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NHMFL REPORTS

NHMFL at UF

UNIVERSITY OF FLORIDA

MR MICROSCOPY IN ALGINATE BEADS AS A TOOL FOR DEVELOPING ARTIFICIAL ORGANS

(page 10)

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NHMFL REPORTS

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FROM THE DIRECTOR'S DESK

Jack E. Crow

Last spring I announced that I would be stepping down at the end of 2002 and that Ray Bye, the FSU Vice President for Research, had established a search committee to recruit a new NHMFL director. Following a year of serious efforts and discussions, it appears that the search requires more time than previously anticipated. Consequently, I have been asked to remain as the laboratory's director until a new director is named. The search for a new director will continue. It is with a great deal of enthusiasm, and humility, that I accept this opportunity and the challenges ahead. I have enjoyed working with the faculty and staff of the NHMFL and the user community over the last many years, as we have all endeavored to serve the science and technology communities. I look forward to continuing to work with everyone, to addressing both challenges and new opportunities, and to guiding the ongoing process of re-inventing the NHMFL. With our combined efforts, the NHMFL will be a better facility when the new director is named.

The timing of a transition to a new director is very important, so it probably warrants further explanation. In the very near term, the laboratory has two major external proposals under development, will install the 900 MHz magnet into its final user bay, and will have an annual NSF site visit in October. Then, in 2004, the laboratory sharpens its sights on its third NSF renewal. Continuity throughout this period serves and strengthens support of users, research and development activities, and the FSU-UF-LANL partnership.

Preparing for the renewal is a major effort across the laboratory. The process will redefine the vision of the laboratory and set new goals for responding to the needs of science and technology. The laboratory has demonstrated significant growth, exceptional scientific productivity, and a high level of responsiveness to user needs. But we can—*and we will*—do better. Areas needing attention that have been tabled in anticipation of a new director will be addressed and improved. Opportunities for new inter-agency and inter-institutional activities will be approached with renewed dedication. I envision a new look for the laboratory in 2005 and am committed to working with the laboratory's leadership, advisory committees and external users, and the administrations of FSU, UF and LANL to ensure that the laboratory presents the strongest possible proposal to the Foundation in January 2005.

Update! The relocation of the 900 MHz was successfully accomplished on April 9. See page 19 for more pictures.

The "new look" I just mentioned refers, of course, to substance rather than style and cosmetics. In a few days, however, the rear laboratory will take on a new appearance, and we are all very excited about it. A new driveway has been built to support the transport the 900 MHz, wide bore magnet from its fabrication site in "A" wing of the laboratory to its permanent location in the "C" wing. (It's a bit like moving the space shuttle to the launch pad!) The destination site for the state-of-the-art magnet was specially designed to support high resolution NMR experiments. It includes an 8' deep by 4' wide pit for user access, a roof extension to accommodate the insertion of sample probes, and an upgrade to the HVAC system. Once installation is complete, commissioning tests will begin, with user operations to follow.

I would like to thank members of the external user community for their continued support. In addition, I want to express my sincere gratitude to the faculty and staff of the laboratory for their loyalty, dedication to excellence, commitment to user support, and friendship. I have always been—and will continue to be—proud to be associated with this extraordinary group of people. It is a joy to work at the Magnet Lab, and I am re-dedicating my efforts to ensuring that the laboratory is strongly positioned for the years ahead and the opportunities at hand.

Best regards,

Jack Crow

FROM THE CHIEF SCIENTIST'S DESK

J. Robert Schrieffer

In this issue, the properties of the novel compound $PrBa_2Cu_4O_8$ are explored. This compound has one-dimensional chains (1D) of CuO that are sandwiched between 2D CuO_2 planes. One finds that despite the one-dimensional character of the chains the resistivity varies as T^2 below 50 K along all three axes. Above 100 K the a and c axis resistivities become insulating indicating a 3D-1D temperature induced crossover. One striking feature is that the magnetoresistance of this material is 1500% at T = 0.5 K and B = 30 T. This is the largest magnetoresistance observed in a cuprate, supporting the high level of purity that has been achieved in this compound. The agreement between the observed magneto-transport and quasi-classical transport theory, coupled with the T^2 resistivity along all three axes is strong evidence that a Fermi liquid ground state develops on the CuO chains at quarter filling. This is in contrast with the compound $SrCuO_2$, which is half filled, where the ground state is a 1D Mott insulator that exhibits spin-charge separation. At room temperature optical response of Pr 124 shows that this compound has a 3D/1D crossover from a Fermi liquid to a Luttinger liquid.

