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NATIONAL HIGH MAGNETIC FIELD LABORATORY

NHMFL REPORTS

ULTRA-WIDE BORE 900 MHz

BUCKET TEST, INSTALLATION, AND COMMISSIONING

(page 14)

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NHMFL REPORTS

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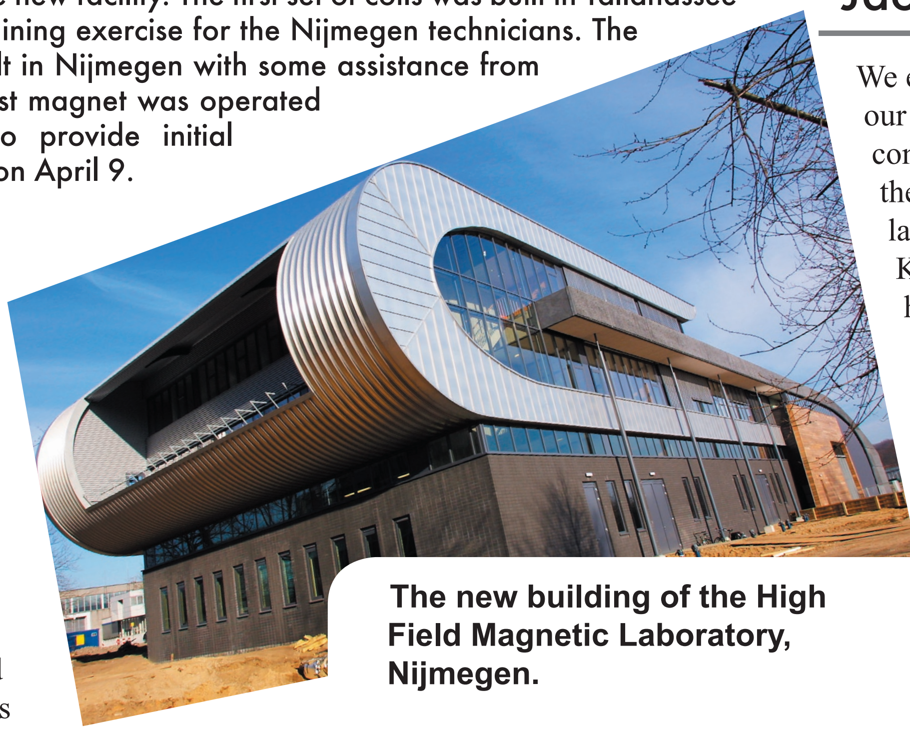
FROM THE DIRECTOR'S DESK

Jack E. Crow

I am very pleased to begin my comments this issue by recognizing the newest magnet laboratory in the world—the High Field Magnet Laboratory at the Catholic University of Nijmegen in the Netherlands. The official opening was held on June 13th, with an open house the following day. As readers can see from the pictures, this is a remarkable building on a beautiful university campus. The facility boasts a 20 MW power supply, which, in principal, can support 40 T for a couple of hours and pulsed fields to 80 T. It currently has superconducting, resistive, and hybrid magnets, and an impressive assortment of novel instrumentation. Three new 33 T magnets of the Tallahassee design have been installed at the new facility. The first set of coils was built in Tallahassee and served as a training exercise for the Nijmegen technicians. The other two were built in Nijmegen with some assistance from Tallahassee. The first magnet was operated to 33.1+/-0.1 T to provide initial experimental data on April 9. 2003.



The new building of the High Field Magnetic Laboratory, Nijmegen.

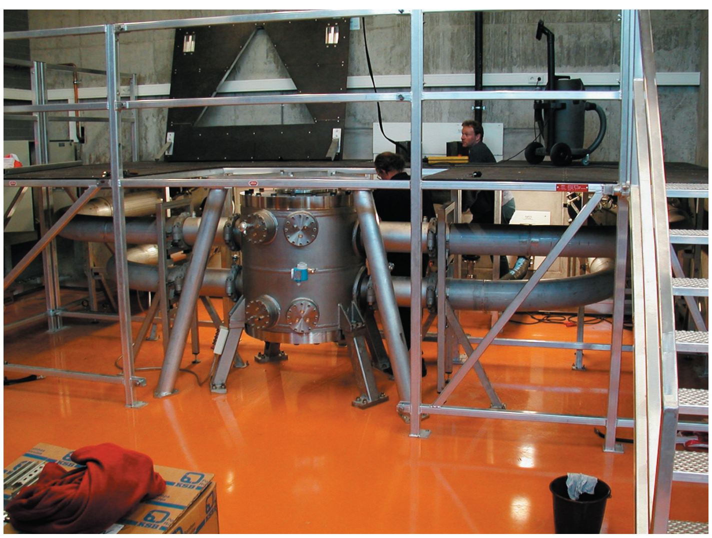
We extend our sincerest congratulations to the director of the laboratory, Jan Kees Maan, and his colleagues, and we look forward to continuing and expanding our ongoing interactions. (See page 23 for comments from Professor Maan.)

In the near future, pulsed magnets will be added to Nijmegen's capabilities, as resources are to be moved from Amsterdam and consolidated. In addition, existing and future NMR facilities further extend and broaden Nijmegen's offerings. Like the NHMFL, "Nijmegen" aims to support and stimulate multidisciplinary research activities and to offer the next generation of scientists rare educational and collaborative opportunities. The investment by the university, the Dutch government, and the European Union into this new user facility is to be highly commended. I believe that it confirms the vital importance of basic research to a greater understanding of our world, to technologies that enhance quality of life, and to economic development.

Another opportunity for expanding the scientific dialogue and exploring new frontiers will be happening here in Tallahassee in late September, as the NHMFL and Florida State University host two neutron scattering workshops with the Spallation Neutron Source. The U.S. neutron users' community is eagerly anticipating the commissioning and operation of beamlines at SNS, currently under construction at Oak Ridge National Laboratory. Many opportunities exist for scientific advances with neutron scattering and spectroscopic investigations by chemists and by biologists working at the chemistry-biology interface. Unfortunately, the number of active neutron users among these communities is small, and the communities as a whole have had little opportunity to communicate their interests and needs. *Neutron Scattering for Chemistry and the Chemistry/Biology Interface,* September 23-25, will begin to bridge these issues, solicit community ideas, and identify tools and directions for the future.

From left to right, the dean of the University of Nijmegen (Roelof de Wijckersloot), Minister of Science and Education (Maria van der Hoeven) and the director of the magnet laboratory (J.C. Maan) discussing a successful opening.

Overlapping the CHEMBIO Workshop will be the "SENSE" Workshop, *Sample Environments for Neutron Scattering Experiments* on September 24-26. This thrust is significant because many of the most exciting neutron science initiatives hinge on the development of advanced sample environments, for example *in situ* studies of catalysis, self-assembling nanostructures, pressure-induced phase transitions, dynamic mechanical stress, and high-field studies of magnetic excitation and structures. For complete information about the workshops, please refer to the Web site: *http://www.sns.gov/jins/tallahassee_workshops_2003/workshops.htm*. I am strongly supportive of these initiatives and encourage broad participation.



Technicians attach power cables to the 33 T magnet in Nijmegen.

In closing, I need to mention, reluctantly, that Greg Boebinger, Director of the NHMFL Pulsed Field Facilities at LANL, has accepted an appointment as Deputy Division Leader of Science Programs in the Materials Science and Technology Division at LANL. On behalf of the NHMFL faculty and staff at all three sites, I would like to publicly thank Greg for his leadership and dedication, his dynamic personality, and his vision. Greg has been an exceptional contributor to the NHMFL, and while we will miss our regular interactions, we look forward to the opportunities that this change presents. In the near term, LANL has named Alex Lacerda (head of the Pulsed Field User Programs) as the Acting Director and will be conducting an international search for a new director. The search committee has been established with representatives from LANL and all three sites of the NHMFL. Under Greg's leadership, the NHMFL Pulsed Field Facility has emerged as one of the finest pulsed field facilities in the world, and we are confident that this legacy will continue for years into the future.

Jack Crow

FROM THE CHIEF SCIENTIST'S DESK

J. Robert Schrieffer

In this issue, path-breaking studies of the so-called FFLO state of superconductors are reported for the first time. In conventional superconductors, electrons of opposite spin and momentum are paired to produce the superconducting condensate. In the FFLO state the electron spin Zeeman energy favors pairing parallel spins to some extent. The orbital state of the superconductor develops nodes in real space leading to alternating layers of superconducting material and spin-polarized magnetic walls. Subsequently, Buzdin and Brison extended the FFLO theory to include interaction of orbital and paramagnetic effects. One finds that in addition to spatially modulated structures the superconducting gap also takes on higher Landau level structure with finite angular momentum. In this case a sequence of first order transitions takes place within the FFLO phase as the external magnetic field is increased. These transitions should be observed in the magnetization or critical current as jumps that separate states of different angular momenta.

These studies were carried out on samples of $CeCoIn_5$ grown by John Sarrao at LANL. This material has a layered structure that inhibits electronic orbital motion for magnetic field parallel to the conducting planes. The large spin susceptibility of $CeCoIn_5$ favors the paramagnetic effects of the FFLO mechanism.

These techniques were used to study the effects, namely heat capacity, magnetization, and penetration depth. The first method gives a direct measure of the thermodynamic state of the material, in particular, the phase transitions. The second method employs a torque method using a cantilever that acts as one plate of a capacitor. The third technique uses a contactess cavity technique that alters its resonant frequency as a function of the state of the superconductor. This is directly proportional to the penetration depth of the magnetic field.

These measurements constitute the first measurements of the FFLO state and demonstrate a fundamentally new state of a superconductor in a strong magnetic field, a long sought goal.

Fulde-Ferrell-Larkin-Ovchinnikov Superconductivity in $CeCoIn_5$

H.A. Radovan, S.W. Tozer, T.P. Murphy, S.T. Hannahs, E.C. Palm, D. Hall, NHMFL
N.A. Fortune, Smith College, Physics Department
C. Martin and C.C. Agosta, Clark University, Physics Department

Historical Background

Superconductivity, a macroscopic quantum phenomenon where electrons of opposite spin and momentum condense into pairs, was discovered in 1911 by Onnes, but eluded theoretical explanation until the work of Bardeen, Cooper, and Schrieffer in 1957. A sufficiently large magnetic field will destroy superconductivity by coupling to the orbital motion of the electrons. This orbital limit (critical field) separates the uniform superconducting state from the normal metallic state. A magnetic field can, however, couple predominantly to the spins of the electrons. The superconductor is then in the paramagnetic limit. It was shown in 1964 by Fulde & Ferrell,[1] and independently, Larkin & Ovchinnikov[2] (FFLO), that this superconducting state would be fundamentally different from the conventional BCS case. In this new state, the magnetic field tries to polarize the opposite spins of the superconducting pairs. In response the superconducting order parameter develops nodes in real space, leading to alternating regions of superconducting layers and spin-polarized magnetic walls. This FFLO state manifests itself as a wedge in the field-temperature (B-T) phase diagram at very low temperatures just below the critical field. The exact shape of the B-T phase diagram depends on many microscopic parameters, such as Fermi surface geometry, dimensionality of the host crystal, impurities, and ratio of orbital-to-paramagnetic effects.

In 1996, Buzdin and Brison[3] extended the FFLO theory to include the interaction of orbital and paramagnetic effects. They showed that in addition to becoming spatially modulated, the superconducting order parameter would also assume higher Landau level states with a finite angular momentum. Under these conditions, a cascade of first order phase transitions within the FFLO phase occurs with increasing external magnetic fields. Each transition should be observable in magnetization or critical current as a discontinuous step that separates sub-phases with different orbital quantum number.

The material in which we observed the FFLO state is the heavy fermion superconductor $CeCoIn_5$, grown by John Sarrao at LANL.[4] $CeCoIn_5$ has a critical temperature of 2.3 K and a layered electronic structure. This anisotropy inhibits orbital motion of the electrons for fields aligned exactly parallel to the conducting planes. Additionally, the large spin susceptibility favors paramagnetic limitation. Thus, this material fulfills the delicate balance of properties needed to observe FFLO superconductivity.

