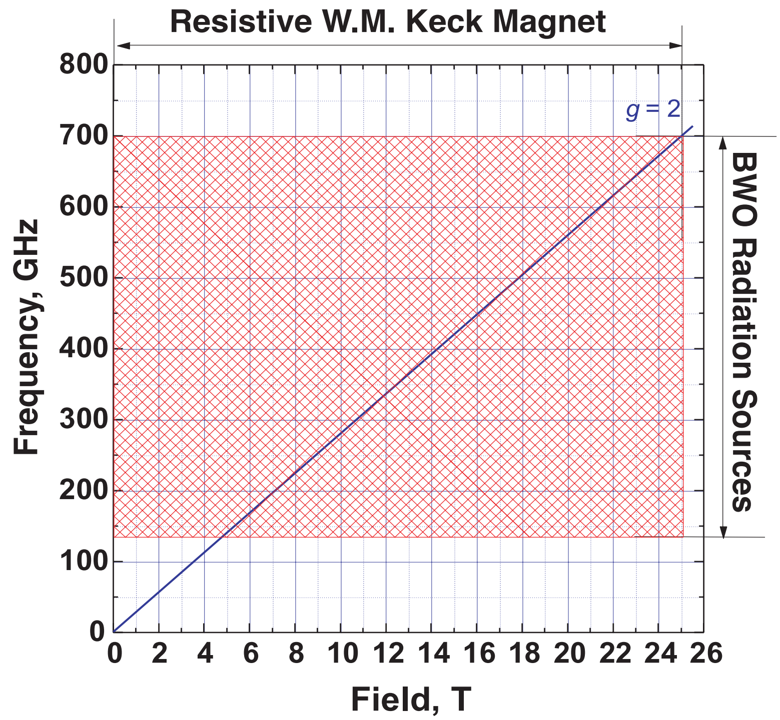


Figure 2. The frequency-field range of the facility. The line shows the frequency-field dependence of excitations with g = 2.

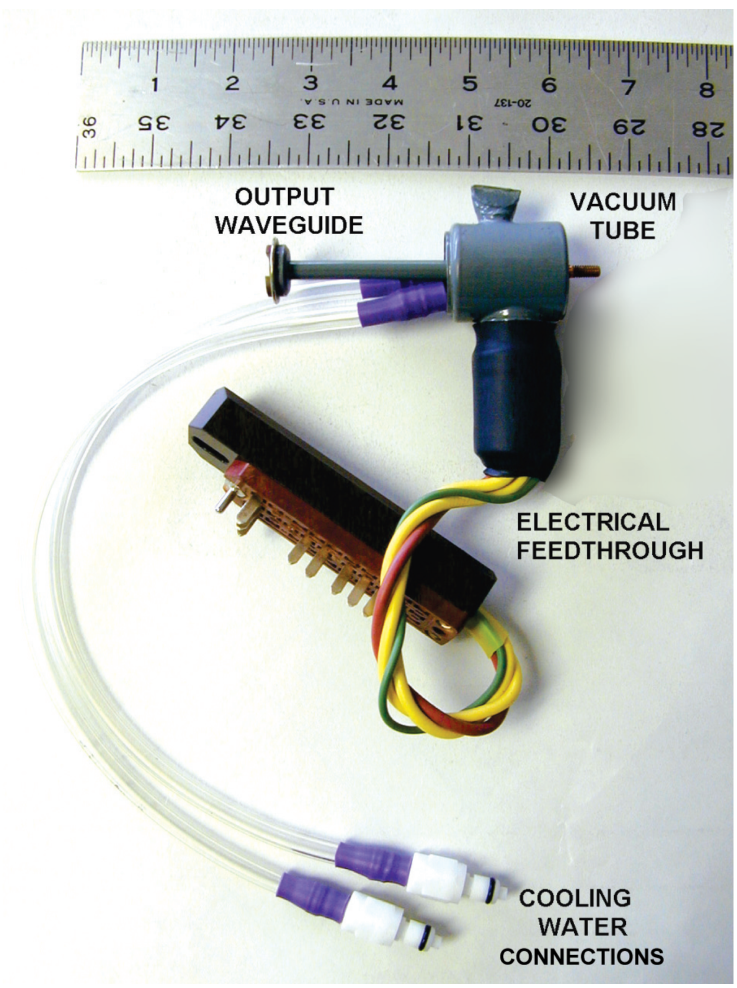


Figure 1. A backward wave oscillator.

covering the frequency ranges of 140 to 260, 200 to 380, 320 to 550, and 450 to 700 GHz with average outputs of 80, 25, 10 and 5 mW, respectively. The output power is a rather complex function of the anode voltage. The long-term frequency stability of the BWOs is better than $\Delta f/f \sim 10^{-5}$. The spectrometer works in transmission mode and employs oversized cylindrical waveguides. The spectrometer allows for experiments at sample temperatures from 1.6 to 300 K. An extremely low-noise, wide frequency range, InSb hot electron bolometer, operated at liquid-He temperature, serves as a detector. The spectra are recorded during the magnetic field sweeping. Two kinds of signal modulation are possible. While modulation of the magnetic field gives a better signal-to-noise ratio for narrower lines, modulation of the microwave power (optical modulation) allows one a direct detection of the absorption/transmission and provides better sensitivity for broader resonance lines. The spectrometer operates in the Voigt or Faraday geometry (magnetic component of the radiation parallel or perpendicular to the external magnetic field, respectively).

The facility was used to map field-induced structural phase transitions and to study resonance properties of the slightly doped spin-Peierls compound $CuGeO_3$ across the different regions of its phase diagram.[2] It is known that $CuGeO_3$, the first inorganic spin-Peierls material, undergoes a continuous structural transition from an undistorted uniform (U) phase with a gapless excitation spectrum to a gapped dimerized (D) phase with a collective nonmagnetic spin-singlet ground state at $T_{SP} \sim 14.3$ K.[3] Below T_{SP}, high magnetic field induces a transition to a new magnetic phase in which an incommensurate (I) lattice modulation is stabilized by the Zeeman energy. The field-induced lattice and spin incommensurability results in a magnetic soliton structure, where dimerized regions are separated by domain walls. It was shown that the soliton-like structure in $CuGeO_3$ exists only in a narrow range of magnetic fields close to the D-I transition.[4] This transition occurs in $CuGeO_3$ +

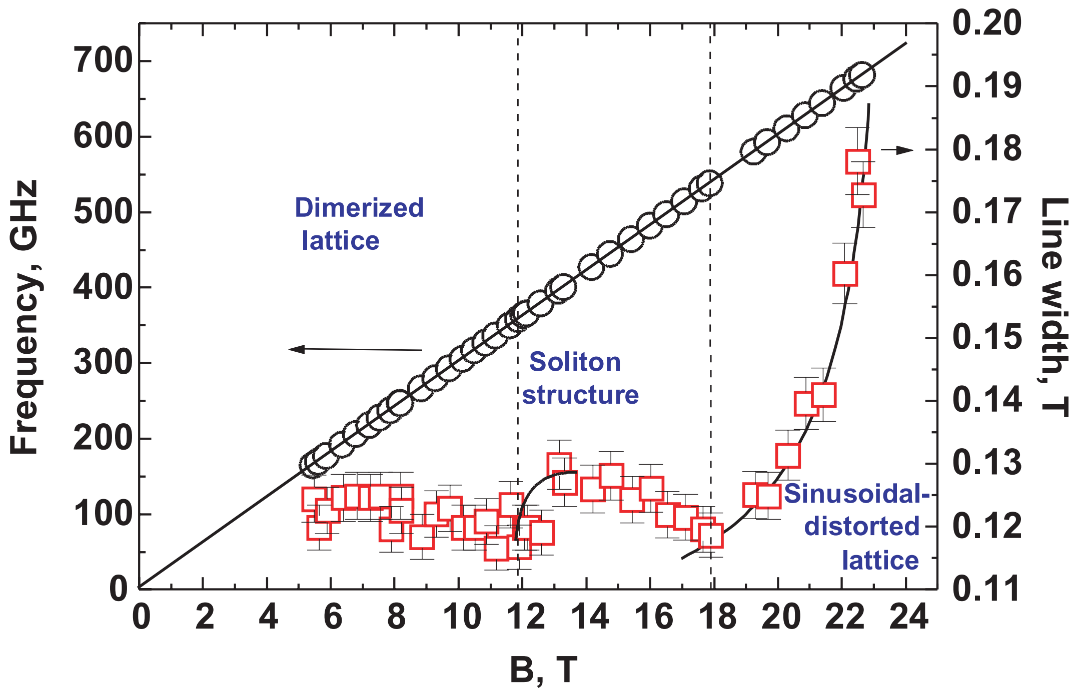


Figure 3. The ESR frequency-field dependence (circles) and the line-width, ΔB/B behavior (squares) in $CuGeO_3$ + 0.4%Si, *B // a*, T = 4.2 K. The lines are guides to eye.