Special thanks to DC Field Facility user Nigel Hussey for contributing this issue's feature article, and to Luis Balicas for bringing this work to my attention.

PrBa2Cu4O8: A New Laboratory for Low Dimensional Physics

N.E. Hussey, H. H. Wills Physics Laboratory, University of Bristol
M.N. McBrien, H. H. Wills Physics Laboratory, University of Bristol
L. Balicas, NHMFL
J.S. Brooks, NHMFL and FSU Physics
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H. Ikuta, Center for Integrated Research in Science and Engineering, Nagoya University

Introduction

Landau's Fermi-liquid theory (FLT) has been the "standard bearer" for understanding electrons in metals for the past half a century. One of its cornerstones is that electron motion is possible in all three dimensions. Once the electron becomes confined to lower dimensions, FLT breaks down and other more exotic ground states, such as the Luttinger liquid, with its associated phenomenon of spin-charge separation, are predicted to emerge. Such possibilities have led many researchers to study those materials on the boundary of this transition, the so-called quasi-1D or quasi-2D metals. The anomalous 2D metallic state in the CuO_2 planes of the high-T_c cuprates is perhaps the most famous example of such anisotropic metals. Recently, however, novel cuprates with even lower dimensionality have begun to arouse the community's interest.

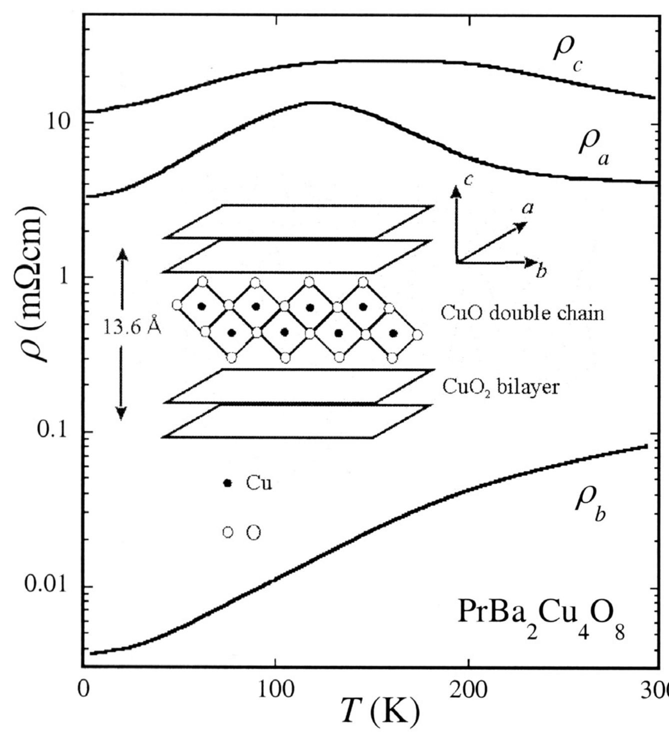

Figure 1. Anisotropic zero-field resistivity of Pr124. Inset: Schematic of the Pr124 crystal structure.

$PrBa_2Cu_4O_8$ (Pr124) is isostructural with the 80 K superconductor $YBa_2Cu_4O_8$, with 1D CuO chains sandwiched between 2D CuO_2 planes (see Figure 1). In Pr124, holes on the CuO_2 planes are localised, hence non-superconducting. The ¼-filled CuO chain, however, remains metallic and thus offers a unique opportunity to study the quasi-1D cuprate chain in isolation. Figure 1 shows the zero-field resistivity of Pr124. The striking anisotropy for in-plane transport, $\rho_a/\rho_b \sim 1000$ at 4.2 K, confirms the insulating character of the CuO_2 planes. Despite the extremely 1D nature of the chain carriers, $\rho(T)$ varies as T^2 below 50 K *along all three axes*,[1] suggesting that an anisotropic yet still 3D FL ground state develops at low ***T*.** Above 100 K, however, ρ_a and ρ_c become semiconducting, indicating a 3D-1D *temperature-induced dimensional crossover*.