Experimental Methods

Two of the three techniques used to perform the heat capacity, magnetization, and penetration depth studies presented here were developed with funding from the Visiting Scientist Program and the In-House Research Program. The heat capacity measurements were performed in a custom designed, non-metallic rotatable calorimeter.[5]

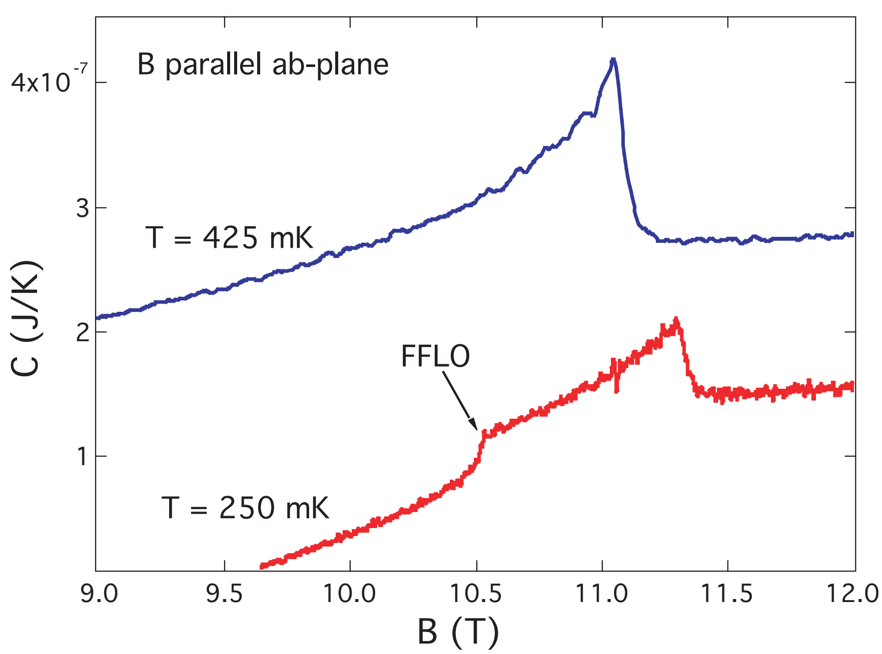


Figure 1. Heat capacity showing the additional FFLO phase transition below the critical field at 250 mK (arrow).

This thermodynamic method provides unambiguous evidence for phase transitions in materials. The second technique employed is a tunnel diode oscillator (TDO) circuit.[6] The TDO allows the experimentalist to make contactless measurements on micron-sized samples that are placed in the coil of a self resonant tank circuit. Changes in materials properties will alter the TDO resonance frequency, which in the superconducting state is directly proportional to the penetration depth of the magnetic field. The third method employs torque measurements using a cantilever that carries the sample and acts as one plate of a capacitor. The measured signal is a voltage proportional to the torque, which, in turn, is directly proportional to the magnetization of the specimen. This method can be used to detect changes to better than 1 ppm.

Results and Discussion

Figure 1 shows heat capacity as a function of field for the field orientation parallel to the planes. The blue curve taken at 425 mK shows a jump at the critical field of 11.1 T. The red curve taken at 250 mK clearly displays a second phase transition at 10.5 T just below the critical field of 11.3 T.[7,8] This additional thermodynamic transition is only present for temperatures below 350 mK and within ±10° of the plane parallel orientation. The lower of the two transitions is the theoretically predicted uniform superconducting-to-non-uniform superconducting (FFLO) state transition. At angles higher than approximately 10°, the orbital effect dominates the paramagnetic effect and FFLO superconductivity cannot be established. This measurement constitutes the first thermodynamic evidence of the non-uniform FFLO state.

In Figure 2, we show the B-T phase diagram as obtained from heat capacity for the plane parallel orientation. The blue squares denote the critical field separating the normal metallic state from the superconducting one. The wedge at low temperatures and high magnetic fields is the FFLO phase, with the red squares separating uniform from non-uniform superconductivity.

Figure 3 shows our TDO measurements as function of applied field at approximately 60 mK. The red curve is taken with the field oriented parallel to the conducting planes. The jump at 11.7 T is the normal state phase transition, while the additional kink at 9.5 T denotes the FFLO phase transition.[9] The blue curve displays data taken at 15° and only the critical field at 9.8 T is seen, behavior identical to that observed in our heat capacity measurements. The kink in the TDO data matches the appearance of the second phase transition seen in heat capacity in both angle *and* temperature. This provides convincing evidence that the

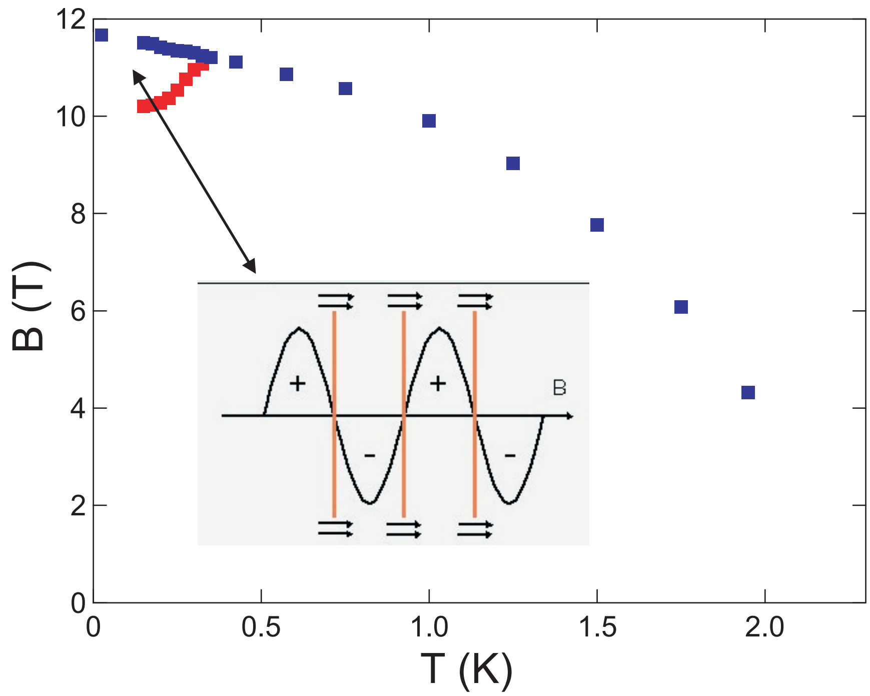


Figure 2. Critical field (blue) and FFLO transition line (red). Inset shows schematically non-uniform FFLO order parameter with magnetic walls. Hysteresis in the heat capacity measurements and the kink and jump nature of transitions in the TDO data confirm that the lower field transition is second order and the higher transition is first order.

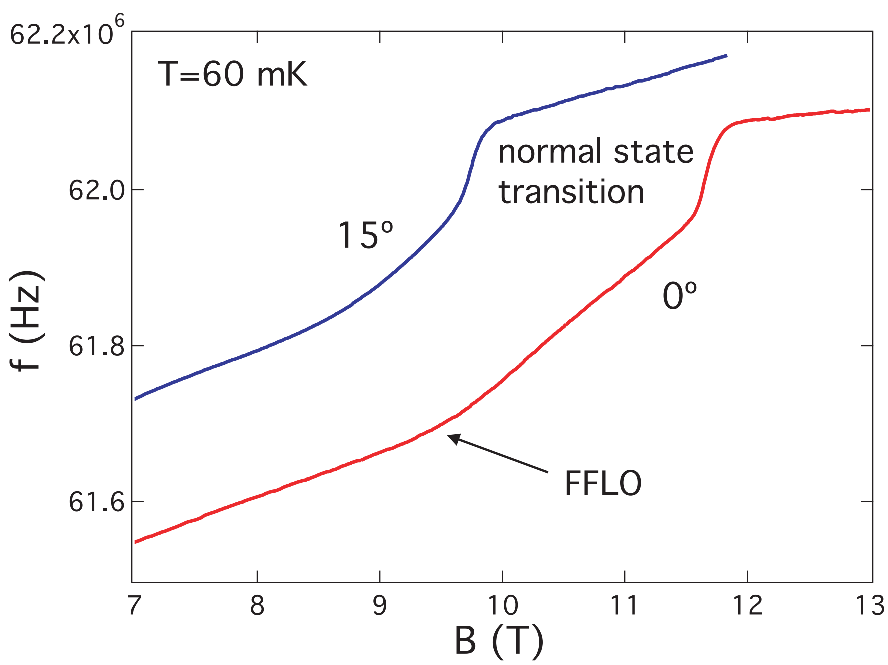


Figure 3. Penetration depth displaying a kink (arrow) in the plane parallel orientation and identified as the FFLO signature.

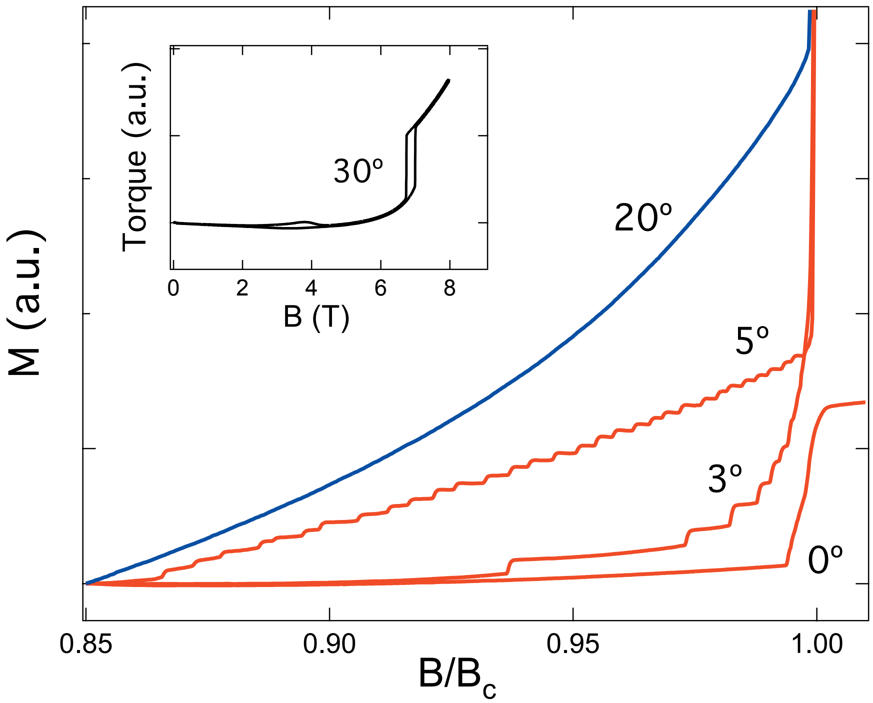


Figure 4. Magnetization displaying Landau level quantization steps close to the plane parallel field orientation. Inset shows cantilever signal for full field cycle outside FFLO regime. Hysteresis is seen in the field sweeps confirming the first order nature of these transitions.

FFLO transition can be seen in penetration depth studies, too, and will allow us to perform high pressure studies of the FFLO state in the near future.

As discussed in the introduction, the coexistence of orbital and paramagnetic effects can promote higher Landau level states of the order parameter. We show in Figure 4 magnetization as function of normalized magnetic field at T = 25 mK. The divergence at $B/B_c = 1.00$ is the critical field. At angles slightly out of the planes (3° and 5°), a cascade of steps appears, which we identify as transitions into sub-phases with higher Landau quantum numbers.[8] The exact plane parallel orientation cannot support higher Landau states, as the orbital effects die out. The blue curve at 20° represents the uniform superconducting state. The phase space in which these steps are observed exactly matches the FFLO wedge defined by our heat capacity and penetration depth studies.

In this new superconducting state magnetism works to prop up or even enhance superconductivity. These two phenomena were mutually exclusive within the BCS theory and only recently evidence started emerging for their constructive coexistence. We hope that our results will help to shed light on the unique coexistence of magnetism and superconductivity in this and other systems.

Acknowledgements

This work was supported by the NHMFL In-House Research Program, a Visiting Scientist Program, NSF through contract DMR-9527035, and the State of Florida. We thank J.L. Sarrao (LANL) for providing the samples, where his work was performed under the auspices of DOE. We thank A. Powell, J. Farrell, V. Williams, R. Desilets, D. McIntosh, and M. Collins of the NHMFL for technical assistance.

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AMRIS Past Present and Future

Arthur S. Edison
AMRIS Director and Associate Professor Biochemistry & Molecular Biology, University of Florida

When I started my job at the University of Florida and NHMFL seven years ago, the NMR equipment in the UF Center for Structural Biology (CSB) consisted of three instruments: 300 MHz, 600 MHz, and a 4.7 T horizontal animal imaging system. Professor Tom Mareci had done an outstanding job starting CSB and obtaining the instrumentation. Tom also was one of the founding members of the NHMFL, and he helped forge the ties between the NHMFL and the McKnight Brain Institute of the University of Florida (MBI). As part of the State of Florida commitment to the NHMFL, Tom also recruited me and Professor Steve Blackband. Without Tom's vision, AMRIS would not be here today.

With the three CSB instruments and two full-time (Dan Plant and Ben Inglis) and one half-time (Jim Rocca) staff members, Tom, Steve, and I agreed to share the burden of directing our NMR facility on a two-year rotating basis with Tom first, Steve second, and me third. That arrangement made a lot of sense at the time, because the instrumentation and staffing were modest in size and the users of the facility did not expand significantly beyond the three of us.

About five years ago things started to change. The grant to build MBI included a significant amount of money for NMR and MRI, and an entire wing of the new building was devoted to housing the new instrumentation. In the move into the MBI, we kept the 600 MHz and 4.7 T magnets but upgraded the consoles. We gave away the 300 MHz instrument and obtained new 500 MHz, 750 MHz wide-bore, and 11.1 T/40 cm bore systems. This collection of five instruments and a new building formed the Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) facility. At this point, AMRIS also became an official core facility within the MBI. To keep the instruments going and allow for growth in usage, we expanded the number of staff scientists from 2.5 to 5 with the addition of Xeve Silver, Gary Blaskowski, and Jim Rocca on a full-time basis. About this time, we also officially became an external user facility for the NHMFL through support from the NHMFL NSF grant.