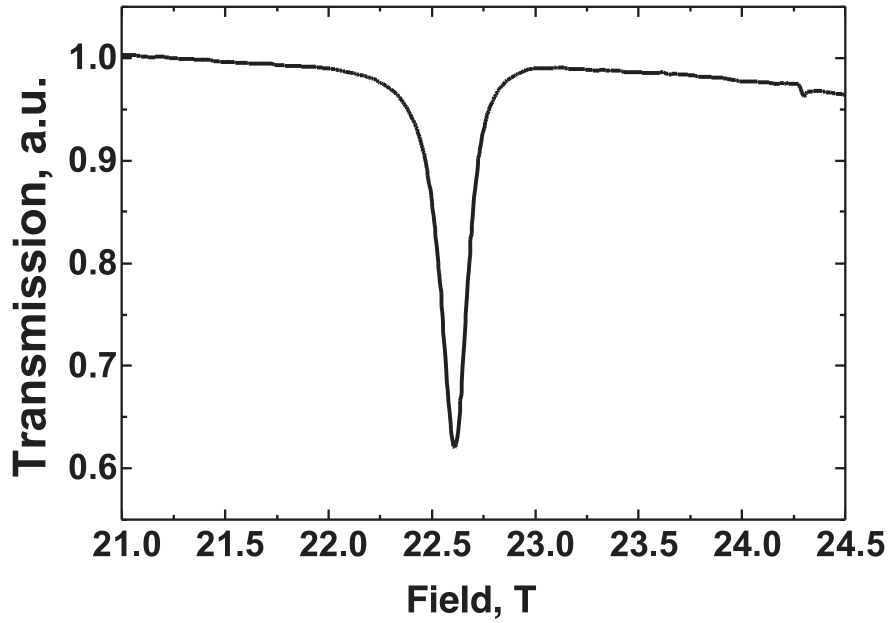


Figure 4. A high-field ESR spectrum of the spin-Peierls compound $CuGeO_3$ + 0.4%Si in the sinusoidal-distorted incommensurate phase. Frequency is 680 GHz, T=4.2 K. The small feature at ~ 24.3 T is a resonance of DPPH that is used as a marker.

0.4%Si at B ~ 12 T and can be seen as a slight change in the ESR line width in Fig. 3. Further developing of the magnetic structure, namely a sinusoidal distortion at higher fields,[5] results in a significant line broadening (more than 50 %) observed by us in the field range of 18 to 23 T. This line broadening corresponds to a continuous change from a soliton-like structure to a high-field sinusoidal-distorted phase and can be explained in terms of a sinusoidal distribution of local environments. Note that the g-factor measured along the *a*-axes does not depend on magnetic field and remains constant (g = 2.15) in the field range of ~ 5 to 23 T. This observation is consistent with results of ESR in pulsed magnetic fields.[6] A typical high-field ESR spectrum of $CuGeO_3$ + 0.4%Si in the sinusoidal-distorted incommensurate phase is shown in Fig. 4. Our results obtained in the wide frequency-field range using new submillimeter/millimeter facility offer a good possibility to test quantitatively various numerical and analytical models developed to describe field-induced structural phase transitions in spin-Peierls materials.

Acknowledgements: We thank R. Desilets for his great job making intricate parts of the spectrometer probe in the micromachine shop.

1 "Microwave" is used here in the traditional sense to mean any electromagnetic wave with wavelength less than a meter.

2 The work was done in collaboration with P.H.M. van Loosdrecht (University of Groningen, The Netherlands), G. Dhalenne and A. Revcolevschi (Université de Paris-Sud, France)

3 Hase, M., *et al*., *Phys. Rev. Lett.*, **70**, 3651 (1993).

4 Lorentz, T., *et al*., *Phys. Rev. Lett.,* **81**, 148 (1998).

5 Ronnow, H.M., *et al.*, *Phys. Rev. Lett.*, **84**, 4469 (2000).

6 Nojiri, H., *et al*., *Physica B*, **16**, 246-247, (1998).

Attention Users

Alex H. Lacerda
Director, NHMFL-Pulsed Field User Program

It is well known that strongly correlated materials, such as heavy fermions and high temperature superconductors, are very anisotropic. In trying to better understand the magnetic and scattering anisotropy, measurements taken of magnetotransport at extreme conditions of high magnetic fields and very low temperatures are of paramount importance. Most of these materials, however, are hard to synthesize and their shape and size even harder to control. The following article by Charles H. Mielke is an excellent example of how to overcome the difficult task of placing contacts for magnetotransport measurements. This technique works very well and I am sure you will find the article of great interest.

Contactless Conductivity Measurements in High Magnetic Fields

C.H. Mielke,
NHMFL/LANL

Magnetotransport measurements continue to be an important measurement for condensed matter physicists. Compounds, such as high-temperature superconductors, organic metals and superconductors, heavy fermion systems, and metals comprise a significant percentage of the condensed matter physics systems studied at the NHMFL. Some researchers have become highly proficient at the *art* of attaching leads to small or difficult shape samples. Physical constraints, however, such as small size or reactive surfaces make attaching four electrical transport leads a very difficult task for certain materials. Efforts to investigate such materials have ultimately lead to a new technique, that is now available to users of the NHMFL. This new technique measures the electrical conductivity of a given sample without the need of physically attaching leads. The *radio frequency contactless conductivity technique* (rfCC) inductively couples a resonant tank circuit to the sample while tracking the shift in resonant frequency of the tank circuit as a physical parameter is adjusted, such as

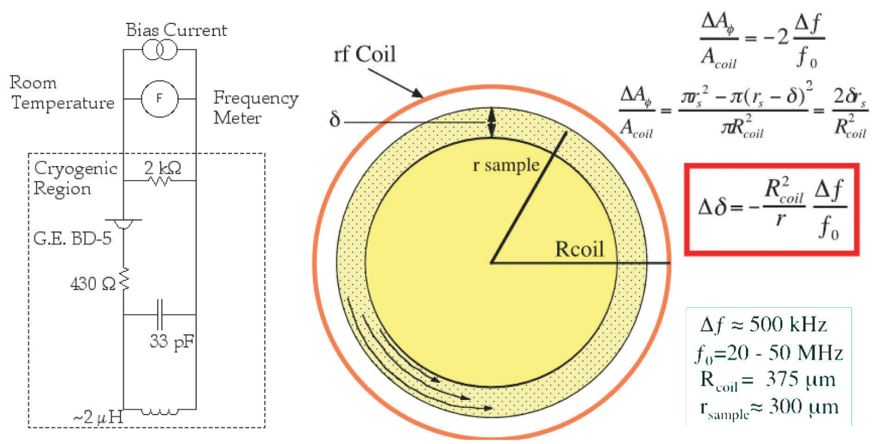


Figure 1. The rfCC tank circuit driven by a tunnel diode. The rf coil is typically 15 turns of #46 AWG Cu wire wound on a 700 micron mandrel. The cylindrical model for determining the change is skin depth, hence the change in resistivity.

the magnetic field or temperature. It is now possible to measure the electrical conductivity of very small samples or insulating surface materials without having to attach any physical leads. These measurements can be made at low temperatures (to 100 mK) and DC or pulsed magnetic fields to 60 T.