At the NHMFL, we carried out a detailed study of the interchain resistivity of Pr124 in magnetic fields up to 30 T.[2] In addition to the thermally-driven crossover, a 3D to 1D *field-induced dimensional crossover* was unveiled at low *T* and high fields. Analysis of the various crossover energy scales allowed us to determine the degree of warping on the quasi-1D Fermi sheets in Pr124 and revealed a new route toward achieving a purely 1D metallic state at low *T*.

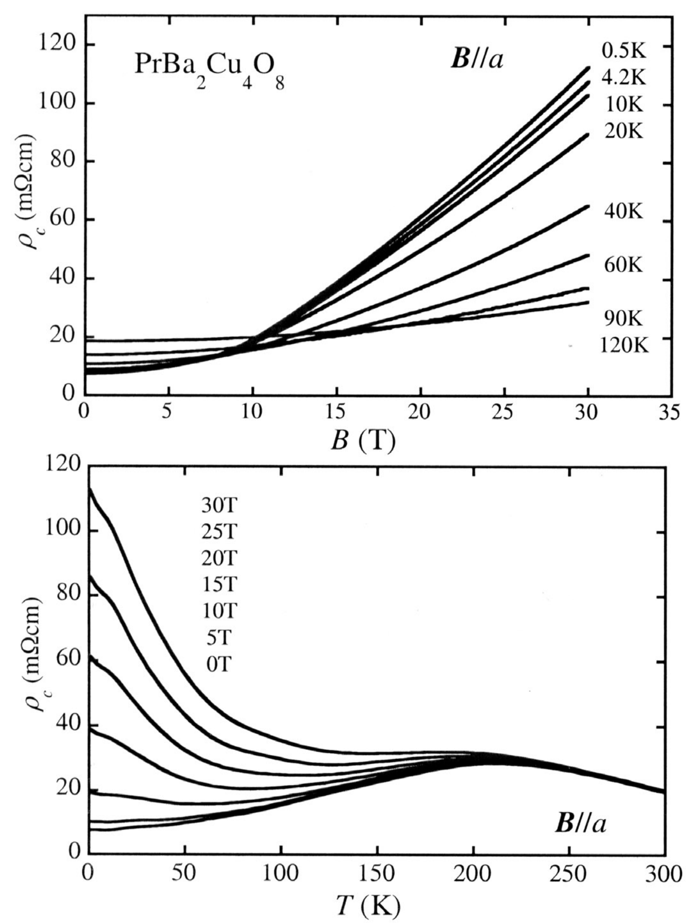

Figure 2. Top panel: c-axis MR field sweeps for Pr124 up to 30 T with *B//a*. Bottom panel: Corresponding $\rho_c(T, B)$ curves obtained directly from the MR field sweeps.

Results and Discussion

The top panel in Figure 2 shows the temperature evolution of the *c*-axis magnetoresistance (MR) $\Delta\rho_c(B)$ data taken at Tallahassee. Several striking features can be noted from this plot. Firstly, $\Delta\rho_c(B)$ is extremely large at low *T*; $\Delta\rho_c/\rho_c \sim 1500\%$ at $T = 0.5$ K and $B = 30$ T. This is by far the largest MR ever observed in a cuprate and illustrates the high level of purity that can be achieved in this stoichiometric cuprate. Secondly, $d\rho_c/dT$ is *positive* at low *B* and *negative* at high *B*, and lastly, the *B*-dependence becomes weaker at higher fields. The bottom panel in Figure 2 shows the resultant $\rho_c(T, B)$, obtained by plotting the value of ρ_c at fixed *B* and different *T*.