One of the first things we did with the NHMFL external user support was to establish a strong *rf* engineering team to allow us to fully utilize the unique AMRIS instruments, especially the 750 MHz and 11.1 T systems. We started with one staff scientist, Barbara Beck, who provided several NHMFL external users with unique coils to conduct research on the AMRIS imaging systems. Barbara's efforts were so good that the demand for novel coils and other *rf* support needs increased rather dramatically over the next year or two, so we have added one more full-time *rf* staff member, Kelly Jenkins.

Through Steve Blackband's heroic efforts, our strong *rf* team, and the talents of several collaborators and vital people at the NHMFL, UF was awarded an NIH/NCRR resource grant for the development of improved NMR and MRI measurement capabilities on high-field magnets in April, 2001. Around this same time, MBI Director Bill Luttge also obtained NIH funding for a new Siemens 3 T/60 cm head imaging magnet for human research subjects that would be added to the AMRIS suite of instruments. Finally, AMRIS has taken over a clinical 3 T whole body magnet located between Shands and the VA hospitals that is being completely upgraded to a GE system with a 90 cm magnet. These two human imaging magnets bring the AMRIS total instrumentation to seven systems.

During this period of fast growth, we have added additional staff members to assist with animal experiments, do additional coil building for the human systems, and operate the human systems. In response to the tremendous NMR resources available, UF has hired several new faculty members with NMR as their primary research. These include Professors Krista Vandenborne (Chair of Physical Therapy), Glenn Walter (Dept. of Physiology), Ionnis Constantinidis (Medicine), Yijun Liu (Psychiatry), and Joanna Long (Biochemistry & Molecular Biology). These faculty members, in addition to many other research groups on the UF campus, conduct research using AMRIS instrumentation ranging from solid-state NMR of biological materials to functional MRI studies of the human brain. We have also had a large increase in the number of NHMFL-supported external users over the last two or three years. We currently have nearly 30 active projects that span the range of capabilities offered by our facility.

The large growth experienced by AMRIS over the last five years has outpaced the informal agreement Tom, Steve, and I had about how to direct the facility. Therefore, over the last several months, a group of faculty members who extensively use AMRIS for their research have come up with a new management structure for the facility. Ideally, we suggested that an AMRIS Director should have 100% of his or her time to devote to running, and managing the growth of, the facility, and this person would be supported by a sizeable endowment. UF, however, is living within the same budgetary problems that everyone else in Florida and most of the country are dealing with, so the ideal solution will not happen for now. Instead, we have created a new administrative structure that should allow us to manage the current facility and provide growth for the future. The major points of the new plan are given below.

- First, the Director of AMRIS is now a "permanent" position with time for the job officially allocated in the Director's academic contract and an administrative supplement for the extra effort involved. The Director will also receive some research support for his or her individual laboratory. The Director will be the primary contact person between AMRIS and the NHMFL and will serve as the UF "biological" member of the NHMFL Executive Committee. I have accepted the new job as AMRIS Director.
- Second, AMRIS will hire a full-time office administrator. This administrator will keep all of the daily activities going and will interact with both the internal and external users and AMRIS staff members. The administrator will track instrument usage and, with the Director, will be the primary contact with the NHMFL.
- Third, we have created five user groups, spectroscopy, microimaging, animal imaging, human imaging, and *rf*. Each of these user groups will meet on a regular basis and interact through Internet e-mail forums to discuss technical details, protocols, common problems, and new hardware or software requirements. There will also be an Associate Director (AD) for each user group. The AD will be a faculty member who is an expert in that field and will advise the Director about policy, usage, or needs in particular areas. We are especially excited about the AD structure, because that system provides a very natural way to establish new collaborations and attract new users.

Over the last seven years, AMRIS has grown into a prominent NMR and MRI facility through its association with the McKnight Brain Institute and National High Magnetic Field Laboratory. We have the instrumentation infrastructure to do cutting-edge research in almost any area of biology, and we have now put an administrative structure to fully support these activities. We look forward to our continued partnership with the NHMFL to provide the best possible research environment for scientists around the world.

Solid State ^{19}F NMR Spectroscopy and Applications to Membrane Proteins

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It is well known that sensitivity is one of the most challenging problems in solid-state NMR studies of biological systems, particularly membrane proteins. Although ^{15}N solid-state NMR has proven to be very advantageous for the development of structural biological methods, its poor sensitivity has made the signal observation extremely difficult, especially for large membrane proteins, thus limiting the use of experimental methodologies. On the other hand, ^{13}C, another

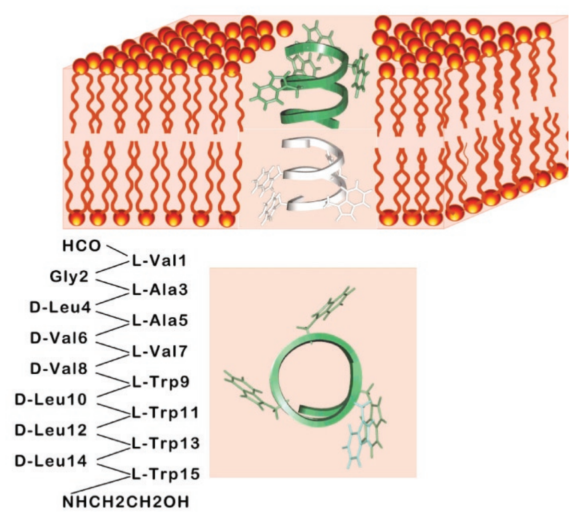

Figure 1. Structure of gramicidin A (gA) in lipid bilayers derived from orientation-dependent solid state NMR studies. Side view (Top) and Top view (Bottom). The structure features an amino terminal to amino terminal hydrogen bonded single-stranded dimer with each monomer folding into a right-handed β-helix of 6.5 residues per turn. All Tryptophan side chains are indicated in this figure.

essential element in proteins, is relatively sensitive compared to ^{15}N, but enormous background signals of natural abundance severely obscure the observation of a labeled peptide in lipid bilayer environments. In contrast, ^{19}F is the most sensitive NMR nucleus besides ^{1}H. In native biological systems, there is no ^{19}F background signal. Therefore, all ^{19}F signals must stem from the specifically labeled sites. Importantly, it is generally believed that replacement of a single hydrogen by fluorine in a protein is unlikely to cause a significant structural or functional effect because the van der Waals radius of covalent fluorine is only slightly larger than that of hydrogen.

High sensitivity and background-free signal from a protein are the two unique advantages of ^{19}F NMR spectroscopy. In addition, the ^{19}F chemical shift is extremely sensitive to local electrostatic and van der Waals environments. Thus, ^{19}F NMR spectroscopy has become a powerful means to probe protein structure and conformational changes in solution.[1-9] However, few solid-state ^{19}F NMR spectroscopic techniques are yet available for comprehensive studies of insoluble proteins particularly membrane-bound proteins and peptides in lipid environments.

Recently we have used ^{19}F multiple-quantum (MQ) solid-state MAS NMR spectroscopy to determine a ^{19}F coupling network (i.e. spin counting). It has been known that MQ modes can be used to probe the extent of a homonuclear coupling network.[10] For instance, in an *isolated* four-spin system, the maximum quantum number of 4 is observed, which corresponds to the number of spins in the network. In solution, the homonuclear coupling network is established through J-coupling thus the MQ modes usually represent isolated local coupling networks within a molecule. In solids, however, the dipolar interactions, much larger than the J-coupling in magnitude, connect spins together forming a complex coupling network. This coupling network may be extended to many molecules because of the existence of strong intermolecular dipolar interactions particularly for ^{19}F. Therefore, a molecule needs to be isolated in order to determine precisely the number of spins within the molecule. Fortunately, in membrane-bound proteins, each functional structure is well isolated because of the presence of lipid environments. For instance, each gA dimer structure, as shown in Figure 1, is surrounded by lipid bilayers so that the near-by gA dimer structures are far away. In addition, the global motion of the dimer structure around the channel axis also effectively removes any residual coupling between the gA dimer structures.

Figure 2 shows the MQ filtering MAS spectra of 3,5F-benzoic acid mixed with adamantane at a molar ratio of 1:10. The two compounds were melted and mixed together. After cooling, the 3,5F-benzoic acid was diluted microscopically so that the intermolecular F-F coupling is greatly attenuated. Double-quantum (DQ) coherences were observed, as shown in Figure 2B, and no triple-quantum (TQ) signal could be detected (c.f. Figure 2C), because the two fluorines in each benzoic acid form a two-spin coupling network. Therefore, the MQ MAS

NMR continued on page 19.

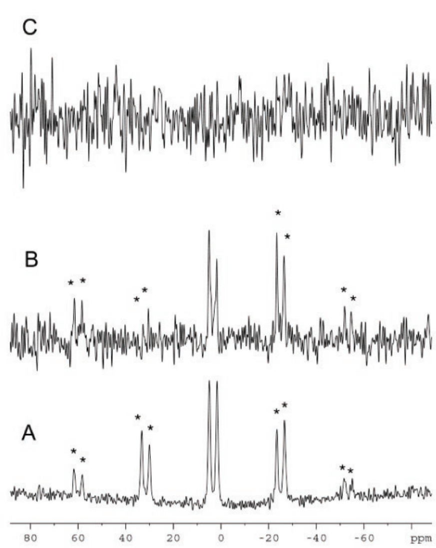

Figure 2. ^{19}F MAS NMR spectra of 3,5F-benzoic acid/adamantane (1:10 molar ratio) recorded on a Bruker 600 NMR spectrometer. The sample spinning rate was 16.0 kHz. (A) Single-quantum MAS spectrum. (B) Double-quantum filtering MAS spectrum. (C) Triple-quantum filtering MAS spectrum. The spinning sidebands are indicated by * in the spectra.

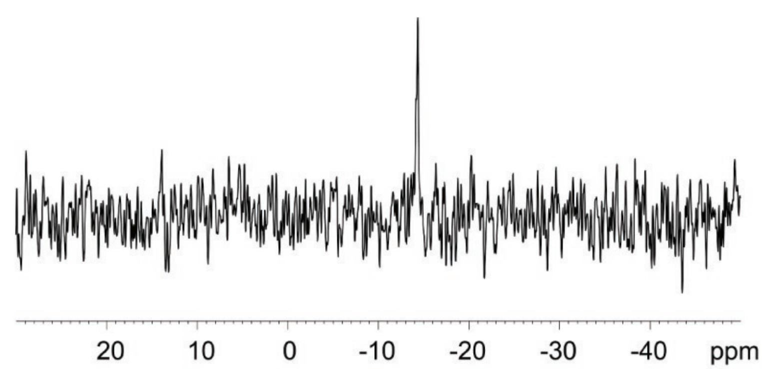

Figure 3. Quadrupler-quantum (QQ) filtering MAS spectrum of M2 TMP in DMPC at 1:16 molar ratio. The observation confirms the tetrameric channel structure of the M2 protein. The spectrum was recorded at 310 K on a Bruker DMX600 with a Doty H/F/X MAS NMR probe.

The NHMFL Ultra-High B/T Facility: *A Study of Transport in Highly Polarized Fermi Fluids*

Neil Sullivan, NHMFL Co-Principal Investigator, Dean of the UF College of Liberal Arts and Sciences, and former chair of the UF Department of Physics

The National High Magnetic Field Laboratory operates a specialized facility at the University of Florida to meet the needs of users who require both high magnetic fields and ultra-low temperatures simultaneously for their experimental investigations. This facility, known as the NHMFL High B/T facility, is designed with a high refrigeration capability to permit studies over a wide range of applications for extended periods of time. A 5-mole $PrNi_5$ nuclear demagnetization refrigerator provides the high cooling power, and following a demagnetization from 8 T beginning at 10 mK, this refrigerator can maintain temperatures below 1 mK for over 100 days, provided the heat leaks are kept below 8 nW.

An ultra-quiet environment is provided to reduce heating due to external electromagnetic fields, and this enables experimenters to carry out highly sensitive measurements on samples held at sub-millikelvin temperatures. An advanced vibration isolation support structure reduces the mechanical vibrations that can lead to eddy current heating in the metallic components that are located in the magnetic field. The entire experimental structure is housed inside a ***tempest*** quality electromagnetic screened room to reduce heating from radio-frequency sources. The current magnetic field capability for the experimental region is limited to 15.5 T, and experiments can be carried out at temperatures down to 0.4 mK (a limit resulting from the nuclear ordering of the $PrNi_5$).