The rfCC technique uses a simple resonant tank circuit that is driven by a tunnel diode.[1] The circuit nominally consists of 5 components (see Fig. 1) which are very common components with the exception of the tunnel diode.[†] The sample is placed inside (or in proximity to) the inductor of the tank circuit. As the sample skin depth changes the rf flux volume is modified, hence the effective inductance and resonant frequency is proportionally changed, since $\omega = (LC)^{-1/2}$

where $\omega = 2\pi f$, L is the inductance, and C is the capacitance of the tank circuit. A change in frequency of the tank circuit can simply be related to the change in skin depth and hence the change in resistivity as follows: $\Delta A_\phi/A_C = \Delta L/L$, where ΔA_ϕ is the change in flux area, A_C is the area of the measurement coil, ΔL is the change in inductance, and L is the total inductance. Using cylindrical symmetry[2] simple geometrical relations yield:

$$\frac{\Delta A_\phi}{A_C} = \frac{2r_S\Delta\delta - \Delta\delta^2}{R^2} \qquad 1)$$

where $\Delta\delta$ is the change in skin depth (or penetration depth), R is the effective radius of the coil, and r_s is the effective sample radius (see Fig. 1). The second order term is negligible so equation 1 can be written as:

$$-\Delta\delta = \frac{R^2}{r_S}\frac{\Delta f}{f_0} \qquad 2)$$

in terms of the change in skin depth, since for small changes in inductance $-\Delta L/L = 2\Delta f/f_0$. The skin depth is simply related to the resistivity by the familiar relation $\delta = (2\rho/\mu_0\omega)^{1/2}$. This cylindrically symmetric model has proven to be ~10% accurate in describing several sample geometries including cubes, platelets, and needles. The model can be tested with small single crystal superconductors in which the minimum physical dimension is measured and the normal state skin depth is exceeded by application of a magnetic field. This would normally be an inconvenience since there is no change in measurable skin depth beyond the minimum sample dimension perpendicular to the applied rf field, however, in this case it serves as a reality check. The tank circuit frequency can then be raised if the skin depth length is reached, however, the square root dependence requires a substantial

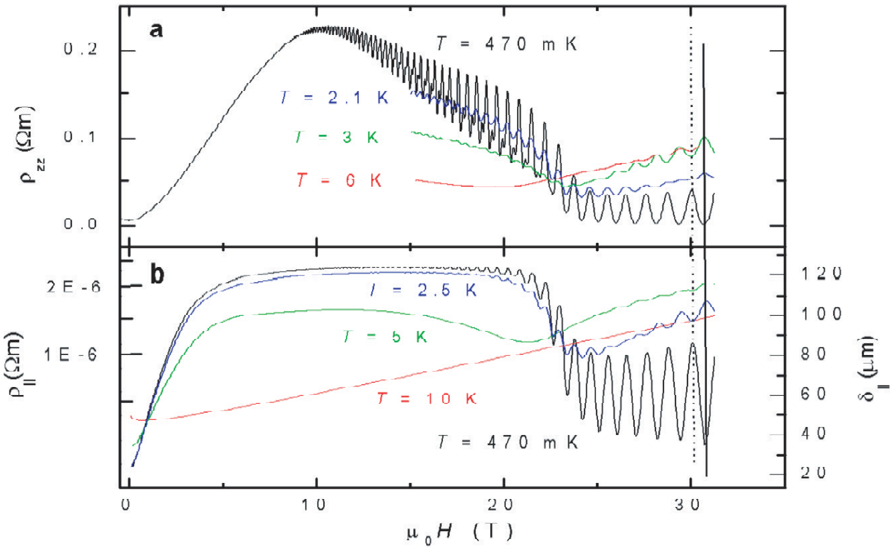


Figure 2. A comparison of conventional 4 terminal transport (top) and the radio frequency contactless conductivity method (bottom).[3] The contactless technique measures the change in skin depth which can be converted to resistivity.

change in frequency. Reduction of either the capacitance or inductance in the tank raise the resonant frequency. As a rough upper limit with tunnel diode driven tank circuits, successful measurements have been made in pulsed magnetic fields with tank circuit frequencies as high as 200 MHz. Tunnel diode device limitations make measurements beyond 500 MHz quite difficult, while practical circuit limitations in a cryogenic environment limit the frequency to about half of that.

Aside from the benefits of measuring the electrical conductivity without having to place contacts, the rfCC method or variants thereof is the most reliable method to determine the “in-plane” resistivity when measuring highly anisotropic bulk single crystals (see Fig. 2). When resistivity anisotropies approach 1000 or so it becomes exceedingly difficult to measure the “in-plane” component of the resistivity. Contacts are placed on surfaces that are rarely atomically flat on the relevant length scales and even if they were the electric fields disperse through layers while micro-cracks, strain, or dislocations cause the electrical current to take a disjointed path of least resistance. The result is of course a contamination of signal with “inter-plane” resistivity. The rfCC method is sensitive to the most conducting regions of the sample since it actually is a skin depth probe. In many cases of highly anisotropic metals, the rf fields will fully penetrate the poor conductivity layer while effectively being screened from the high conductivity layer.

When measuring superconducting samples with the rfCC method, a reliable method for determining the upper critical field has also been developed. Fig. 3 shows data taken on a 80 x 25 x 500 micron sample of λ–$(BETS)_2GaCl_4$. For a detailed description of rf fields in superconductors, see Ref. 4 (also see the appendix in Ref. 2). In essence the penetration depth diverges at H_{C2}, while the resistivity becomes finite and saturates to the normal state resistivity. By fitting straight lines to the data, the upper critical field plot can be constructed. Fig. 4

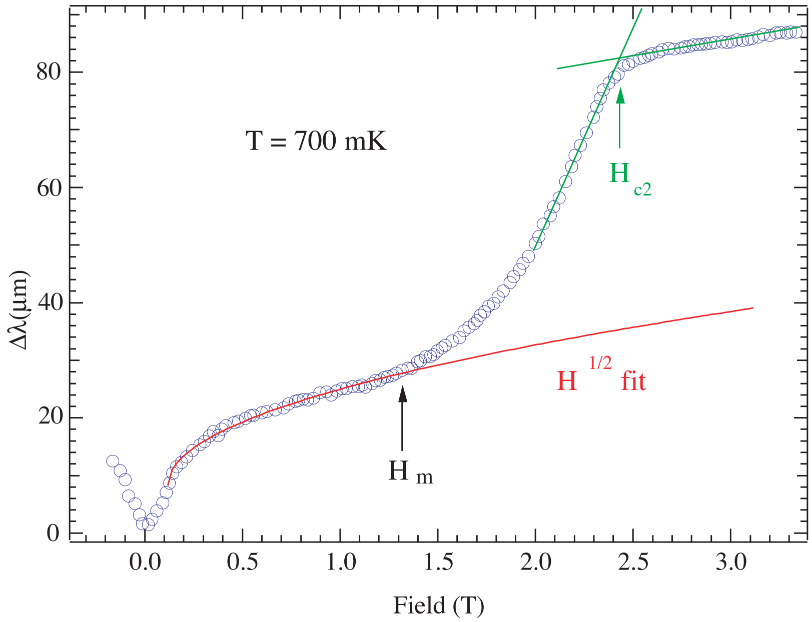


Figure 3. The change in penetration depth as a function of applied magnetic field. For a more complete explanation of the features in the data see Ref. 2.

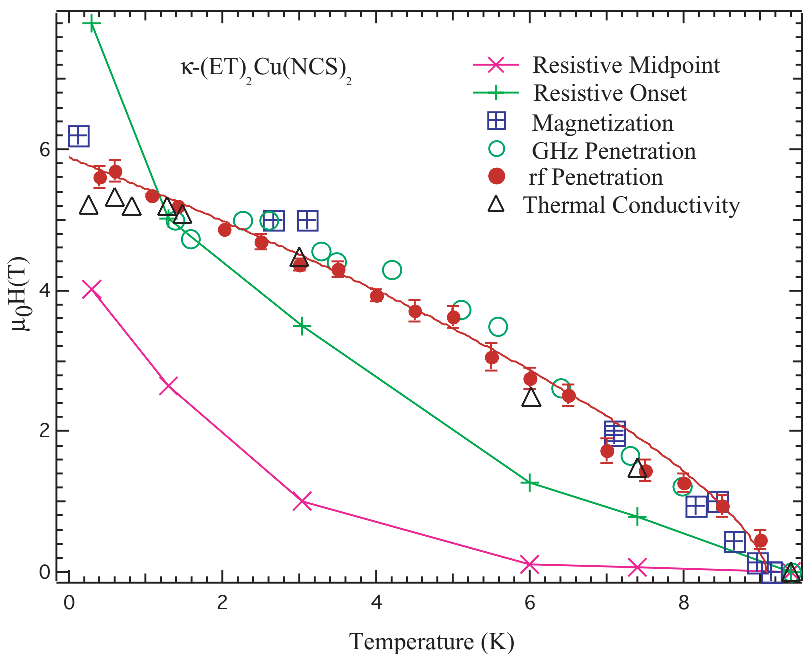


Figure 4. Comparisons of different techniques for the organic superconductor κ(ET)$_2$Cu(NCS)$_4$. The rf penetration data is a reference to the rf contactless conductivity technique.

shows the *H-T* plot for what is perhaps the most well studied organic superconductor, κ-(ET)$_2$Cu(NCS)$_4$. Comparison with other techniques show significant difference with conventional resistivity, which has proven to be especially unreliable on highly anisotropic superconductors.