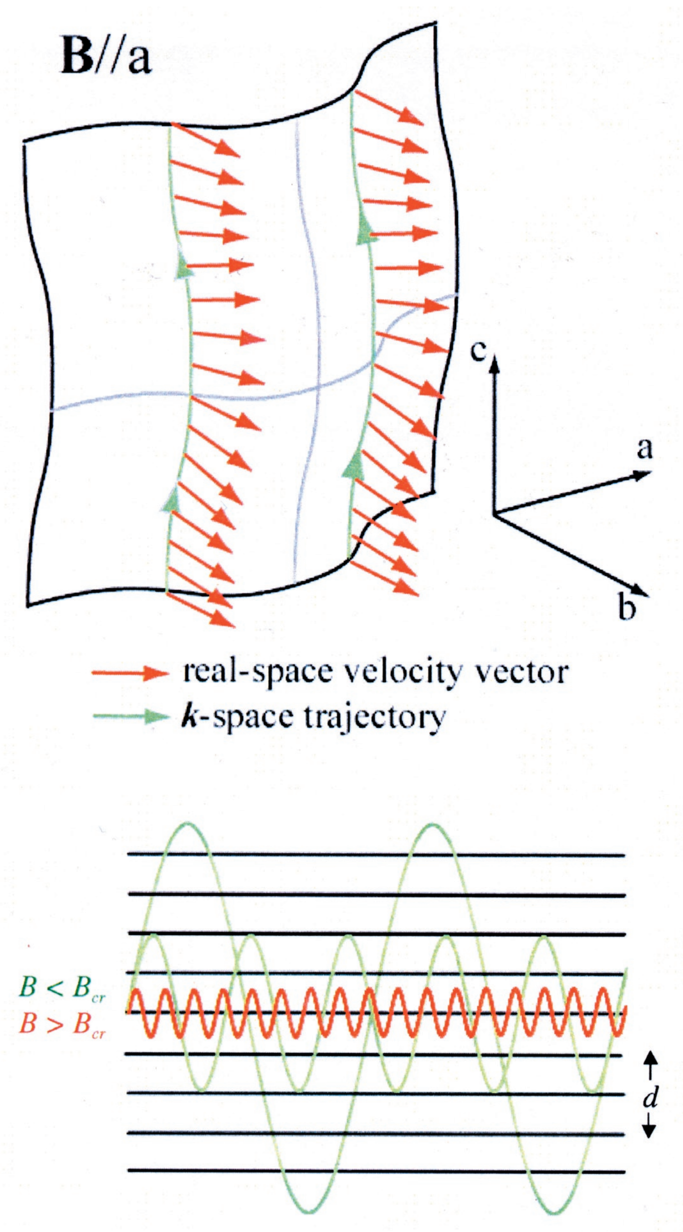

Figure 3. Top panel: Schematic of one of the quasi-1D Fermi sheets of the CuO chain in Pr124. For *B//a*, the main Lorentz force component is along k_z. Bottom panel: Variation of the real-space c-axis trajectory with increasing *B*. Charge confinement occurs once $B > B_{cr}^c = 2t_c/ev_bc$.[2]

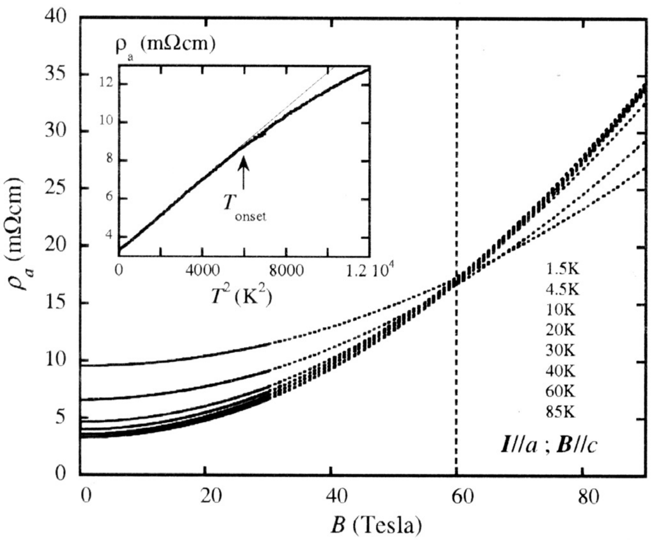

Figure 4. *a*-axis transverse MR up to 30 T with ***B//c*** (solid lines). The dashed lines are extrapolations of the B^2 dependence up to 90 T. The dotted line represents the predicted B_{cr} for ***I//a***. Inset: Low *T* zero-field $\rho_a(T)$ data plotted versus T^2. The arrow indicates the deviation from T^2 at $T \sim 75$ K.