A number of new research studies have been made possible with the use of this facility. One of the projects recently completed has been the investigation of transport in highly polarized Fermi fluids, an NHMFL In-House Research Program-funded research project lead by Don Candela of the University of Massachusetts. A distinct anisotropy is predicted for the transport of magnetization and for the spin diffusion for highly polarized Fermi liquids.[1] This is due to the difference in phase space scattering for the spin-up and spin-down Fermi spheres. For a spin polarization, P, the diffusion constant for motion in a plane perpendicular to the applied magnetic filed is given by

$$D_\perp = \frac{D_0}{1+[T_a(P)/T]^2}$$

where $D_0 = \frac{1}{3} v_F^2 \tau_F$, v_F is the Fermi velocity and τ_F is the mean time between scattering

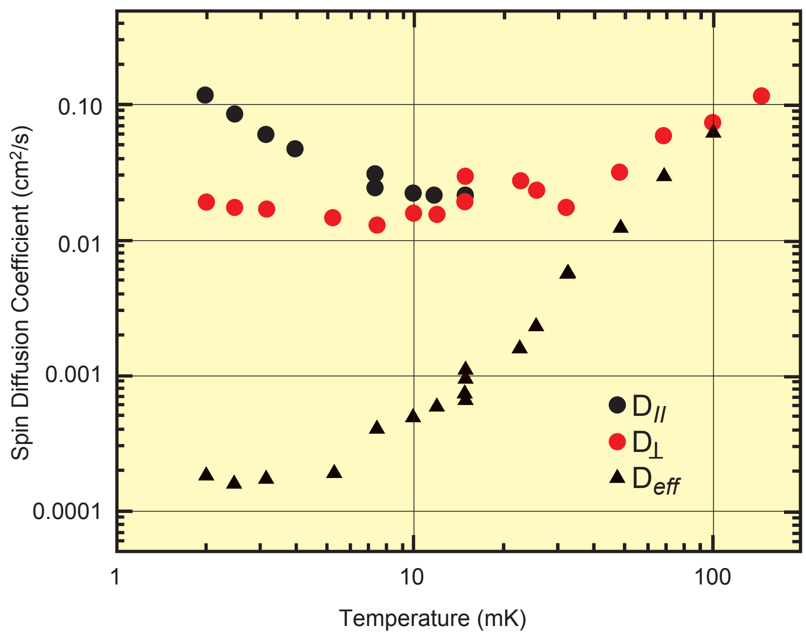

Figure 1. Results of NMR measurements of the nuclear spin diffusion of ^3He dissolved in ^4He for a ^3He concentration of 3.8%.

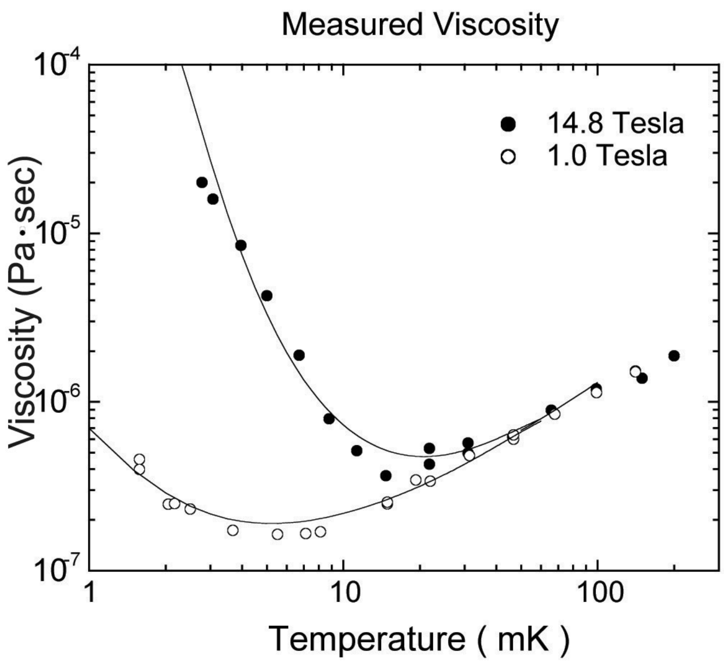

Figure 2. Temperature dependence of the viscosity of a dilute Fermi fluid, a solution of ^{3}He (150 ppm) in ^{4}He, for two different applied magnetic fields.[3]

events. The characteristic temperature at which the anisotropy sets in is given by $T_\alpha = \hbar\gamma B_0 / 2\pi k_B$ where B_0 is the applied magnetic field, and γ is the gyromagnetic ratio for the spin bearing species. T_α=2 mK for ^{3}He in an applied field B_0 = 15 T. For diffusion parallel to the applied magnetic field,

$$D_{//} = D_0(1+\alpha P)$$

where α is a constant of order unity. Experiments have been carried out to test the existence of this field-induced anisotropy for a solution of helium three in helium four with a helium three concentration of 3.8%.[2] For this special value of the concentration, the spin-wave diffusion coefficient vanishes, permitting a direct measurement of the diffusion without large corrections due to the Leggett-Rice effect. The measurements were carried out using pulsed NMR techniques for Larmor frequencies up to 650 MHz. The results shown in Figure 1 clearly demonstrate the existence of a strong anisotropy and the expected temperature dependence for the diffusion constant.

We have also measured the field dependence of the mean viscosity, the root mean square geometrical average of the diffusion perpendicular and parallel to the applied field, for a very dilute Fermi system, namely 150 ppm of helium three in helium four. For this dilution, the Fermi factors are very close to unity, and the system is expected to be treated reliably using first principles. The observed temperature dependences for two different applied fields are shown in Figure 2. The measurements were made using vibrating wire magnetometers[4] calibrated against helium three melting curve thermometers. For the highest field of 14.8 T the helium-three spin polarization reaches 99% for the lowest temperatures studied. The solid lines in Figure 2 are best fits to the theory, and while the fit to the temperature dependence at low temperatures is reasonably good, the absolute magnitude of the fit at high temperatures shows that some problems remain with the theory.

These experiments illustrate the wide range of capabilities available for users at the High B/T Facility; including pulsed NMR techniques up to 1 GHz, vibrating wire viscometers, melting curve thermometry and high cooling capability for signal averaging for extended time periods. The facility is available to all qualified users, and scientists interested in conducting experiments at the High B/T unit should contact either Jian-sheng Xia (352-392-8871) or Dwight Adams (352-392-0485).

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Ultra-Wide Bore 900 MHz Bucket Test, Installation, and Commissioning

Tom Painter, Magnet Science and Technology

Contributors:
Steve Van Sciver and Kurt Cantrell, Magnet Science and Technology
Tim Cross and Bill Brey, NMR

The world's first 105 mm bore, 900 MHz NMR system will soon begin its commissioning phase at the NHMFL in Tallahassee. The entire NMR magnet system has been designed, built, and tested. The cryostat is nearly completed. Facilities have been upgraded. NMR probes and equipment are being prepared and we are on the threshold of commissioning. Since our last report in the spring of 2002 (*NHMFL Reports*, **9**(2), 2002), at which time the magnet system had just undergone 4.2 K testing, much has been accomplished. Specifically, the final 2.3 K bucket testing has been completed. Fabrication of the 1.8 K superfluid helium cryostat is nearly finished. The 900 MHz magnet and cryostat assembly has been relocated to the final user area, and preparations are being made for commissioning. This report describes the progress made over the past year and a half of the NHMFL Wide Bore 900 MHz NMR System and facilities and goes into some detail on the designs of the cryostat and NMR measurement systems.

Completion of the Bucket Test

At the end of August 2002, the bucket test of the magnet system was completed. The magnet system was tested in a temporary "bucket" cryostat to confirm operation of each of the sub-systems assembled together as an integrated unit for the first time. The bucket test confirmed operation of the magnet system, the quench protection system, and all the associated superconducting switches, coils, shims, and electronics. The bucket cryostat provided saturated 2.3 K helium and relatively easy access to the test assembly to allow modifications required as determined by the system testing. The bucket cryostat, due to its easy access requirement, could not provide the sub-cooled, 1.8 K helium environment of the permanent cryostat, and it was realized that this cryogenic limitation might prevent achievement of 900 MHz. ***The system, however, was charged to 875 MHz on its first attempt at 900 MHz!*** Subsequent attempts reached 810 MHz and 843 MHz and showed no indication of magnet system degradation as a result of quenching. Several modifications were made to the quench protection system and the associated subsystems during the bucket testing. The superconducting shim sets were fully characterized and their shim capabilities were confirmed. The decay rate of the magnet system was measured and found to be higher than specified. As a result, a current injection method of correcting for field drift was incorporated into the final system design and will be tested during the upcoming commissioning phase. Overall, the bucket test was very successful. It characterized the basic capabilities of this first-of-its-kind system and allowed modifications to the integrated magnet and quench detection system before installation into the permanent cryostat. But most promising, it nearly achieved its full operational field in the relatively low thermal stability provided by the saturated 2.3 K helium environment.

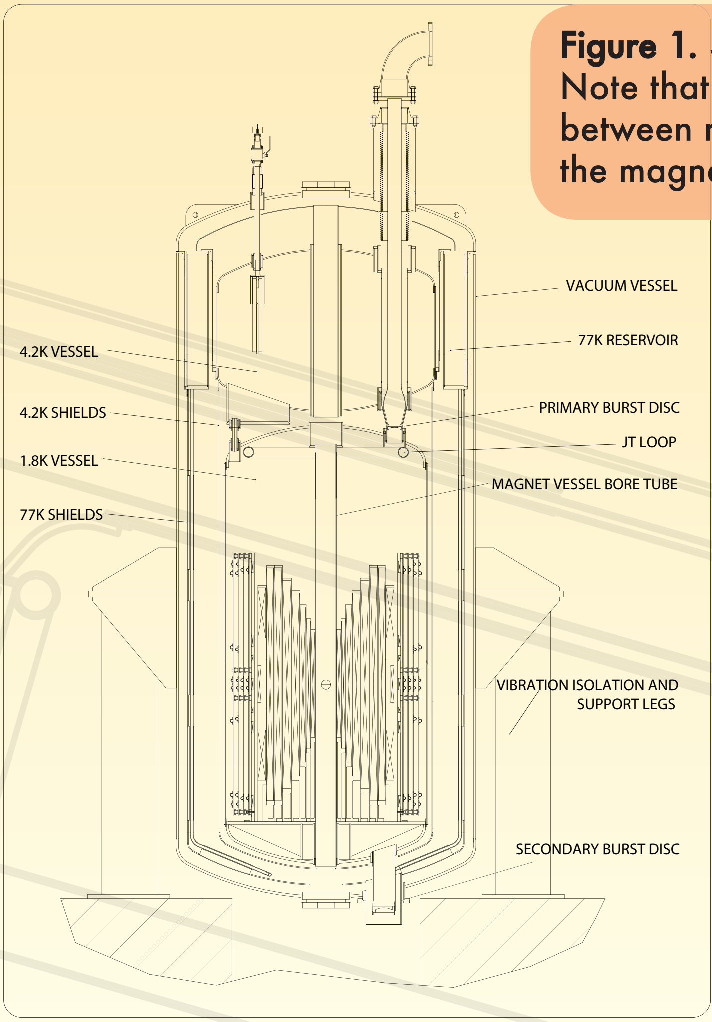

Figure 1. Some of the key features of the cryostat. Note that only two of the eight service penetrations between room temperature, the 4.2 K reservoir, and the magnet vessel are shown.

The Permanent 900 MHz NMR Cryostat

The permanent 900 MHz NMR cryostat, designed by Steve Van Sciver, Kurt Cantrell, and Scott Welton, is described as follows. The 900 MHz NMR magnet cryostat consists of a vacuum vessel and two liquid helium reservoirs as shown in the assembly schematic in Figure 1. The upper reservoir, which is made of 316 stainless steel, contains a volume of saturated liquid helium at 4.2 K. There are eight penetrations from room temperature to the 4.2 K reservoir, one each for: (1) the main current leads, (2) quench and switch heaters, (3) the auxiliary power leads, (4) the burst disc assembly, (5) the cool down port, (6) the instrumentation probe, (7) voltage taps, and (8) the JT refrigerator. The 4.2 K reservoir consists of approximately 1,100 liters of saturated helium (He I) and is sized so that the hold time between refills is 23 days.

The lower reservoir, also made of 316 stainless steel, holds the magnet in a volume of sub-cooled superfluid helium (He II) at 1.8 K and one atmosphere. The magnet reservoir has an enclosed volume of approximately 3,500 liters, which contains the 900 MHz magnet system assembly and approximately 2,400 liters of He II. The 1.8 K operating temperature is maintained by a JT refrigeration system. This component consists of a copper heat exchanger containing saturated 1.8 K He II, which is in thermal contact with the sub-cooled helium in the magnet vessel. The temperature of the saturated He II in the heat exchanger is controlled by regulating the vapor pressure above the bath with a vacuum pump located at room temperature. The liquid level in the heat exchanger is controlled by a feedback loop that monitors the liquid level and controls the JT valve position.

Thermal radiation shielding is provided at two temperatures, 4.2 K and 77 K. The magnet reservoir is surrounded on its bottom and outer surfaces by the 4.2 K shield. The 4.2 K shield is conductively cooled and thermally anchored to the 4.2 K reservoir. Due to a lack of available space, there is no 4.2 K radiation shield on the inner bore of the magnet vessel or on the secondary burst disc nozzle. The 4.2 K reservoir and shield are in turn surrounded on their outer and inner surfaces by 77 K shields, which are actively cooled by liquid nitrogen (LN_2) beneath the 77 K reservoir and conductively cooled above the 77 K reservoir and in the 4.2 K vessel bore. The 77 K shield below the reservoir is a continuous cylinder of ¼” thick aluminum. A custom designed and fabricated composite 77 K shield is located on the inner diameter between the magnet vessel and warm bore tube and is actively cooled by LN_2. The 560 liter toroidal 77 K reservoir is sized for a 24-day hold time.