The rfCC method has been applied to many different correlated electron systems, including heavy fermions, high temperature superconductors, elemental metals, organic superconductors and metals, etc. The technique is robust and user friendly, over a dozen NHMFL users have used the technique in either DC or pulsed magnetic fields. At the pulsed magnetic field facility, the author recently collaborated with users, Professor C. Agosta, and I. Mihut of Clark University, to develop a rfCC probe on a rotational stage for use in the ^{3}He insert for the 60 T millisecond pulsed magnet. This new probe allows unprecedented capabilities for measuring highly anisotropic metals or very small resistivity metals such as UNiGe to 60 T at temperatures as low as 320 mK. By relying on frequency measurements, many experimental uncertainties are overcome while post processing allows for time constant optimization. This work is supported by the National Science Foundation and the U.S. Department of Energy.

†Available from Metelics (408) 737-8181 (for example the model MBD-3057-E28X).

1. VanDeGrift, C.T., *Rev. Sci. Instrum.*, **46**, 599 (1975).
2. Mielke, C.H.; Singleton, J.; Nam, M-S.; Harrison, N.; Agosta, C.C.; Fravel, B. and Montgomery, L.K., *J. Phys.:Condens. Matter,* **13**, 8325 (2001).
3. Harrison, N.; Mielke, C.H.; Singleton, J.; Brooks, J.S. and Tokumoto, M., *J. Phys.: Condens. Matter,* **13**, L389 (2001).
4. Coffey, M.W. and Clem, J.R., *Phys. Rev. Lett.,* **67**, 386 (1991).

NHMFL Awards First Schuler Fellowship

The NHMFL is proud to announce a new fellowship program for international postdoctoral candidates. The Schuler Fellowship is named in honor of Mr. and Mrs. John N. Schuler of Longboat Key, Florida, for their generous gifts to Florida State University and the NHMFL. The program is designed for those scientists and engineers who have received their Ph.D.'s within the last ten years and who are affiliated with an institution of higher learning or comparable research organization. It is especially structured to attract those scientists and engineers who aspire to become the next generation's leaders in their chosen fields and who welcome the opportunity to pursue research on their new ideas at the NHMFL. The Schuler Fellowships are also aimed at building bridges between the NHMFL and institutions of higher learning and research organizations throughout the world, which could ultimately lead to broader collaborative relationships between the NHMFL and these institutions.

This one-year fellowship is open to both experimentalists and theorists. Applicants submit a research proposal to be conducted at the laboratory and designate a faculty/research mentor at the NHMFL. Applicants also provide a research plan that will further his or her career and field of study. They are encouraged to address how the fellowship can enhance the quality of research at their home institutions.

Fellows receive up to a $50,000 grant and matching support is encouraged but not required. In addition, a $5,000 research allowance is administered through the laboratory to help support the fellow's research program throughout the year. Travel expenses to the NHMFL and returning to the home institution are provided.

The first Schuler Fellow, Horacio Aliaga, began working at the NHMFL this summer with Adriana Moreo in the Condensed Matter Theory Group. His home institution is the Comision Nacional de Energia Atomica, Centro Atomico in Bariloche, Argentina. His research work includes characterization of ceramic samples of the type $Ca_{1-x}Y_xMnO_3$, measuring transport and magnetization, and developing a model based on the formation of magnetic polarons. He has also worked on the competition between Double-Exchange and Super-Exchange found in perovskite manganites. (See page 23 for more information on Aliaga.)

Applications for the 2003 fellowship must be received by October 1, 2002. Interested applicants should submit the following materials:

- proposed plan of research and letter of support from NHMFL mentor;
- a two-page discussion on how this research will help advance your career;
- current curriculum vita that lists publications and courses taught in the last five years;
- one-page abstract of doctoral dissertation; and
- three letters of recommendation.

These materials should be submitted to:

Janet Patten
Director of Government & Public Relations
National High Magnetic Field Laboratory
1800 East Paul Dirac Drive
Tallahassee, FL 32310 U.S.A.
E-mail: *patten@magnet.fsu.edu*
850-644-9651

NHMFL in Tallahassee and Los Alamos Bid Farewell to —and Say Thanks to— HEINRICH BOENIG

Power Engineer Heinrich Boenig, a pioneer of the NHMFL Pulsed Field Facility, retired at the end of June 2002. After 27 years of service at LANL, Boenig turned in his badge and moved to Texas, bidding farewell to the Magnet Lab family and the rest of New Mexico.

Boenig was instrumental in the birth of the NHMFL/LANL facility as he was responsible for the purchase of the 1.4 GVA (or 600 megajoules) generator, which was essential to locating the NHMFL pulsed field facilities at LANL). Boenig had been working in the CTR-9 (Controlled Thermonuclear Reaction) division and was bringing in the generator to LANL for use in a fusion experiment. Boenig said that when a colleague, Fred Mueller, told him of the Magnet Lab's interest in coming to Los Alamos, he was inspired. "I recognized that our generator was a perfect choice," said Boenig, "We could use the power supplies from the fusion experiment for the magnets."

Boenig determined that the generator pulses could be used for both the fusion experiment and the large magnets. When the fusion experiment idea dissolved with the closure of the CTR-9 division (just after the generator was installed and commissioned), the generator was available entirely for use by the NHMFL. Boenig then joined the NHMFL to help develop the power supplies for the new facility.

Boenig first came to the United States as a Fulbright Scholar and earned his Ph.D. in Electrical Engineering at the University of Wisconsin. Before coming to New Mexico, Boenig worked on industrial and utility power electronics at Siemens R&D Center at Erlangen, Berlin, Germany, and then taught at the University of Wisconsin. Upon arrival in Los Alamos, Boenig's career at the laboratory began in group Q26 (which is now MST-10) working on a 30-megajoule superconducting magnetic energy storage unit in Tacoma, Washington—a project he shared with the late John Rogers. He eventually ended up in CTR-9 designing power supply systems for the fusion experiment and orchestrating the purchase of the generator.

Once the fate of CTR-9 was decided, Boenig transferred to the newly formed NHMFL/LANL campus to help it get started, and to oversee the use of the generator and the power supply for the 60 T Long Pulse magnet. From 1992-1993, Boenig spent a sabbatical in Tallahassee, Florida, installing and commissioning the 40 megawatt highly regulated DC power supply for the NHMFL/Tallahassee facility.

Since his return to Los Alamos, Boenig continued to help with the power supplies for the magnet systems, but also developed a unique power supply for a pulse magnet for neutron science—which is under construction. He also worked with the Superconductivity Technology Center (STC) to develop a Superconducting Fault Current Limiter, based on a patented design of his own, for use in a utility power grid.

NHMFL Physicist Charles Mielke got to know Boenig well while working with him to install and test the Fault Current Limiter in Los Angeles, California. "He commanded a lot of respect from people," said Mielke, "He was the only person reported to receive a standing ovation for his annual project review."

Engineer Jim Sims agreed. "He is very unassuming but he knows what he is doing. He was very complimentary." Sims said that Boenig is considered a world expert in many areas and was actively sought out for his expertise. He recalled once when the LANCE group at LANL (previously LAMPF) was seeking an expert in power engineering and queried across the country to find the best person. It came back that Heinrich Boenig was the most qualified—right here at LANL.

Center Leader Greg Boebinger explained that the Magnet Lab continues to receive royalties for many of Boenig's patents, and that this is only one of many contributions Boenig made to the NHMFL. Boebinger said he corresponded with Boenig a great deal before accepting the job as NHMFL Center Leader. "It was always amazing to me how ready he was to help with information and contacts." Boebinger also felt Boenig really cared about the group. "Anytime he's had a problem, it was phrased in a way that he was looking in the best interests of the Magnet Lab."

Through his expertise, mentoring, patents, and helpfulness throughout all aspects of the Magnet Lab, Heinrich Boenig's contributions will continue indefinitely. Everyone at the NHMFL/LANL facility wishes him the best of luck in his retirement!

In Memoriam John Rogers

John would have hated this article.

One of the most remembered characteristics about John Rogers is his modesty and avoidance of praise and recognition. Rogers passed away on June 24, 2002 after a long battle with heart disease; he was 80 years old. In spite of his wishes to have no memorial or obituary, it is very difficult for the NHMFL/LANL family to say goodbye to John without sharing how important he was to both the lab and the entire Los Alamos community.

John Rogers arrived at LANL in 1944 as a young officer to help with the then-secret Manhattan Project. He finished his Ph.D. in chemical engineering at Ohio State University in 1950 and worked at the Los Alamos Lab in numerous areas. He was notably an expert in cryogenics and superconducting magnets and also worked as a program manager, project leader, group leader, and many times was the interface between the lab and contractors, working to oversee projects as an advocate for the lab's interests.