This *field-induced dimensional crossover* arises from the slightly warped nature of the Q1D Fermi sheets of the double CuO chains in Pr124. For ***B***//*a*, the dominant Lorentz force is directed along the *c*-axis, as depicted in the top panel of Figure 3. This gives rise to an oscillatory *c*-axis component to the real-space trajectory with an amplitude A_c that shrinks as *B* increases until eventually $A_c \sim c$ (= 13.6 Å), the *c*-axis lattice spacing, and all carriers become confined to a single plane of coupled chains.[3] This real space confinement is illustrated in Figure 3 (bottom panel). The value of the crossover field $B_{cr}^{\ c}$ gives directly an estimate for the *c*-axis warping $2t_c \sim 50$ K, consistent with the temperature at which ρ_c first deviates from T^2,[1] i.e. when *c*-axis hopping first begins to lose coherence.

A similar coherent/incoherent crossover is also expected to occur in the reciprocal configuration ***I***//*a* and ***B***//*c* once the amplitude of oscillation of the real-space trajectory *along the a-axis* $A_a \leq a$ = 3.8 Å. Figure 4 shows *a*-axis MR sweeps (***B***//*c*) up to 30 T for 1.5 K $\leq T \leq$ 85 K (shown as solid lines). No crossover is observed up to 30 T and no features are observed in $\rho_a(B)$. Indeed, $\rho_a(B) \sim B^2$ for the entire experimental field range. By extrapolating this B^2 dependence to *higher* fields (dashed lines in Figure 4), however, we find that *all* field sweeps eventually converge to a single point at $B \sim 60$ T. $d\rho_a/dT$ is negative (positive) above (below) 60 T respectively, indicating a *second field-induced dimensional crossover*. We ascribe this convergence to the crossover field for *a*-axis hopping $B_{cr}^{\ a}$ and obtain an estimate for $2t_a \sim 70$ K. Again this is consistent with the onset temperature (T_{onset} = 75 K) for incoherent transport along the *a*-axis (inferred from the deviation from T^2 resistivity) shown in the inset to Figure 4. Note that since $a \sim c/4$, a much higher field is required to decouple the chains in the *a*-direction, even though $t_a \sim t_c$.

Conclusion

The ubiquitous agreement between the magneto-transport behavior in Pr124 and quasi-classical transport theory, coupled with the T^2 resistivity along all three axes, is strong collective evidence that a FL ground state develops on the CuO double chain at quarter-filling. The ratios of the hopping parameters, $t_b^{\,2}: t_a^{\,2}: t_c^{\,2} \sim 2500:2:1$, make Pr124 one of the most 1D Fermi liquids ever to have been characterized. Intriguingly, when the double chain is half-filled (i.e. one electron/site), as in $SrCuO_2$, the ground state is a 1D Mott insulator that exhibits spin-charge separation, the hallmark of a Luttinger-liquid.[4] It appears then that the effect of doping and the presence of a small but finite coupling between the individual chain units have combined to stabilize a FL ground state on the CuO chain at low *T*, despite the presence of strong electron correlations and extreme one dimensionality. At room temperature, evidence for Luttinger-liquid behavior has already been reported in the optical response of Pr124,[5] hinting that the thermally-driven 3D/1D crossover is indeed a Fermi-liquid to Luttinger-liquid transition. Our work in Tallahassee has revealed a tangible route to achieving a Luttinger-liquid ground state *at low temperatures*, i.e. in an appropriately tilted field that contains components larger than B_{cr} in *both* interchain directions. Clearly, probing the charge dynamics in the different dimensionality states in Pr124 and its structural derivatives should provide invaluable insight into the nature of electron transport in low dimensions. Moreover, the ease with which dimensionality can be changed in Pr124 suggests it is an ideal laboratory for exploring the fundamentals of low dimensional physics in strongly correlated electron systems.

Acknowledgements: This work was partially supported by EPSRC, grant reference GR/R35995/01. SH was financially supported by the Japan Society for the Promotion of Science (JSPS).