The weight of the magnet and cryostat assembly is supported internally by composite support cylinders and stainless steel straps and externally by four support columns, which also provide vibration isolation. Within the cryostat, two G10 composite support cylinders and six stainless steel straps carry the weight of the magnet assembly from the top. One composite cylinder and six stainless steel straps are located between room temperature and 77 K and carry a load of approximately 23,000 lbs. A second composite cylinder is located between 77 K and 4.2 K and carries a load of approximately 17,000 lbs. The cryostat is supported externally by four Fabreeka® support columns and vibration isolation units. The vibrational stability requirement is met by the vibration isolation pads located on the support columns and by six horizontal anti-vibration straps located between the vacuum vessel and the magnet vessel near the bottom of the magnet vessel.

The cryostat is built around the magnet on site at the NHMFL. Subassemblies were fabricated at the cryostat supplier then shipped to the NHMFL for final assembly in Cell 16 which has a 25 T overhead crane available. After the magnet assembly was attached to the 4.2 K vessel and the 1.8 K vessel was welded in place, it was transported to its final operation area in NM112 for final assembly of the thermal shields and vacuum vessel.

Figure 2.
A Goldhofer trailer was used to relocate the 900 MHz assembly along the newly graded road.

Fabrication of the Permanent Cryostat and Relocation into the Final User Area

Since bucket testing, the primary emphasis has been on fabricating the permanent cryostat around the magnet assembly. These activities at the NHMFL, led by Iain Dixon, have involved many hundreds of tasks, but the basic steps completed before relocation to the final user area were as follows. The 4.2 K vessel assembly, received as a fabricated unit from the cryostat supplier, comprises essentially the upper half of the cryostat and weighs approximately 6,000 lbs. This assembly was lowered over the magnet and welded to the magnet vessel bore tube. Welding to the bore tube was quite a challenging exercise considering the massive, large diameter 4.2 K vessel assembly had to be located and balanced in mid-air above the magnet assembly to within a few ten thousandths of an inch to mate to the partially inserted bore tube. Note that the magnet vessel bore tube is designed inside the magnet assembly with extremely tight tolerances to provide maximum space to the NMR scientists. After the bore tube weld was leak checked—while hanging in midair—the entire 6,000 lb assembly was lowered into its final position by sliding the bore tube inside the innermost superconducting coil with nearly zero clearance between the two. Finally, the outer shell of the magnet vessel was welded in place and leak checked at which point the magnet and cryostat assembly was ready for relocation to the final user area.

In early April 2003, the magnet and cryostat assembly was safely relocated to the opposite end of the laboratory. Up until this point, the cryostat assembly required the use of the high bay area and crane in the Cell 16 fabrication area. Attachment of the next hardware items, the thermal shields, however, would have raised the risk of damaging the 16 foot tall, 23,000 lb. assembly during the relocation process. After exploring many options for the method and the path by which to move the assembly, it was finally decided to subcontract the relocation

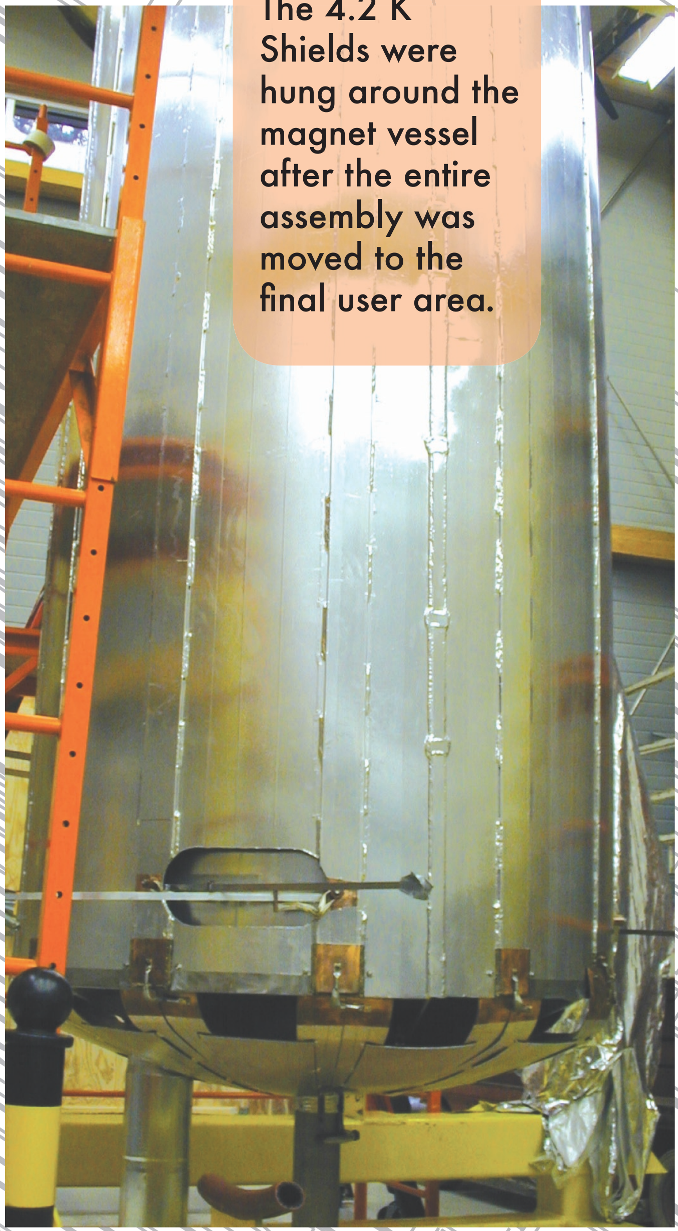

Figure 3. The 4.2 K Shields were hung around the magnet vessel after the entire assembly was moved to the final user area.

task to Barnhart Crane and Rigging. Barnhart used a Goldhofer trailer to relocate the magnet and cryostat assembly, and a road was newly graded behind the lab to clear the way for the move. The Goldhofer trailer can independently raise and lower multiple sections of the trailer to maintain the transported load as level as possible. A custom transportation frame was designed and built at the NHMFL specifically for the move and for the remaining fabrication tasks required in the final user area. A practice run with a full size test load was performed the day before the actual relocation was performed, and special rails were laid down to move the assembly out of and into the buildings at each end. Vibration measurements during the move indicated the typical vibration was consistently less than 0.02 g and only during one event did it reach just over 0.06 g. In all cases, the recorded vibrations were less than the specified maximum allowable of 0.1 g. Figure 2 shows a picture of the 900 MHz assembly being moved by the Goldhofer in its transportation frame along the newly graded road. More details of the relocation process can be seen in photographs shown in the last issue of *NHMFL Reports* (**10**(2), 2003). The relocation process resulted in a successfully and safely transported 900 MHz assembly.

Presently, the final fabrication of the 900 MHz cryostat is being completed in NM112. The 77 K traced bore tube has been installed. The 4.2 K shields and 4.2 K multi-layer insulation (MLI) have been attached as shown in Figures 3, 4, and 5. The 77 K shields and 77 K MLI are the present focus of activities. This will be followed immediately by attachment of the vacuum vessel and vibration isolation and support legs. Finally, the yellow relocation frame will be removed, the user platform will be installed, the utilities and controls will be connected, and the commissioning phase will begin.

Facilities Activities

It is important to note the key role that the NHMFL Facilities group, led by John Kynoch, is playing in the installation of the 900 MHz system with respect to utilities, control, and safety. The Facilities group has literally laid the groundwork to allow the system to be relocated and installed. First of all, the path chosen to relocate the magnet was an uneven, rocky road until Facilities led the activities to grade the path to ensure a safe and secure relocation process for the magnet as well as provide an environmentally friendly road construction process. Furthermore, the Facilities group has been working closely with the 900 MHz team on a daily basis to develop the utilities required of an NMR user facility including the programming and installation of the control logic that will help run the magnet system and ensure the safety of equipment and personnel. Facilities has also assisted in the design and installation of the helium recovery and vacuum systems. But perhaps most challenging, ***Facilities has upgraded the HVAC to attempt to meet a temperature stability requirement of +/- 1 degree Fahrenheit throughout the 900 MHz user area, which will maximize the ability to perform the best NMR science.***

Figure 4. Multi-layer insulation (MLI) required between the 4.2 K and 77 K shields was fabricated into five-layer blankets in NM112 before being applied to the assembly. Shown here paying careful attention to an accurate and clean process are Lee Marks, Steve Lydzinski, and Don Richardson from left to right.

Figure 5. The MLI has to be custom cut to match the dished head contours and to interface with the secondary burst disk and bore tube penetrations at the bottom of the shields.

The Commissioning Phase

The installed wide bore 900 MHz system will undergo extensive commissioning. During the commissioning, we will fully characterize and fine tune the operation of the magnet, shim sets, bucking coils, cryogenics, data acquisition, active quench protection system, and NMR operations in their final location. The first item to be confirmed during the commissioning phase is the safety of the pressure vessel. This will be performed by a proof pressure test at 77 K to 6 atmospheres, 20% over the design pressure. After that, the system will be warmed up to allow installation of a 5 atmosphere secondary burst disc as a redundant pressure vessel safety precaution. Next, the system will be cooled again, filled with liquid 4.2 K helium, and then cooled further to 1.8 K. At this point, the magnet will be charged to 900 MHz. It is typical for a superconducting NMR magnet to undergo a training period of quenches until full field is reached, and it is likely that the 900 MHz system will also experience some training quenches.

Once the magnet is at field, a range of activities will be carried out to prepare for NMR application science as follows. The magnetic field will be homogenized in several steps to achieve the high uniformity required for many NMR studies. First, the current in the superconductive shim coils will be adjusted based on iterative NMR mapping of the field. Then a custom-designed room temperature shim coil insert will be installed and tested. The room temperature shim coils will leave a full 89 mm inner diameter for user instrumentation. The novel current injection system will be tested and adjusted to compensate for field drift. Design calculations indicate that the current injection will produce a minor loss of field homogeneity that may be significant for some solutions experiments. The shim and current injection power supply is being designed to allow for continuous compensation of this effect, once it has been measured. When these basic mapping and adjustment operations are complete, installation and testing of the NMR console and sample probes can proceed.

The NMR science activities, led by Tim Cross and Bill Brey, are described as follows for the commissioning phase. A new, multichannel, high-power NMR console and suite of sample probes has already been partially delivered by Bruker Instruments. It includes a triple axis gradient HCN probe for solution NMR of proteins, a triple resonance CPMAS probe for materials chemistry and solid state NMR, and a set of imaging probes for biomedical applications. Specialized probes for membrane protein analysis are under development at NHMFL through an In-House Research Program-sponsored collaboration with leading NMR scientists. Extensive testing and adjustment of the equipment and demonstration of NMR techniques by both NHMFL staff and Bruker engineers will be carried out during the commissioning phase. The NMR experiments run during this phase will both prove the quality of the magnet and illustrate baseline capabilities for the NMR user community. As the commissioning phase progresses, more and more magnet time can be devoted to user applications. A strong emphasis will be placed on experiments that require the unique wide bore as well as the 900 MHz field. A discussion of the NMR science priorities for the 900 and the capabilities of a wide bore instrument can be found in the "Attention Users" column by Tim Cross in the Fall 2002 *NHMFL Reports* (**9**(3) 2002).

Having outlined our plans for the commissioning phase above, it is worthwhile to note at this time that any superconducting magnet system is a high tech instrument operated in a very technically challenging environment. In our case, we are dealing with several difficult feats in one combined system: a large bore 900 MHz (equivalent to 21.1 T) superconducting magnet system, a sub-cooled 1.8 K cryostat (only the second such large scale NMR cryogenic system in the world), and finally the exploitation of unique NMR science. During the commissioning phase, we will be operating this system in the permanent cryostat and finding our balance for these combined feats for the first time. We applaud the scientists, engineers, and technicians who have risen to the challenge and are joining their skills towards the common goal of creating the world's first 105 mm bore, 900 MHz NMR system.

NMR continued from page 13.

experiments allow one to precisely determine how many spins are in close proximity.

This strategy has been applied to determine the channel bundling structure of M2 because the monomers bundle with each other to form a channel. The M2 membrane-bound protein from Influenza A virus consists of 97 amino acid residues serving as a pH-regulated proton channel across the transmembrane. Since each monomer consists of a Tryptophan in the transmembrane segment, a single 5-F-Trp label in each monomer forms a coupling network from monomers because of the bundling. Thus, MQ measurements will provide direct evidence for the modeled tetrameric channel structure.[11] The preliminary result is shown in Figure 3 confirming the tetrameric structure.

A solid-state ^{19}F NMR project including F-F and F-X distance measurements is being conducted by a team of scientists at the NHMFL in collaboration with Prof. Anne Ulrich at the University of Jena and supported by the NHMFL In-House Research Program. Currently there are two ^{19}F NMR probes available at the NHMFL: a Doty 4 mm ^{1}H/^{19}F/X triple resonance MAS NMR probe for the 600 WB and a Doty ^{1}H/^{19}F double resonance wide-line NMR probe for the 830 MHz. The former, capable of spinning up to 24 kHz, allows one to observe ^{19}F NMR with high power ^{1}H decoupling and to measure ^{19}F-^{19}F and ^{19}F-X dipolar interactions. The latter one has a rectangular sample coil with a dimension of 7 mm (width) x 2.5 mm (height) x 10 mm (length), allowing one to perform CPMG-type experiments[12,13] to measure ^{19}F-^{19}F dipolar couplings in peptides in anisotropic phases. Scientists who might want to use these capabilities should contact Dr. Riqiang Fu at *fu@magnet.fsu.edu* or Dr. Tim Cross at *cross@magnet.fsu.edu*.