Toward the end of Rogers' career, he was the Group Leader of CTR-9 (Controlled Thermonuclear Research Team) and worked to help acquire and install the 1.4 GVA generator that is now part of the NHMFL/LANL. The generator was to be used in a fusion experiment. The timing of the generator's arrival and installation was crucial to the establishment of the Magnet Lab because just after commissioning the generator, CTR-9 was dissolved and Rogers and others worked to keep the generator around for use with the big magnets in the new NHMFL facility. Rogers then worked with the new magnet group to help with the generator, power supplies, and cryogenics.

"John's efforts and reputation were critical for the survival of the early NHMFL. His participation and encouragement helped everyone else do the job," explained engineer Jim Sims.

Rogers worked as a consultant for the Magnet Lab after his retirement, and later as a no-fee consultant. According to NHMFL Deputy Center Leader, Dwight Rickel, Rogers was instrumental in developing cooling systems for the NHMFL magnets and often interfaced between engineers and cryogenic contractors. Rickel also said that Rogers' attitude was just as important of a contribution to the lab. "He never got involved in office politics. He was always there to be a mentor and to smooth things out."

NHMFL Center Leader Greg Boebinger said that Rogers was involved in various construction projects around the lab, most notably the installation of the new experimental hall in 1998. "He knows when a bid is too high and how to find ways to hammer it down," said Boebinger. Rogers had a wealth of experience, not only through his work at the lab, but also through his work in the community, which included serving as state senator, helping build the utilities and highway infrastructures, and being one of the first to help establish the Los Alamos ski hill. Boebinger said that Rogers was always quick to share what he knew and help in any way to get things done.

Power engineer Heinrich Boenig also noted Rogers' knowledge and ability to cut costs. "John was a real penny pincher. He wanted the general public to get its money's worth. He was extremely hard working and an extremely dedicated public servant."

Engineer Joe Schillig said that Rogers also helped with the fault/failure analysis of the big magnets and was helpful in the current designs for the 60 T Rebuild and the 100 T magnet. "He just took on anything you gave him—and he took care of it right away."

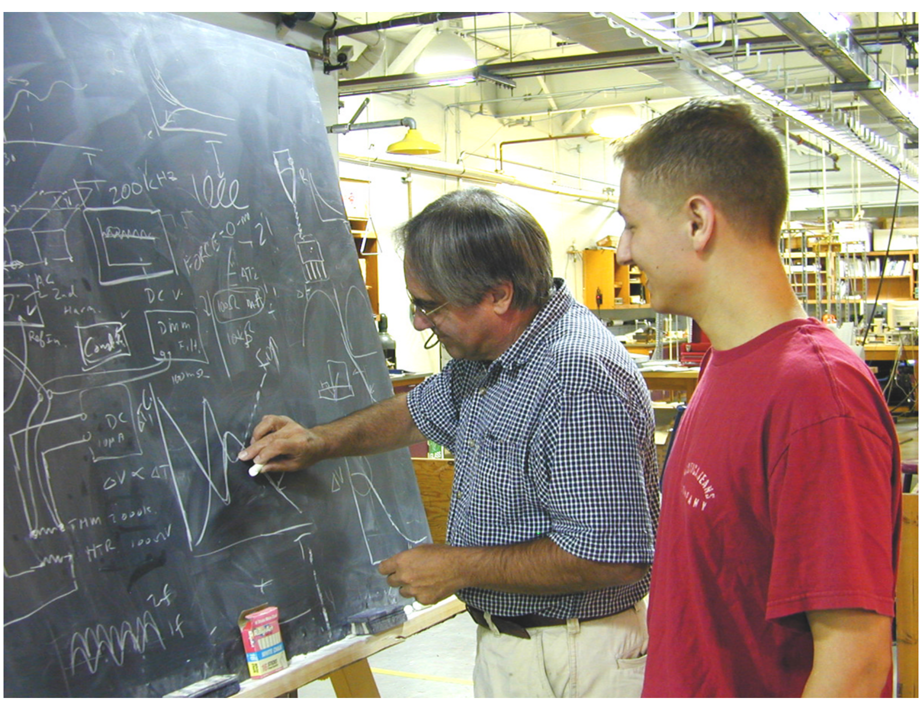
On July 2, 2002, the NHMFL/LANL gathered at the ski hill with Rogers' family and friends to informally remember his life. At the event, it was clear that Rogers' influence extends throughout the Los Alamos Lab and town community. John Rogers was an integral part of the NHMFL/LANL, even before it existed, and he will be fondly remembered and greatly missed.

REU AND RET ATTRACT THE BEST AND THE BRIGHTEST

While most educational institutions become quiet during the summer months, the Center for Integrating Research and Learning is a bustling, high-energy area that is home away from home for 10 undergraduate students and 18 teachers. The Research Experiences for Undergraduates (REU) program and the Research Experiences for Teachers (RET) programs have attracted the best and the brightest from all disciplines of science and teaching. The laboratory is pleased to recognize the students, teachers, and mentors, along with their research topics in the tables presented on pages 20 and 21.

The Center staff conducts weekly seminars and mini-workshops that address issues such as Web-based resources, creating Web pages as tools for students and teachers, incorporating literature in the science classroom, using PowerPoint and other presentation software, and integrating writing into science activities. Student seminars have included lectures and demonstrations by Sastry Pamidi, Donovan Hall, Chris Hendrickson, Hamid Garmestani, and NHMFL Director Jack Crow. The current state of magnet research was the focus of several seminars, as students expanded their areas of expertise to the Center for Advanced Power Systems, ion cyclotron resonance, instrumentation and operations, especially user support, and micromechanics of materials. A combined weekly colloquium has been the venue for discussions of student-teacher classroom interactions, how to publish student and teacher work, and how to conduct research presentations. Students and teachers traveled to the University of Florida to visit the Magnet Lab facilities there. The Microkelvin Laboratory and the McKnight Brain Institute were two highlights, with a spirited discussion of animal research and ethics of live animal testing.

In addition to the REU and RET programs, CIRL staff conducted a four-day summer institute for 44 area teachers. The response was overwhelming and teachers conducted such diverse activities as crystal-making and use of a digital microscope, creating model MagLev trains and conducting a competition, making kaleidoscopes, keeping science and nature journals, and making liquid nitrogen ice cream. The consensus among the 44 participants was that there would be changes in the science being done in area classrooms this fall!



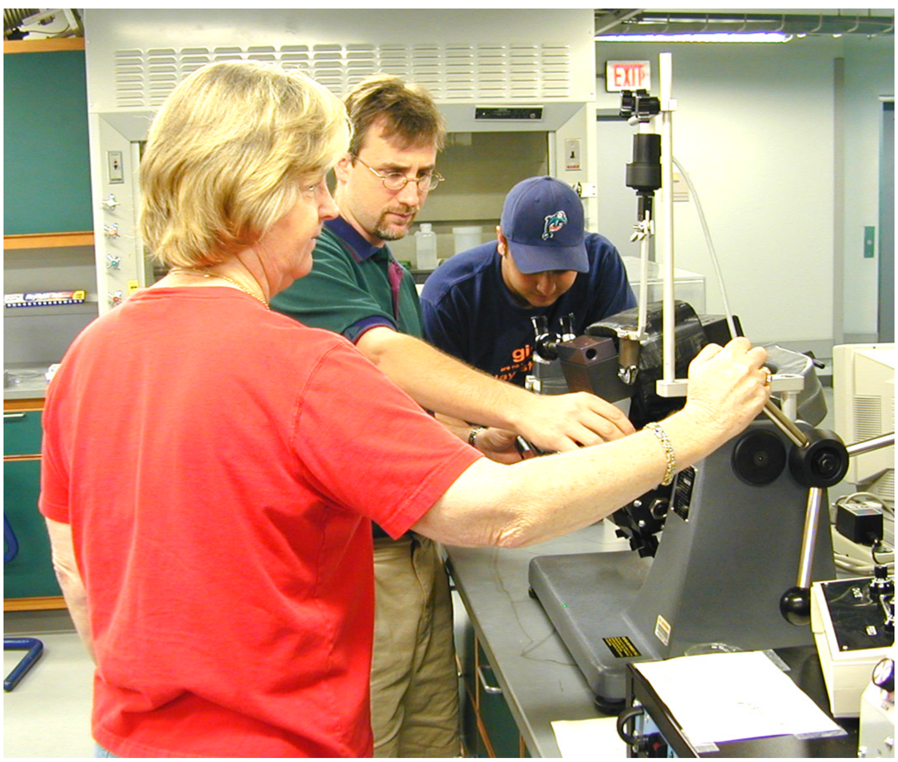
Research Experiences for Teachers (RET) 2002