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3 L.P. Gorkov and A.G. Lebed, *J. Phys. Lett*. (Paris), **45**, L433 (1984).
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EDUCATION AT THE NHMFL

Opportunities for Students, Teachers, and the General Public

Left to right: Gina LaFrazza-Hickey (Education Specialist), Dave Sheaffer (Web Developer), Carlos Villa (Outreach Coordinator), Tom Hawkins (Ph.D. student), Dr. Pat Dixon (Center Director).

Educators with the Center for Integrating Research and Learning began this academic year with five regional educator workshops, providing quality professional development to 250 Florida teachers and disseminating 500 curriculum packages. This effort supported the greater part of a contract with Florida Department of Health, a partnership that has been in effect since March 1999. We are extremely pleased that Florida's science and health educators recognize the materials created by the Center as quality, standards-based, inquiry activities for elementary and middle school students. In addition to fulfilling its responsibility for this contract, several other continuing and new initiatives have been the focus of Center efforts.

Since the addition of an Outreach Coordinator, the Center's outreach to area schools has tripled. Outreach and tours were provided for over 7,000 people, not counting the more than 2,700 people who attended the 9th Annual Open House on March 1, 2003 (see page 8). New outreach materials have been created to make the experience more meaningful for students and to help teachers translate what students have learned at the laboratory when they return to their classrooms. More and more teachers are turning to the Center as a resource. For that reason, we have branched out and offer outreach not just on magnets and magnetism, but on optics, use of scientific tools such as digital microscopes, technological tasks such as building model MagLev trains and gauss meters, and on general physics principles and concepts.

Center educators have been contracted by the local school district to provide two 4-day summer institutes to provide science content and strategies to area teachers. *The World Is Your Classroom* extends beyond the Magnet Lab to other area scientific, historical, and cultural resources such as the Museum of Florida History, the Brogan Museum of Art and Science, and the Tallahassee Museum of Science and Natural History. This workshop looks at the processes of science, communicating in science, using models, and presentation skills in science instruction. *Changing Perspectives* provides content in magnets, magnetism and related concepts, and light, color and optics. Teachers participate in practice with hands-on inquiry based activities to translate these complex concepts for their students grades K-12.

Work continues to progress on fine-tuning summer professional development offerings as well as getting ready for both the Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET) programs. Nineteen undergraduates have committed to 14 positions at the main site in Tallahassee, 4 positions at LANL, and 1 at the University of Florida in Gainesville. The Center expects to host 16 teachers as well, one-third of them returning for a second summer.

Two presentations were given at the National Science Teachers Association meeting in Philadelphia in March, 2003, one focusing on the Research Experiences for Teachers program and one providing hands-on experiences for teaching magnets and magnetism. One area of concentration at national educators' meetings is providing unique resources for and approaches to teaching science. This includes descriptions of how scientists and researchers have worked successfully with students and teachers. Currently there are 17 middle school students participating in a mentorship with 8 scientists at the laboratory. Each Friday, seventh grade students spend 3 hours working on a semester-long project culminating in a public presentation of their research.

Enhancements to the Web site, *http://education.magnet.fsu.edu* are an ongoing process with the assistance of a web page designer. The Center has instituted a number of dynamic elements, such as *Book of the Month*, which is a resource for teachers, students, and parents. Literature that has a strong science component is recommended for readers from kindergarten to adult. Digital microscope images and time-lapse photography of crystal growth provide an on-line teacher resource laboratory. There are plans to expand this so that students and teachers can access the images as well as add their own images to the site. A movie clip created by the Educational Media group that highlights exhibits and demonstrations from the March Open House is also included on the Web site.

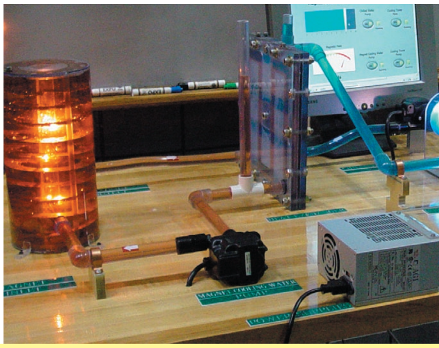
The Center has expanded its outreach to underrepresented groups in science through *The Girls in Science After School Enrichment Program*, a joint venture between the Center at the NHMFL and the Center for Equity at Florida A&M University. This initiative targets middle school girls with the purpose of facilitating and maintaining interest in science and technology by increasing science literacy and content knowledge. The immediate goal is to provide middle school girls with an after-school experience that encourages them to look at science as a possible career or academic option. A secondary goal is to encourage girls to choose upper level high school science and technology classes, expanding their career and academic options. Currently, the *Girls in Science Program* hosts 30 middle school girls from the Tallahassee area. The Center is hoping to expand this program for the 2003-2004 school year.