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ATTENTION USERS: Bruce Brandt, Director, DC Field User Program

The NHMFL Users' Committee was established by NSF mandate with the founding of the NHMFL to provide advice on all questions that relate to users. Committee members are nominated and elected by a large group of past, present, and potential users. The "at large" members are users of the Los Alamos facilities, the DC general purpose magnet facilities in Tallahassee, and/or the High B/T Facility in Gainesville. The "CIMAR" representatives represent the EMR, ICR, MRI/S, and NMR Facilities in Tallahassee and Gainesville. The ICR, MRI/S and NMR facilities also have their own advisory committees. The directors of the user facilities at the NHMFL, and NHMFL management in general rely heavily on the advice given by the users' committees. Roy Goodrich, Users' Committee Chair, prepared the summary that is reproduced here.

NHMFL's first 27 T User.

Users' Committee Meeting of November, 2002
Summary Report by Roy Goodrich, Users' Committee Chair

The annual meeting of the Users' committee was held on the 8th and 9th of November, 2002 in Gainesville, FL. The NMR Users' Committee met on the 8th and submitted their contribution to the report, focusing on issues of particular interest to the NMR community, on the 9th. A workshop on long wavelength optical measurements also preceded and reported to the Users' Committee meeting. The following is a summary of the items that were on the agenda and were discussed, with any recommendations included.

- The committee unanimously commended Jack Crow for the magnificent job he has done as Director of the NHMFL. In an expression of this appreciation, a small gift of a desk lamp in the shape of a resistive magnet was presented to him.

- The success and improvement of the laboratory infrastructure was a major item of discussion. The committee recommends that the new director negotiate with the FSU administration for increased funding from overhead return and the establishment of new faculty lines that will be filled by people who can lead the development of new measurement areas.

- The combined imaging and biological spectroscopy activities in Gainesville represent an important "extreme" end of the cross-disciplinary activities of the NHMFL. For these reasons, it is critical that this component continue to be recognized, encouraged, and partially funded by NHMFL.

- It is essential that the superconducting 900 MHz fabrication and installation be completed and that a transition to its practical use be undertaken. This is critical because, among other reasons, this machine will provide unique, critical technology both for cutting-edge MR research and as a "platform" of technology for reaching even higher fields. *(See the report on the 900 MHz system elsewhere in this issue.)*

- The NMR users' group strongly supports the development of the 35 T series connected hybrid magnet. A list was made of 10 different interesting phenomena or effects in biological materials science that may be seen only at fields dramatically higher than the current 21 T limit. The 35 T will allow preliminary tests of these predictions and motivate development of higher field persistent superconducting magnets.

- The condensed matter researchers on the committee also strongly support the development of a 35 T series connected hybrid.

- There is a need for funds to support an imaging faculty position in Tallahassee in order to realize the spectacular imaging potential of the new 900 MHz.

- Concerns about the continuing costs involved in constructing the 900 MHz NMR are continuing within the committee. We requested an explanation of the sources of funding for the completion and testing of this facility, and how the costs will affect the completion of other established projects.

- We again request and recommend that the split pair resistive magnet, as proposed in the renewal, be completed as soon as possible.

- We recommend that the laboratory establish rigid infrastructure priorities including guidelines for ending projects that drastically overrun original cost estimates. We suggest that additional support personnel should be part of the cost of new projects.

- The group of far infrared users and experts had the following recommendations:
  - Improve existing probes and spectrometers to increase signal, reduce noise, and extend the temperature and wavelength ranges.
  - Develop a new roadmap for instrumentation development.
  - A dedicated infrared cell.
  - New probes for infrared polarimetry, reflectance etc. with He-3 detector to be used in the 50 mm, 32 T resistive magnet.
  - One or two new spectrometers - Bruker 66v and/or a step-scan.

  (Development of a dedicated optics cell, new probes, and a new spectrometer is in progress and will be reported on in the next issue of this newsletter.)

- We recommend that if young Ph.D.s are employed for user support, the possibility of their being promoted to a Scholar/Scientist position as their career progresses should be available.

- The committee requests that a report on the In-House Research Program (IHRP) be made to the committee for their input in assessing the effectiveness of the program.

- To help in our desire to aid the NHMFL in their relations with the NSF, we recommend that program officers be invited to future meetings of the committee. In addition, we decided to hold bi-monthly telephone conferences to discuss issues as they arise. Their results are summarized below.

- We discussed and support the idea of holding one-day workshops on new measurement techniques the day preceding the beginning of each annual meeting of the committee.

- Finally, we urge the laboratory to write into the proposal for the next five-year renewal funds for additional DC magnet shifts due to the large oversubscription for time that now exists.

Bi-monthly conference calls.

There have been three conference calls during the Spring of 2003. These conferences have kept the committee updated on the progress of various activities discussed during the 2002 Gainesville meeting. In particular, we have had updates on the progress of the 900 MHz NMR magnet from Tom Painter and the 60 T long pulse magnet from Alex Lacerda. Detailed discussions of these reports were held with Painter and Lacerda as well as private discussions among the committee members.

NHMFL Welcomes Summer Interns and Teachers

The 11th class of REU students (Research Experiences for Undergraduates) and the 5th group of RET educators (Research Experiences for Teachers) are now actively engaged in their summer internships at the NHMFL. We are pleased to introduce the 20 students and 16 teachers to our user community, and to thank the mentors who are essential to the longevity, strength, and success of the both programs. NHMFL mentors—dedicated volunteers who contribute significant time and sometimes resources—represent LANL and UF, and the Magnet Science & Technology, Geochemistry, NMR, and Condensed Matter Theory/Experiment programs in Tallahassee.

Both the REU and RET programs have features that promote communication among the students, between students and teachers, and with resident NHMFL faculty and staff. Each week, students and teachers attend seminars conducted by scientists, who provide insights to scientific activities outside of the students' and teachers' assigned research laboratories. In addition, there is a joint colloquium during which teachers and students discuss mutual successes and challenges in their research experiences. Teachers work with students both in the laboratories and outside the NHMFL, and social events foster exchanges and understanding. The interaction between these groups is essential to the success of the programs and has been consistently identified by students and by teachers as important to the overall success of their experience.

2003 Research Experience for Teachers

Teacher	School	City*	Mentor
Kenneth Bowles	Apopka High School	Altamonte Springs	Justin Schwartz
Logan Chalfant	Gateway High School	Kissimmee	Yusuf Hascicek
Dani Dulin	Canopy Oaks Elementary	Tallahassee	Arneil Reyes & Phil Kuhns
Susan Goracke	Ruediger Elementary School	Tallahassee	Robert Goddard
Kristen Green	Pre-service	Tallahassee	Vincent Salters & Leroy Odom
Jennifer Haid	Fairview Middle School	Tallahassee	Yan Xin
Mark Johnson	Lake Weir High School	Ocala	Eric Palm
Robert Krouch	Winston Park Elementary School	Margate	Michael Davidson
Pamela Mawson	West Port High School	Ocala	Arneil Reyes & Phil Kuhns
JoAnne McBrearty	Hawks Rise Elementary School	Tallahassee	Yan Xin
Brian McClain	Amos P. Godby High School	Tallahassee	Justin Schwartz
Jessica Peddie	Pre-service	Hosford	Robert Goddard
Vana Richards	Kenneth J. Carberry Intermediate School	Emmett, Idaho	Yusuf Hascicek
Farrell Rogers	Marshall Middle School	Lakeland	Michael Davidson
Carol Smith	Odyssey Charter School	Palm Bay	Eric Palm
Kimberlain Zenon	Braden River Middle School	Bradenton	Vincent Salters & Leroy Odom

* All cities are in Florida, except for Emmett, which is in Idaho (see Vana Richards).

2003 Research Experiences for Undergraduates

Student	School	Site	Mentor
James Adler	Cornell University	Tallahassee	Ke Han
Christine Amwake	Florida State University	Tallahassee	William Brey
Mercedes Castañeda	University of Puerto Rico, Mayagüez	Tallahassee	James Brooks
John Challis	University of Kentucky	Tallahassee	Dragana Popovic
David Elam Jr.	University of Florida	UF	Mark Miesel
Nathaniel Falconer	Florida A&M University	Tallahassee	William Brey
Melinda Graham	Florida State University	Tallahassee	Leroy Odom
Jacob Grimes	Southwest Texas State University	Tallahassee	Stanley Tozer
Alison Hatt	University of Utah	LANL	Alex Lacerda
Shawna Hollen	Occidental College	LANL	Alex Lacerda
Cassandra Jackson	Florida A&M University	LANL	Alex Lacerda
William Keim	Cornell University	LANL	Alex Lacerda
Meryl McDowell	University of Oklahoma	Tallahassee	Leroy Odom
Evelyn Mervine	Dartmouth College	Tallahassee	Leroy Odom
Timothy Noble	Boston College	Tallahassee	Justin Schwartz
Manuel Ramos	University of Texas at El Paso	Tallahassee	Justin Schwartz
Lee Sears	Dartmouth College	Tallahassee	Justin Schwartz
Jonathan Shanks	Michigan State University	Tallahassee	Ke Han
David Siegel	Cornell University	Tallahassee	Stanley Tozer
Alexander Vitkalov	Cornell University	Tallahassee	Dragana Popovic

For further information about the NHMFL Center for Integrating Research and Learning, contact the program director, Dr. Pat Dixon, pdixon@magnet.fsu.edu, *850-644-4707.*

Nijmegen Director Describes New Laboratory

Editor's Note: As this newsletter was nearing final production, we requested a few comments on the HMFL opening from its director, Jan Kees Maan. We are pleased to present his remarks here.

On June 13 the Dutch Minister of Science and Education officially opened the new High Field Magnet Laboratory at the University of Nijmegen, the Netherlands. At the push of a button she triggered a fountain on top of the roof which sprinkled the entire new building as a symbolical bottle of champagne. She was assisted by the winners of a competition among groups of children who had written a paper on their findings of an unaccompanied tour through the laboratory. The HFML cost 23 M Euros (sponsored by the national science foundation and the University of Nijmegen) and features three 33 T resistive magnets and a 20 T magnet; a 41 T hybrid magnet is under development. One of the resistive magnets was provided by the NHMFL while the other two were assembled in Nijmegen in close collaboration.

The laboratory is equipped with a 20 MW power source with very high stability (a few ppm) and a cooling plant with chillers, water buffers, and cooling towers. All equipment and infrastructure are housed in a building especially designed for the new magnet laboratory. The guiding principle in the design was to create experimental conditions at the magnet sites which, from the point of view of noise, vibrations, and ease of access, were as close to the normal conditions found in a good laboratory. Therefore the industrial installations are all situated in the back part of the building and penetrate the experimental part through a narrow corridor that acts as an umbilical cord to feed the magnets. Magnets can be accessed from the ground floor and from the top floor through holes. Fragile and bulky equipment (lasers, Raman spectrometers, FTIR, etc.) is all situated on the top floor in a roomy "lab-garden."

HFML serves as a European user facility and receives yearly some 50 to 70 researchers from external institutions. The local research program is centered around, nanoscience (local probes, SNOM, confocal microscopy, single molecule spectroscopy) with emphasis on quantum phenomena (correlated low dimensional electron systems, high "B/T" ratio) and the Manipulation of Molecular Matter.

New Zealand Research Institute Connects the Continents

The 8,100-mile distance between Tallahassee, Florida and Wellington, New Zealand was bridged in early June when NHMFL Director Jack Crow participated in a monthly video conference seminar series run by the MacDiarmid Institute for Advanced Materials and Nanotechnology. Dr. Crow reached a large multidisciplinary audience at five institutions, with an overview talk on high magnetic fields, facilities, and science opportunities. The laboratory was keenly interested in this experience because it is considering investing in these technologies to facilitate communications and extend science interactions with user groups, advisory committees, and other academic organizations.

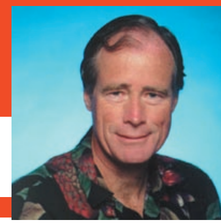
The MacDiarmid Institute for Advanced Materials and Nanotechnology is one of five inaugural New Zealand Centres of Research Excellence started about a year ago. It is hosted by the Victoria University of Wellington in partnership with the University of Canterbury, Industrial Research Ltd. (a national laboratory called the Crown Research Institutes-CRIs), the University of Otago, Massey University, and Geological & Nuclear Sciences, Ltd. (another New Zealand CRI). The director is Prof. Paul Callaghan (Victoria University of Wellington), and the deputy director is Dr. Richard Blaikie (University of Canterbury).

The seminar series was born out of a need for ways to bring researchers at the geographically separated sites together as a true "Research Centre." They established video links among the institutions, and refined the format to include locally-run PowerPoint presentations. Faculty and staff quickly realized that the new technologies could support speakers anywhere in the world, thus enabling them to form links with other institutions such as the NHMFL.