Name	School	Mentor	Area of Research
Pat Cramer	Deerlake Middle School- Tallahassee, FL	James Walker Sensory Research Institute	Measuring Canine Olfactory Function
Matt Guyton	Griffin Middle School- Tallahassee, FL	James Brooks Condensed Matter/Theory	1. The physics of microgranular material 2. A practical handbook of material science
David Lang	Sealey Elementary School Tallahassee, FL	Yusuf Hascicek Magnet Science & Technology	Preparing & Testing Superconductors
Monique Quinones	Hunter s Creek Elementary School- Orlando, FL	Eric Palm Instrumentation & Operations	Be Cool In School: The History of Refrigeration
Rich McHenry	Leon High School- Tallahassee, FL	Phil Kuhns and Arneil Reyes CIMAR	Modeling Nuclear Magnetic Resonance
Alan Turner	Roosevelt Middle School- Danielson, CT	Bob Goddard Magnet Science & Technology	Illusions - That's How I See It
John Willoughby	Rickards High School- Tallahassee, FL	Phil Kuhns and Arneil Reyes CIMAR	Modeling Nuclear Magnetic Resonance
Pat Wagner	Essrig Elementary School- Palm Harbor, FL	Roy Odom Geochemistry	Uranium Dating of Conglomerate Samples
Kim Zenon	Braden River Middle School- Bradenton, FL	Bob Goddard Magnet Science & Technology	Illusions - That's How I See It
Jennifer Rogers	Metro West Elementary School- Orlando, FL	Eric Palm Instrumentation & Operations	Be Cool In School: The History of Refrigeration
Farrell Rogers	Marshall Middle School- Lakeland, FL	Yusuf Hascicek Magnet Science & Technology	Preparing & Testing Superconductors
Ken Bowles	Apopka High School, Altamonte Springs, FL	Justin Schwartz Magnet Science & Technology	Superconductors: A Mobile Museum Exhibit
Brian McClain	Godby High School- Tallahassee, FL	Justin Schwartz Magnet Science & Technology	Superconductors: A Mobile Museum Exhibit
Scott Mazur	Killearn Lakes Elementary School- Tallahassee, FL	James Walker Sensory Research Institute	This Chamber s Smokin
David Rodriguez	Raa Middle School- Tallahassee, FL	Roy Odom Geochemistry	Uranium Dating of Conglomerate Samples
Joann Hartmann	Preservice teacher- Flagler College	Bob Goddard Magnet Science & Technology	Illusions - That's How I See It
Laura Harrison	Preservice teacher- Flagler College	James Brooks Condensed Matter/Theory	1. The physics of microgranular material 2. A practical handbook of material science
Carlos Villa	Preservice teacher- Florida State University	Roy Odom Geochemistry	Uranium Dating of Conglomerate Samples

The Center for Integrating Research & Learning is focusing on new programs for the fall and spring academic terms. The Director, Pat Dixon, will continue to teach science methods courses at Flagler College, which has provided the alternative of a four-year teaching degree for local community college students. Outreach is expected to reach record numbers, far surpassing the over 11,000 contact hours spent with school children since January. Materials used in outreach sessions are being revised to include a component on superconductors and additional resources for middle and high school students. “Girls in Science” continues to be a priority project for the Center with a weeklong spring break camp for girls in the planning stages.

Research Experiences for Undergraduates (REU) 2002

Name	School	Mentor	Area of Research
Autumn Wyda	Carnegie Mellon University	Justin Schwartz Magnet Science & Technology	Effects of Doping in the MgB_2 Superconductor
Elizabeth Stringer	University of the South	Dragana Popovic Condensed Matter/Experimental	An Examination of Gallium Arsenide Semiconductors
Mark Wang	Dartmouth College	Yang Wang Geochemistry	Carbon Isotopic Ratios of Ancient Herbivore Diets
Keirse Crockett	Harvard University	Justin Schwartz Magnet Science & Technology	Effects of Doping in the MgB_2 Superconductor
Jason Crowe	Clarkson University	Philip Gao CIMAR	
Evan Goetz	University of Washington	James Brooks Condensed Matter/Theory	Heat Capacity of Heavy Fermion Compounds
April Jue	University of North Carolina- Chapel Hill	Philip Gao CIMAR	The Purification of "Mycobacterium Tuberculosis" Membrane Proteins
Alex Graffeo	FSU-FAMU College of Engineering	Luis Balicas Instrumentation & Operations	Changes in resistance of certain materials while exposed to various magnetic fields (0 to 33 T) at different angles
Melinda Lee Graham	Florida State University	Roy Odom Geochemistry	Staurolite Indicates Regional Metamorphism
Alisha Elsebough	Florida State University	Roy Odom Geochemistry	Staurolite Indicates Regional Metamorphism
Vanousheh Ghandehari	University of California-Berkeley	Hamid Garmestani Magnet Science & Technology	Biomechanical Comparison of Reptilian and Mammalian Prismatic Enamel Microstructures
Andrew Steinberg	Duke University	Mark Meisel UF Physics Affiliated Faculty	Biomagnetics: Middle Range Magnetic Fields and Its Effect on the Transcription of the Adh/GUS and Adh/GFP Promotor-Reporter Systems in ARABIDOPSIS thaliana
Jerrold Keilbasa	University of Florida	Mark Meisel UF Physics Affiliated Faculty	Low temperature techniques for detecting structural and magnetic transitions
Mary Woodruff	Iowa State University	Alex Lacerda LANL Pulsed Field Facility	Ytterbium Nickel Boron Carbide in High Magnetic Fields
Kathleen Leenerts	Colorado State University	Alex Lacerda LANL Pulsed Field Facility	Magnetic Properties including the Brillouin function
Winston Czakon	Georgia Institute of Technology	Alex Lacerda LANL Pulsed Field Facility	Fast Response Frequency Counter



Evaluation of CIRL programs is a focus for the next two years, with a Ph.D. student in Educational Leadership and Policy Studies at Florida State University heading up a structured program to investigate the results of signature programs such as the REU and RET. This takes CIRL to a new level of credibility among other RET and REU sites. CIRL will combine this data with data from the BRISC (Bringing Research into Science Classrooms) study to add new features to the programs.

The Center staff is excited about exploring new programs to respond to the needs of students, teachers, and the general public. This June saw the completion of the fourth year of providing professional development sessions for *Science, Tobacco & You.* Through the Florida Department of Health Awareness and Tobacco, the Center will again be conducting five regional training sessions in Florida. The successful curriculum package is now in use in over 20 states and Canada.

Support from the National High Magnetic Field Laboratory's scientists, researchers, staff, and faculty has enabled the Center to expand its educational programs into a national resource. We look forward to continuing already-successful programs and expanding to new directions.

For further information about the laboratory's education programs, contact Dr. Pat Dixon at 850-644-4707 or *pdixon@magnet.fsu.edu.*

PEOPLE IN THE NEWS

Horacio Aliaga, of Argentina, is visiting the NHMFL as the laboratory's first Schuler Fellow. He earned his B.A. in electronic engineering at the Universidad Nacional de San Juan, and received his Ph.D. in Physics in 2001 at the Instituto Balseiro, Universidad de Cuyo. Aliaga's research interests include Condensed Matter-Strongly Correlated Electrons-Collosal Magnetoresistive Manganites, and the novel physical properties that present manganites. Previous awards include a CNEA (Comision Nacional de Energia Atomica) undergraduate fellowship and CONICET (Consejo de Investigaciones Cientificas y Tecnicas) Ph.D. fellowship. Aliaga plans to work a lot and believes the lab will give him the opportunity to make important contributions to the research field. For more information on the Schuler Fellowship, see page 16.

Power Engineer **Heinrich Boenig**, a pioneer of the NHMFL Pulsed Field Facility, retired at the end of June 2002. After 27 years of service at LANL, Boenig turned in his badge and moved to Texas, bidding farewell to the Magnet Lab family and the rest of New Mexico. For more details, see his tribute on page 17.

Robert R. Hudgins, member of the NHMFL ICR program, will be leaving the lab to begin his academic career as an assistant professor at York University in Canada. He received his Ph.D. in Chemistry from Northwestern University in 1999 and joined the lab in 2000; academic honors include a 1999-2000 NSF International Research Fellowship and a James Monroe Scholarship from the College of William & Mary from 1990-1994. His research interests include studies of peptide dynamics using novel photochemical probes, extensive chemical synthesis of photochemical peptide derivative, and experimental and computational studies of host-guest complexation.

Christine A. Hughey, member of the NHMFL ICR Group, will begin her academic career as an assistant professor at Chapman College in California. Hughey, who completed her Ph.D. in July, has also been awarded an Honorable Mention for a Division of Analytical Chemistry Graduate Fellowship from the American Chemical Society. (She completed her Ph.D. before the fellowship could be activated).

Alan G. Marshall, FSU Kasha Professor of Chemistry and Biochemistry and director of the ICR Program at the NHMFL, has been elected to Vice President for Programs of the American Society for Mass Spectrometry (5,500 members). He will be responsible for organizing the annual ASMS Conference (~2,000 talks and posters) for the next two years and will then become President of ASMS for the following two years.

John Rogers passed away on June 24, 2002, after a long battle with heart disease; he was 80 years old. In spite of his wishes to have no memorial or obituary, it is very difficult for the NHMFL/LANL family to say goodbye to John without sharing how important he was to both the lab and the entire Los Alamos community. For more details, see his tribute on page 18.

Bruce E. Wilcox, member of the NHMFL ICR Group, has accepted an industrial position at Hamilton Sundstrand Sensor Systems in California as their Mass Spectrometer Development Engineer. He received his Ph.D. in Analytical Chemistry in 2000 from the University of New Mexico, a 2000 Smith-Dow Award for Outstanding Chemistry Graduate Student, and a 2001 nomination for Phi Kappa Phi membership. A member of the American Society for Mass Spectrometry and the International Society of Mass Spectrometry, Wilcox's research experience at the lab included the design, computer simulation, and characterization of a new ion optical system for the efficient storage and transfer of ions into the FT-ICR cell.

Jack E. Crow, director of the NHMFL, was awarded the Distinguished Citizen Award for 2002 by the Rotary Club of Tallahassee for "Reaching Beyond the Ordinary." The Sunrise Rotary Club also made Crow a Paul Harris Fellow with a contribution of $1,000 to the Rotary International Foundation.

J. Robert Schrieffer, NHMFL Chief Scientist, was honored by Florida Secretary of Education Jim Horne with the following education award for his service and research contributions:

"J. Robert Schrieffer is the kind of thinker who is so far ahead in his vision that it takes others decades to catch up.

In 1957, as a freshly minted Ph.D., Robert Schrieffer was only 26 years old and not all that removed from his high-school days in Eustis, Florida. But he was wise beyond his years.

It was in 1957 when Dr. Schrieffer published a paper on a then unknown field. His was a piercing, pioneering argument—and it provided the first workable theory on superconductivity, the capacity for certain exotic materials, under certain conditions, to carry current with extremely low resistance.

His groundbreaking work earned him many awards, including, in 1972, the Nobel Prize.

Now, he is the Chief Scientist of the National High Magnetic Field Laboratory—the first faculty member appointed to the research center run by Florida State University and the University of Florida, in partnership with Los Alamos National Laboratory.

There, Dr. Schrieffer is continuing his path-finding work in high-temperature superconductivity and magnetism, work that has profound promise for modern science, modern industry and modern society.

We honor Dr. Schrieffer today for this unparalleled life of scholarship and achievement. He is bringing a new day to Florida through his research at the world-class laboratory out at Innovation Park here in Tallahassee.

He has put Florida on the map as a center of world-class research. Thanks to him and his colleagues at the National High Magnetic Field Laboratory, we have a dream of a high-tech future for Florida.

We also honor Dr. Schrieffer for his commitment to the classroom. This world-class physicist and Nobel Laureate continues to teach freshman physics. He takes time to impart his knowledge and his love of discovery to the next generation.

So we salute Dr. J. Schrieffer, world-class scientist and teacher, for all that he has done and for all he brings to our State University System and the State of Florida."

IN THE NEWS

2002 SEMRC

32nd Southeast Magnetic Resonance Conference and Symposium Honoring Edward O. Stejskal (SEMRC)

October 24-27, 2002
Research Triangle Park, North Carolina
Hotel Headquarters: Sheraton Imperial Hotel and Conference Center
http://www.ncsu.edu/chemistry/semrc/index.html

The SEMRC provides an ideal opportunity for scientists in all areas of magnetic resonance to come together and share new applications and technique developments. This year's meeting will be particularly important as a special symposium will be held in honor of Edward O. Stejskal, who has made significant contributions to the science of magnetic resonance. The invited speakers will be R. David Britt of University of California, Davis, Balarama [Raman] Kalyanaraman of Medical College of Wisconsin, and David D. Thomas of University of Minnesota. Plenary speakers will be Jacob Schaefer and Alex Pines.

The NHMFL is pleased to sponsor SEMRC and support the hosting institution, North Carolina State University. Other sponsors include Advanced Chemistry Development, Bruker, GlaxoSmithKline, Eli Lilly, Magellan Laboratories, NC ACS, and Varian, Inc. For registration information and further details, visit the conference Web site.

43rd Sanibel Symposium

February 22 - March 1, 2003
St. Augustine, Florida
Hotel Headquarters: Ponce de Leon Resort
Abstract Deadline: January 3, 2003
http://www.qtp.ufl.edu/~sanibel/

This symposium held by the Quantum Theory Project at the University of Florida will focus on forefront theory and computation in quantum chemistry, condensded matter physics, molecular dynamics, quantum biochemistry and biophysics. A new feature is Thursday tutorial lectures on simulation methods. There will be two special plenary sessions for everyone, and a computationally-oriented, hands-on Workshop for Graduate and Advanced Undergraduate students. Invited and poster sessions, as well as informal discussions, will include topics on carbohydrates, coherent control, advanced materials, energy transduction, electronic structure theory, and more. Short course topics include force fields and molecular dynamics. Organizers include NHMFL-affiliated UF faculty, Rodney Bartlett, Hai-Ping Cheng, Henk Monkhorst, John Sabin, and Samuel Trickey. IBM is the sole corporate sponsor. For more information, e-mail *sanibel@qtp.ufl.edu* or visit the conference Web site.

VI Latin American Workshop on Magnetism, Magnetic Materials and their Applications (LAW3M)

April 7-11, 2003
Chihuahua, Mexico
Advanced Materials Research Center (CIMAV)
Abstract Deadline: October 15, 2002
http://www.law3m.org.mx

The NHMFL is assisting in organizing this biennial meeting initiated in La Habana, Cuba in 1991, and followed by workshops in Guanajuato, Mexico (1993), Merida, Venezuela (1995), Sao Paulo, Brazil (1998), and San Carlos de Bariloche, Argentina (2001). The workshop is designed to support scientific exchanges in the Americas. The LAW3M is a great forum to support scientific exchanges among researchers and institutions interested in recent developments in all branches of fundamental and applied magnetism.

QAMTS 2001

XIIth International Quantum Atomic and Molecular Tunneling in Solids Workshop (QAMTS)

June 22-25, 2003
Gainesville, Florida
Hotel Headquarters: Reitz Union Hotel and UF Hotel & Conference Center
Abstract Deadline: March 22, 2003

The XIIth QAMTS will be held on the campus of the University of Florida in Gainesville. NHMFL Principal

Investigator and UF Dean of the College of Liberal Arts and Sciences Neil Sullivan and Juergen Eckert of Los Alamos National Laboratory are the principal organizers of the workshop. The topics for this important international meeting include Macroscopic Tunneling in Nanomagnets and Related Molecular Systems; Rotational Tunneling of Symmetrical Groups; Proton Tunneling in Hydrogen Bonds; Molecular Dynamics Simulations; Coupled Rotors; Tunneling in Life Sciences; and Tunneling in Glasses and Amorphous Systems.

Sponsors for XIIth QAMTS include the NHMFL, LANL, Spallation Neutron Source, National Institute of Standards and Technology, and UF.

Interested scientists and students should note the following key dates:

March 15, 2003	Deadline for registration and payment
March 20, 2003	Deadline for submission of abstracts
May 20, 2003	Deadline for hotel reservations

UF is Florida's largest and oldest university, and is one of the state's centers of education, medicine, cultural events, and athletics. The extended campus includes a Center for Performing Arts, the Harn Art Museum, and the Florida Museum of Natural History. The City of Gainesville continues to rank as one of the best places to live in the United States. Situated in the heart of North Central Florida, there are 40 nature parks within 50 miles of Gainesville to picnic, swim, hike, camp, or enjoy some boating or fishing. There are also six fresh water lakes and seven excellent golf courses in the area.

A conference Web site is under development. In the interim, and for further information, contact Carol Binello at the conference office, *cbinello@clas.ufl.edu*; (352) 392-0780; fax (352) 392-3584.