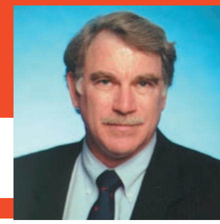
New Zealand / NHMFL continued on page 25

PEOPLE IN THE NEWS

J.Crow



Z.Fisk



A.Marshall

NHMFL Director Jack Crow has been in the spotlight lately—receiving a number of recognitions and honors. The laboratory is pleased and proud to mention his achievements.

- Jack Crow was awarded the John and Geraldine P. Schuler Chair of Physics for his substantial contributions to the success of the Florida State University. Dr. Crow requested that his professorship be named for the Schulers of Longboat Key, Florida, who established a postdoctoral program for scientists or engineers who received their Ph.D.s within the last ten years and who are affiliated with an institution of higher learning or comparable research organization. The Schuler Fellowships aim toward building bridges between the NHMFL and universities and major research organizations throughout the world, with the expectation of broader collaborative relationships. Dr. Crow has a longstanding commitment to these goals and facilitated the establishment of the Schuler Fellowship at FSU.
- Dr. Crow was elected by the American Physical Society Division of Condensed Matter Physics to the post of Secretary-Treasury, for a term of four years.
- Dr. Crow was awarded the 2003 Distinguished Alumni Award from Cleveland State University, where he earned his undergraduate degree, and the 2003 Distinguished Scholar Award from the University of Rochester, where he earned his Ph.D. He was an invited speaker at the institutions' respective spring graduations.

Zachary Fisk was named Florida State University's first Francis Eppes Professor of Physics in April 2003. With this distinction, he joins the ranks of the university's most eminent scholars. Dr. Fisk is an internationally recognized experimentalist in condensed matter research. He explores the electronic properties of magnetic and superconducting maters and his work shows promise of establishing whole new classes of electronically-important materials. He joined the NHMFL in August 1994, from the University of California, San Diego, and Los Alamos National Laboratory. In 1992, he received the E. O. Lawrence Award from the U.S. Department of Energy, is a Distinguished Fellow and LANL, and is a recipient of the lab's Distinguished Service Award. In 1996, he was inducted into the National Academy of Sciences.

In commenting on Dr. Fisk's most recent honor, NHMFL Director Jack Crow said, "I have known Zach Fisk for more than 20 years and during this time, he has been one of the most impressive scientists I have known. His deep understanding and love of science are reflected in the outstanding contributions he has made to many areas of condensed matter physics. In addition to being a great scientist, he is a wonderful, friendly, and open person."

The Francis Eppes professorships are names for President Thomas Jefferson's grandson, who was one of the founding fathers of the Seminary West of the Suwannee, FSU's institutional predecessor.

Alan Marshall and the FT-ICR Program at the NHMFL continue to be recognized extensively. In addition to the award from the Swedish Foundation for International Cooperation in Research and Higher Education (STINT award, see page 25) and a very successful 4th North American FT-ICR Conference (see page 27), here are a few more highlights.

FT-ICR at the NHMFL has been featured on the cover of major journals:

- Marshall, A. G.; Hendrickson, C. L. and Shi. S. D.-H., "Scaling MS Plateaus with High-Resolution FTICR MS," *Anal. Chem.* **2002**, *74*, 252A-259A.
- Lanman, J.; Lam, T.-K. T.; Barnes, S.; Sakalian, M.; Emmett, M. R.; Marshall, A. G. and Prevelige, P. E. Jr., "Identification of Novel Interactions in HIV-1 Capsid Protein Assembly by High-Resolution Mass Spectrometry," *J. Mol. Biol.* **2003**, *325*, 759-772.

Dr. Marshall and other program members have been featured speakers and significant participants at three "Petroleomics" symposia this year:

- *Petroleomics: the Next Grand Challenge for Chemical Analysis*, PittCon 2003, Orlando, CA, March, 2003
- *Petroleomics Symposium*, 51st American Society for Mass Spectrometry Annual Conference on Mass Spectrometry & Allied Topics, Montreal, Canada, June, 2003
- ***Petroleomics: From Petroleum Composition to Commercial Reality*, International Applied Statistical Physics Molecular Engineering Conference,** Puerto Vallarta, Mexico, August, 2003

Additional publications and news:

- BioMedNet Gateway for Hot Papers (**2003**). *http://www.bmn.com/immunology*.
- ISI Essential Science Indicators most-cited paper in "Ion Cyclotron Resonance Mass Spectrometry: ISI Website: Special Topics, March, **2003.** *http://www.esi-topics.com/fmf/2003/march03-KuangnanQian.html*.
- Borman, S., *Chem. & Eng. News* **2003**, *81 (13)*, 29.
- Henry, C., "Fine Look at Crude Oil," *Chem. & Eng. News* **2003**, *81 (13)*, 39. (Description of Petroleomics Symposium at PittCon 2003).
- Petkewich, R. "Cracking the Structure of Petroleum," *Environ. Sci. Technol.* (Science News), 17 April 2003. *http://pubs.acs.org/subscribe/journals/esthag-w/2003/apr/science/rp_petroleomics.html*. (Description of Petroleomics Symposium at PittCon 2003).

FT-ICR Program STINT Grant Renewed

Mark R. Emmett, Ph.D. (FT-ICR program, NHMFL) and Carol L. Nilsson, M.D., Ph.D. (Medical Biochemistry, Göteborg University, Sweden) were recently renewed for year two of funding for their application to the Swedish Foundation for International Cooperation in Research and Higher Education (STINT) entitled, ***An international consortium for structural glyco- and phosphoproteomics as studied by 2D electrophoresis and high resolution mass spectrometry, and applied in neuroscience***. The funding for the academic year 2003/2004 was set at 500,000 SEK (approximately $64,500 U.S.). The grant will cover travel for physical exchange of scientists and living expenses during the exchange period. In the past year, these funds were used to bring two students (Elisabet Gustafsson and Carina Sihlbom) from Dr. Nilsson's laboratory to the NHMFL in Tallahassee, where they used FT-ICR facilities. These funds will permit the exchange of students/postdoctoral fellows/ scientists between Göteborg University and NHMFL-FSU to permit training of true multidisciplinary scientists.

This year, the research consortium will once again meet in Göteborg, Sweden (August 25-27). Five consortium members from the United States will attend this meeting: Mark R. Emmett and Michael J. Chalmers (members of FT-ICR program, NHMFL) and Charles A. Conrad and two other colleagues yet to be announced (M.D. Anderson Cancer Institute-Houston, Texas). During the trip to Göteborg, the members of the consortium will also attend the 6th Annual Functional Genomics Conference, which will be held in Göteborg on August 28-29. STINT is funding the meeting and expenses for all members attending.

Finally, Dr. Carol Nilsson (Göteborg University, Sweden) and Dr. Roman Zubarev, (Uppsala University, Sweden) were recently awarded 21 million Swedish Crowns (~$2.7 million U.S. dollars) from the Wallenberg Foundation in Sweden for their proposal entitled, ***Advanced Mass Spectrometric Instrumentation for High-Sensitivity, High Throughput Analysis of Post-translational Modifications in Proteins***. The funds are earmarked to purchase two FT-ICR mass spectrometers; one instrument is to be placed in Göteborg and one in Uppsala. This proposal was strongly supported by the NHMFL FT-ICR facility, and much of the data presented in the proposal was collected at the NHMFL. We would like to congratulate Dr. Nilsson and Dr. Zubarev on their significant award.

FSU RECOGNIZES NHMFL FACULTY AND ASSOCIATES

Promotions:

- Riqiang Fu, NMR User Program, to Associate Scholar/ Scientist
- Xing Wei, DC Field User Program, to Associate in Research
- Hubertus W. Weijers, Magnet Science & Technology Program, to Visiting Associate in Research
- Iain R. Dixon, Magnet Science & Technology Program, to Research Associate

Developing Scholar Award, including grant award:

- Vladimir Dobrosavljevic, Condensed Matter Science Program

Distinguished Research Professor Awards, including one-time stipend:

- Naresh S. Dalal, EMR Program, and chair of the FSU Department of Chemistry & Biochemistry

University Teaching Award, including stipend:

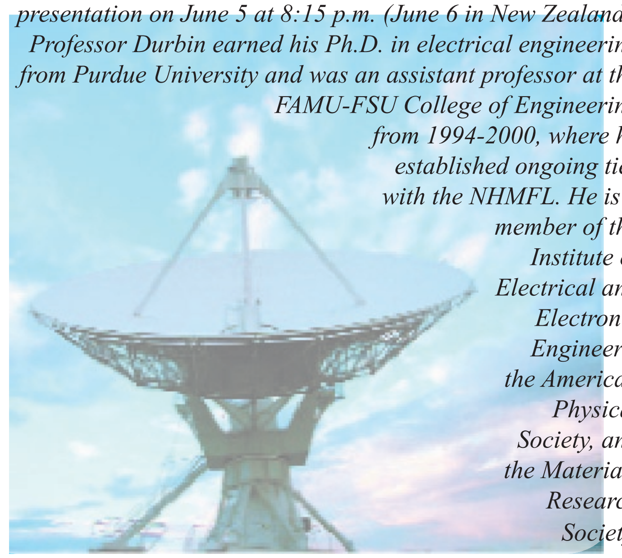
- Timothy Logan, NMR Program

Program Enhancement Grant:

- Yan Xin, Magnet Science & Technology Program, "Monolithic Integration of Strongly Correlated Transition Metal Oxides, with Complementary Functionalities Through Thin Film Nano-Engineering"

New Zealand / NHMFL continued from page 23

The Institute comprises 38 principal investigators, 14 associate investigators, approximately 10 postdoctoral fellows/researchers, and 39 postgraduate students. Numerous disciplines are represented, including electrical engineering, physics, and chemistry, but all participants have a strong materials science emphasis. The seminar audience is far larger than these numbers suggest, however, as they are advertised to staff and students outside the Institute through each organization's internal system, as well as via local branches of the Royal Society of New Zealand.



Special thanks to Steven M. Durbin, senior lecturer at the University of Canterbury, who facilitated Dr. Crow's presentation on June 5 at 8:15 p.m. (June 6 in New Zealand). Professor Durbin earned his Ph.D. in electrical engineering from Purdue University and was an assistant professor at the FAMU-FSU College of Engineering from 1994-2000, where he established ongoing ties with the NHMFL. He is a member of the Institute of Electrical and Electronic Engineers, the American Physical Society, and the Materials Research Society.

LANL Update

On Wednesday, May 7, the NHMFL Pulsed Field Facility gathered at a luncheon to bid farewell to Greg Boebinger. After 5 years as Center Leader, Boebinger decided to move on to a position at Los Alamos National Laboratory as the Deputy Division Leader of Science Programs in the Materials Science and Technology Division.

This event was just one in a number of management changes at the Los Alamos Magnet Lab. Some of these include Alex Lacerda taking over as Acting Center Leader, Kathleen Paul joining the group as the new Office Administrator, and Deputy Center Leader Dwight Rickel returning to research after 12 years in management. Although the changes have taken some getting used to, magnet lab employees are optimistic and excited about what lies ahead.

In 1998, Boebinger came to the Pulsed Field Facility from Bell Labs. At the time, the laboratory infrastructure had taken shape but the scientific program was just starting to be defined, according to Rickel.

"Greg's vision, knowledge, and international reputation helped propel our laboratory into the position of a first-rate, world-recognized research group," said Rickel.

Other staff members also expressed appreciation for the work Boebinger did during his tenure to improve scientific research and to enhance laboratory relations, especially those with LANL upper management. His new position will involve some of these same skills, as his job will be to oversee all the science programs within the Materials Science and Technology Division.

"It is an exciting career opportunity to broaden the scope of science of which I'm involved," said Boebinger. "It is of course one step further from the laboratory, but I will be able to maintain my research collaborations, and I will always be interested in helping the magnet lab in any way."

"I'm pleased to see him move into such an important and influential position. It is an appropriate thing, important in his career development," said staff member and LANL Fellow Albert Migliori.

An international search will be conducted for a new Center Leader. In the interim, Alex Lacerda, Head of the User Program and Acting Deputy Center Leader, has taken over as Acting Center Leader. Lacerda has been a part of the NHMFL since its inception and brings not only a wealth of research experience but also 12 years of commitment to the NHMFL.