Applied Superconductivity Conference (ASC04)

October 4-8, 2004
Jacksonville, Florida
Hotel Headquarters: Adam's Mark

This important international conference is held every two years and typically attracts approximately 1,800 participants. In September 2000, ASC00 was held in Virginia Beach, Virginia; in August 2002, ASC02 will be in Houston, Texas, and in October 2004, ASC04 comes to Jacksonville, Florida. For information, contact ASC04 Conference Chair Justin Schwartz in NHMFL's Magnet Science & Technology program, 850-644-0874, fax 850-644-0867; *schwartz@magnet.fsu.edu.*

15th Conference of the International Society of Magnetic Resonance (ISMAR 2004)

October 24-29, 2004
Jacksonville, Florida
Hotel Headquarters: Sawgrass Marriott Resort
http://www.ismar.org/

The scientific program of this major triennial program encompasses lectures and posters representing the various fields of magnetic resonance, showing its breadth and interdisciplinary nature. The program reflects the progress and exciting developments of new techniques, theory, and applications in chemistry, physics, biology, medicine, and material science. This large, international meeting brings together magnetic resonance practitioners from many countries and from all domains, including NMR, NQR, ESR, MRI, ICR, and aspects of coherent optics. Junior scientists are particularly encouraged to participate.

A preconference summer school will be held at the NHMFL in Tallahassee, FL, focusing on modern methodology in magnetic resonance. Buses will be available to transport attendees to the Sawgrass Resort on Sunday, October 24.

ISMAR is a society devoted to the advancement of magnetic resonance and its applications. The conference Chairman is Timothy A. Cross, NHMFL/FSU NMR Spectroscopy and Imaging Program Director/Professor. For complete details, see the conference Web site.

GRANTS

Junichiro Kono (Rice University) and **David Reitze** (UF) have been awarded a $167,000 Instrumentation for Materials Research grant from the National Science Foundation for the acquisition of an ultrashort pulse high power laser system to investigate the dynamics of exciton states in semiconducting quantum well structures in strong magnetic fields.

This award, entitled "Acquisition of an Optical Parametric Amplifier for High Magnetic Field Ultrafast Exciton Spectroscopy and Education," is closely coupled to an NHMFL In-House Research Program awarded to Reitze, Kono, and Christopher Stanton (UF) in 2001 for studies of how excitons behave when subjected simultaneously to intense laser fields and strong magnetic fields. The laser system, to be based at the NHMFL, will enable the investigators to produce intense mid-infrared optical pulses with 100 fs durations, resonant with excitonic internal energy states, enabling them to investigate rapid relaxation mechanisms and coherent phenomena by using the magnetic field to create localized excitonic "atoms." These investigations ultimately aim to answer the question of whether the interaction of light and electronic states in solids is truly quantum, in a manner analogous to quantum optics of atoms, and could point the way toward the observation of Bose-Einstein condensates in solids.

Roy Odom and **Vincent Salters** of the NHMFL and FSU Department of Geological Sciences, **William Landing** of the FSU Department of Oceanography, and **Eric Prestbo** of Frontier Geosciences Inc. were awarded a three-year grant from the Environmental Protection Agency totalling $827,147, entitled "Mercury Isotopes as Tracers of Sources, Cycling and Deposition of Atmospheric Mercury."

In the past years, Odom has developed a technique that allows high precision analysis of mercury isotopic composition. To their knowledge, this new analytical technique is unique and allows, for the first time, the use of the natural variations in the isotopic composition of mercury as fingerprints for its source. Atmospheric mercury contains components from far-field, regional, and local sources. The research intends to determine the isotopic composition of atmospheric mercury (1) thought to be little influenced by local sources (Olympic Peninsula WA, Barbados, and New Zealand, (2) influenced by both far field and regional or local sources (Florida "Supersite" in the Everglades), and (3) influenced by known point sources (coal burning generators as well as waste incinerators). This research will result in a better understanding of the cycling of mercury in the environment which will be part of the scientific justification for the regulation of mercury in the environment by the EPA.

This large grant is the first grant the Geochemistry Division has received from the EPA. The project involves collaboration with researchers at the University of Nevada at Reno, the University of Otago, New Zealand, Florida DEP, as well as collaboration with private sector: Frontier Geosciences Inc. and the Southern Company (largest electrical power generator in the southeastern United States).

REPORTS

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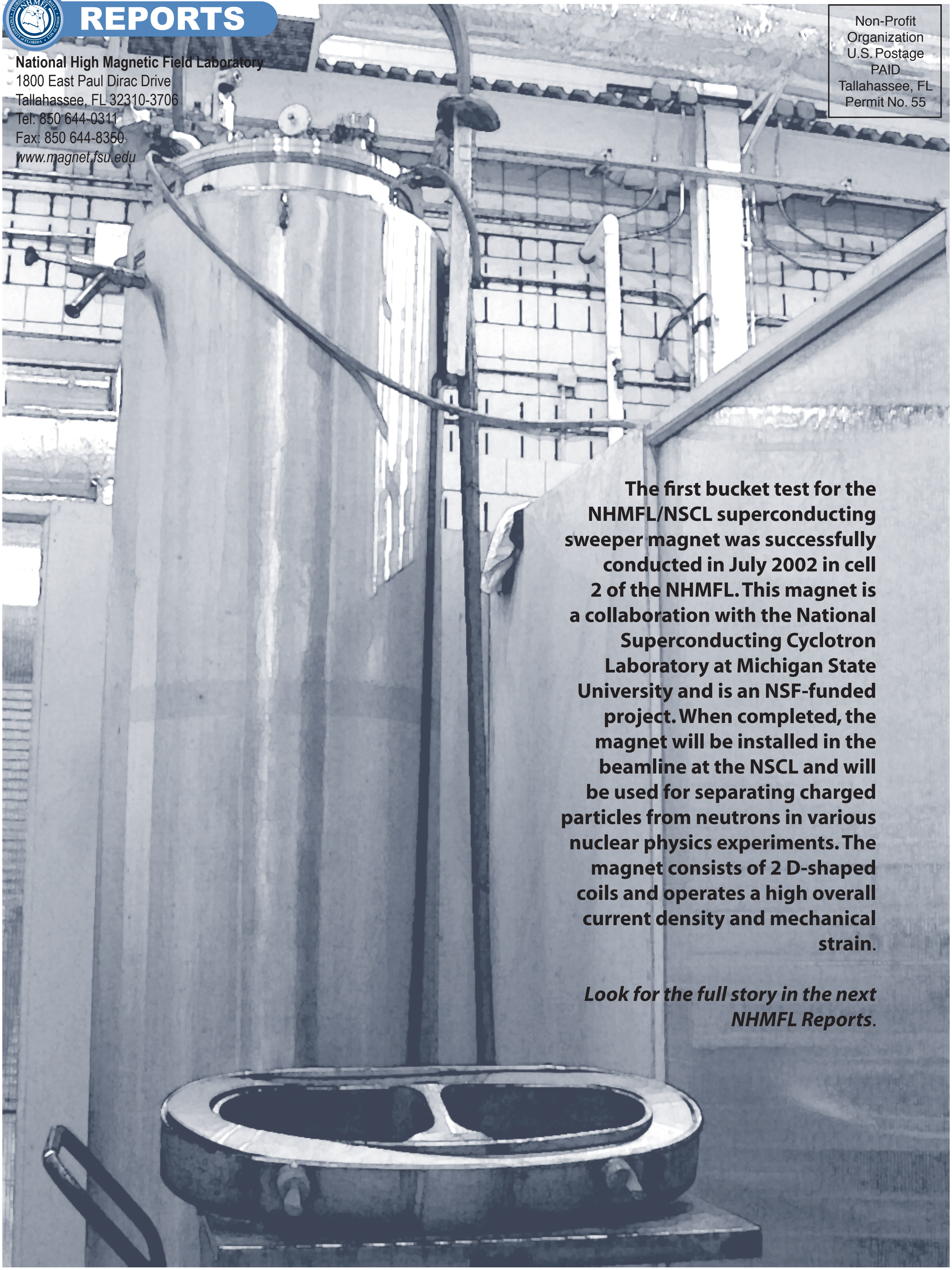

The first bucket test for the NHMFL/NSCL superconducting sweeper magnet was successfully conducted in July 2002 in cell 2 of the NHMFL. This magnet is a collaboration with the National Superconducting Cyclotron Laboratory at Michigan State University and is an NSF-funded project. When completed, the magnet will be installed in the beamline at the NSCL and will be used for separating charged particles from neutrons in various nuclear physics experiments. The magnet consists of 2 D-shaped coils and operates a high overall current density and mechanical strain.

Look for the full story in the next NHMFL Reports.