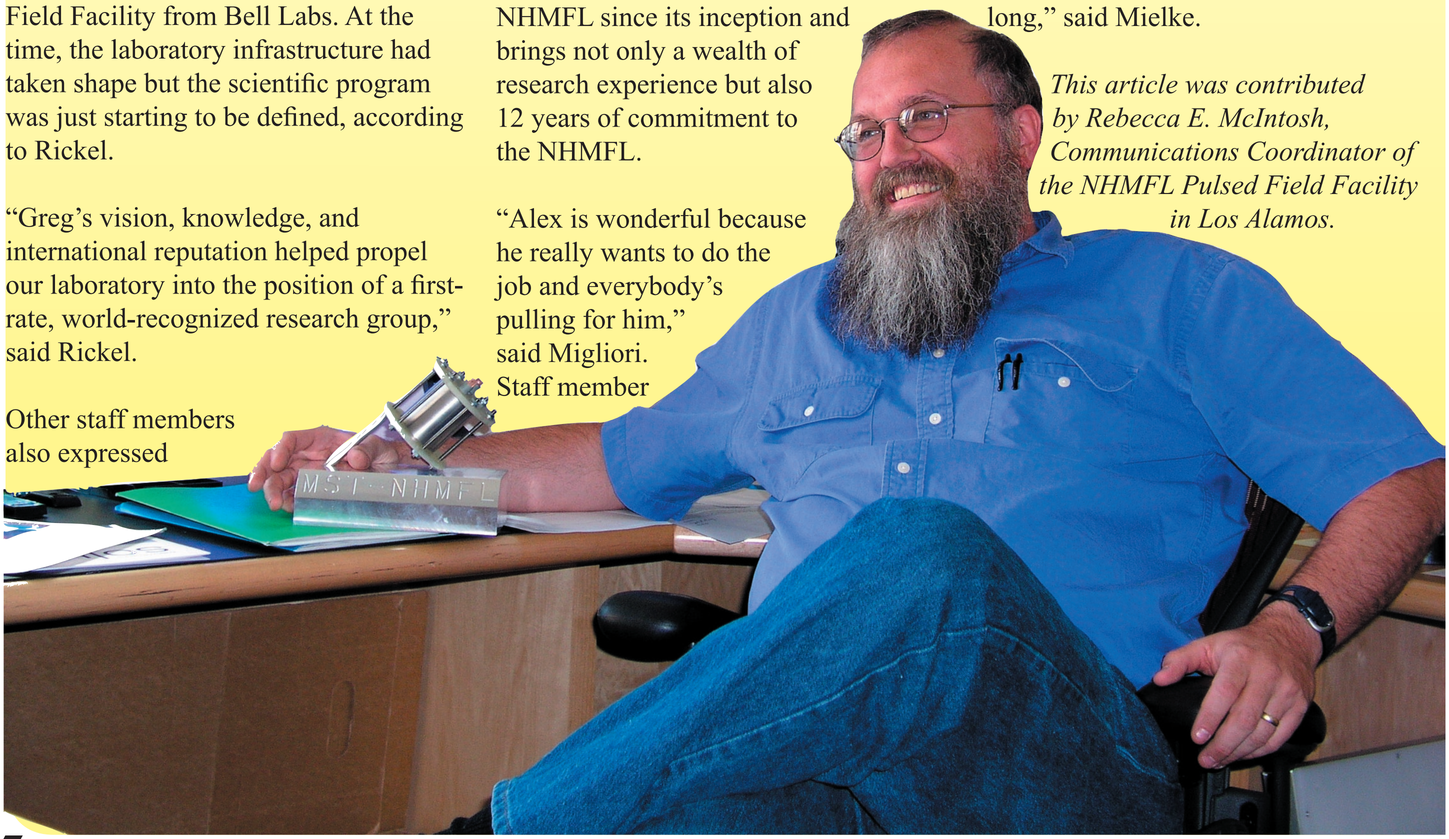
"Alex is wonderful because he really wants to do the job and everybody's pulling for him," said Migliori. Staff member Charles Mielke is also supportive: "He puts his heart and soul into the job and cares a lot about the people and the program, and I appreciate him taking on this responsibility at this point in the history of this program."

Another change occurred this spring when Dwight Rickel decided to focus on research and instrumentation development efforts full time.

"When I came to the magnet lab, I was supposed to be a project leader, but at the time there wasn't any science going on," said Rickel. He explained that he helped take over certain line management roles while the group was engineering magnets. Now, Rickel plans to collaborate with Albert Migliori on adapting ultrasound techniques in pulsed fields, to work on pulsed field NMR, and to work with Scott Crooker on quantum optics.

"Dwight has dedicated a huge portion of his career to the magnet lab and has solved numerous technical and managerial problems. We have always felt comfortable going to him, and we are lucky to have had him around for so long," said Mielke.

This article was contributed by Rebecca E. McIntosh, Communications Coordinator of the NHMFL Pulsed Field Facility in Los Alamos.



Events for 2003

Neutron Scattering Workshops

http://www.sns.gov/jins/tallahassee_workshops_2003/workshops.htm
September 23-26, 2003
Tallahassee, Florida
Hotels: Holiday Inn Select and Wingate Inn

The inherent interface between high magnetic fields and neutron scattering research has forged natural collaborations among faculty at the NHMFL, the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL), and other institutions. This fall, the NHMFL and FSU are pleased to host *two workshops* that are expected to enhance these interactions and expand interest in the growing field of neutron scattering.

Joint Institute for Neutron Sciences (JINS) Workshop: Neutron Scattering for Chemistry and the Chemistry/Biology Interface
September 23-25, 2003

SENSE Workshop: Sample Environments for Neutron Scattering Experiments
September 24-26, 2003

The workshops will be held at the Turnbull Florida State University Conference Center. Complete, up-to-date details, including synopsis, speakers, registration, reservations, and travel information, are provided on the Web site.

33rd Southeast Magnetic Resonance Conference and Symposium (SEMRC)

http://semrc2003.magnet.fsu.edu
October 17-19, 2003
Ramada Inn & Conference Center
Tallahassee, Florida

The NHMFL is pleased to bring SEMRC back to Florida and to host the conference again, as it did in 1995 and 1999 (in Tallahassee) and in 1997 and 2001 (at University of Florida in Gainesville). The focus of this biennial meeting is the exchange of ideas and recent magnetic resonance research highlights, including new applications and technique developments. Particular emphasis is placed on activities in the region.

Contact: Conference Co-chairs (NHMFL): Hans van Tol and Bill Brey *(semrc2003@magnet.fsu.edu).*

Events in 2004 & 2005

5th Biennial Structural Biology Symposium
Membranes: A Challenge for Protein Magnetic Resonance
http://fajerpc.magnet.fsu.edu/IMBconf/home.htm
January 23-24, 2004
Tallahassee, FL
Contacts: Conference Co-Chairs Tim Cross (*cross@magnet.fsu.edu,* 850-644-0917) and Peter Fajer (*fajer@magnet.fsu.edu,* 850-644-2600)

5th Magnetic Microsphere Meeting
http://www.magneticmicrosphere.com
May 20-22, 2004
Lyon, France

16th International Conference on High Magnetic Fields in Semiconductor Physics
http://SemiMag16.magnet.fsu.edu
August 2-6, 2004
Tallahassee Holiday Inn Select
Tallahassee, Florida
Contact: Conference Chair Yong-Jie Wang (*SemiMag16@magnet.fsu.edu*, 850-644-1496).

Applied Superconductivity Conference (ASC04)
October 4-8, 2004
Adam's Mark Hotel
Jacksonville, Florida
Contact: Conference Chair Justin Schwartz (*ASC04ConfChair@magnet.fsu.edu,* 850-644-0874).

15th Conference of the International Society of Magnetic Resonance (ISMAR 2004)
http://www.ismar.org/
October 24-29, 2004
Sawgrass Marriott Resort Hotel
Jacksonville, Florida
Contact: Conference Chair Timothy A. Cross (*mail@ismar.org,* 850-644-0917)

Physical Phenomena at High Magnetic Fields - V
August 2005 (tentative)
Tallahassee, Florida
Contact: Conference Coordinator Alice Hobbs (*aclark@magnet.fsu.edu*, 850-644-3203).

24th Low Temperature Physics Conference
August 10-17, 2005
Orlando Hyatt Conference Center
Orlando, Florida
Contact: Conference Chair Gary Ihas (*ihas@phys.ufl.edu*, 352-392-9244).

4th North American FT-ICR Conference

The 4th North American FT-ICR Conference was held April 3-6 at the Marconi Conference Center in Marshall, California. A total of 86 participants were registered (only 2 no-shows), which filled the on-site housing available to the conference registrants. The invited talks, poster session, and plenary session by Helmut Schwarz from the Technical University-Berlin were all well attended and stimulated many scientific discussions during the breaks. The conference organizers have received numerous positive comments about the conference.

The talks ranged from theory to applications, but it is becoming apparent that applications, especially biological applications, are starting to dominate this biennial conference. This year, corporate sponsors gave an interesting 10-minute presentation on their latest instrumentation. Thermo-Finnigan MAT also gave a talk on their new quadrupole ion trap FT-ICR, which promises to be a "user friendly" high-resolution instrument. The ongoing interactions between the industry and the FT-ICR MS Facility continue to be strong, and we are pleased to note that most of the commercial vendors of FT-ICR MS have incorporated ion optics, which was pioneered at facilities in Tallahassee.

Special thanks go to the sponsors of this year's conference: Bruker-Daltonics, IonSpec Inc., Thermo-Finnigan MAT, and Oxford Instruments. Through careful management, the conference budget was provided solely from the vendor contributions and the collected registration fees. The conference provided registration, room and board for all of the 24 invited speakers and for 14 student awardees. Since students are the future, the organizers felt that it was important to provide such awards to students in an effort to encourage them and to give them the opportunity to attend the conference.

We look forward to the 5th North American FT-ICR Conference in 2005.

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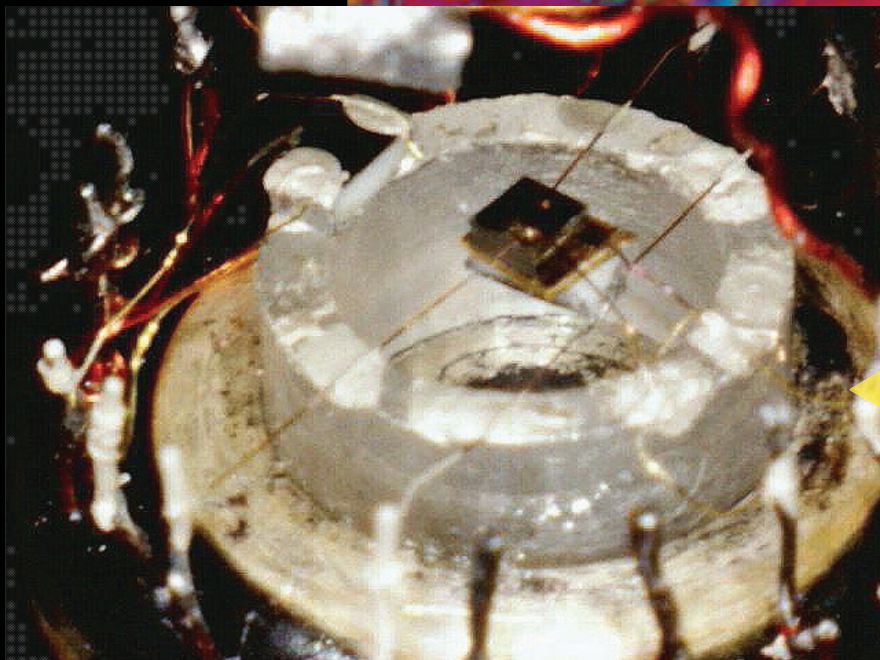

Heat Capacity System: The sample is placed between a heater and thermometer anchored to a temperature regulated sapphire ring. The ring with a diameter of 3.5 mm is housed within a small vacuum can allowing for rotation of the sample at dilution refrigerator temperatures.

Tunnel Diode Oscillator System: In the center is a 0.3 mm diameter resonant coil holding a sample, as seen through one of the diamonds of an anvil pressure cell. Above it is the actual tunnel diode circuit and below a rotator that can accommodate pressure cells such as the one shown on the right.

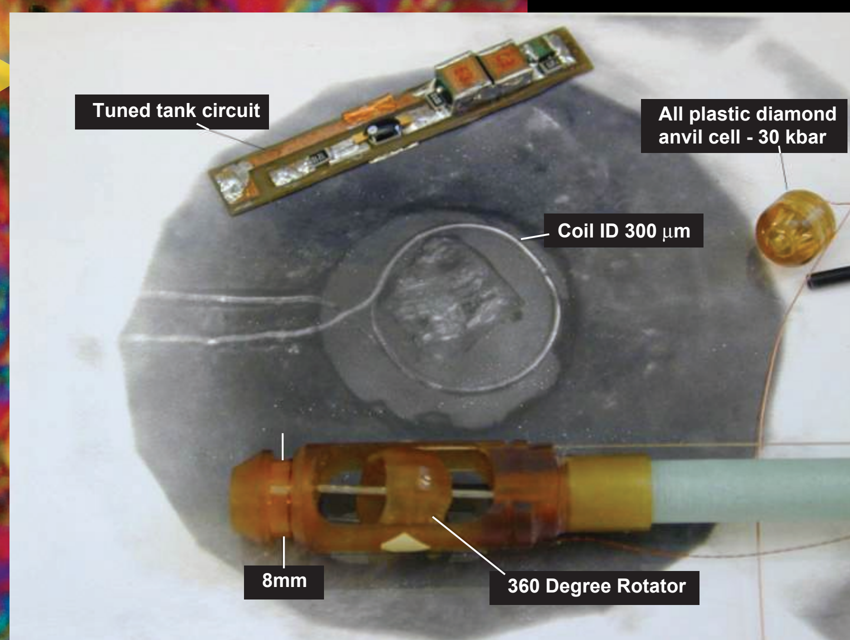

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Image of the surface of a superconducting heavy fermion $CeCoIn_5$ crystal at 500x magnification taken with the differential interference contrast method (courtesy of Molecular Expressions).