We continue to network with other universities and university programs to expand our own offerings. Currently, the Director is conducting evaluation for the University of Nebraska-Lincoln, is working with the RET program coordinator at Columbia University, is maintaining a long-standing working relationship with Northwestern State University. In partnership with Justin Schwartz of the NHMFL Magnet Science and Technology Group, we are working on a unique opportunity to provide an educational component to the 2004 Applied Superconductivity Conference. The NHMFL, with support from the U.S. Department of Energy, Institute for Electrical and Electronics Engineers, and the Applied Superconductivity Conference, Inc., and in collaboration with the University of Houston and the University of Wisconsin, Madison, propose a mobile educational exhibit showcasing superconductivity and applications of superconductivity. Science museums, schools, and community groups will have access to the exhibit to translate the concept of superconductivity through hands-on experiences on magnetism, electricity, and related concepts. Discussions have been held with Florida Department of Education decision makers to institute a teacher-in-residence program to facilitate this effort.

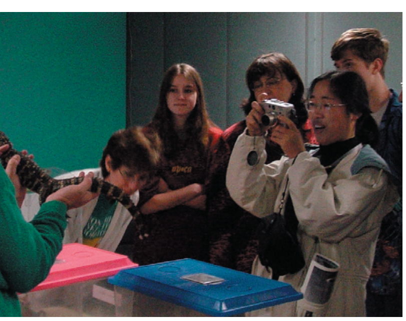
Center staff, NHMFL staff, and university staff will hold a retreat in May 2003 as the culmination of a year-long outside study being conducted to identify areas of focus for the next 5-year period. We look forward to reporting a reinvigorated program of innovative educational opportunities for students, teachers, and the general public.

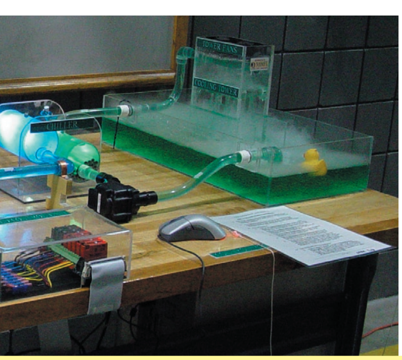
For further information, contact Dr. Pat Dixon, Director, NHMFL Center for Integrating Research and Learning, 850-644-4707, pdixon@magnet.fsu.edu.

MARCH 1st OPEN HOUSE 2003




OUR WorlD





NEWS FROM AMRIS

THE ADVANCED MAGNETIC RESONANCE IMAGING AND SPECTROSCOPY FACILITY AT THE UNIVERSITY OF FLORIDA

MR Microscopy in Alginate Beads as a Tool for Developing Artificial Organs

S.C. Grant, UF Department of Neuroscience and the McKnight Brain Institute
N.E. Simpson, UF Department of Medicine, Division of Endocrinology
S.J. Blackband, UF Department of Neuroscience; McKnight Brain Institute; Center for Structural Biology; and the NHMFL
I. Constantinidis, UF Department of Medicine, Division of Endocrinology

In the field of tissue engineering, alginates have been employed extensively to encapsulate islets and cells (for example, references 1,2) that may then be implanted into humans, for example in an effort to develop a bioartificial pancreas. In this respect, the goal is to have the implanted alginate structures substitute pancreatic function, producing insulin in a controlled fashion for the treatment of diabetes. It is well known that different alginate structures support cell growth to differing degrees, but these properties have not been characterized. Generally, alginates with high guluronic acid content develop stiffer, more porous gels that maintain their integrity for longer periods of time and hinder cell growth after encapsulation. Conversely, alginates rich in mannuronic acid residues develop softer, less porous beads that tend to disintegrate more quickly, but cells encapsulated in these alginates tend to proliferate without inhibition. Additionally application of a poly-L-lysine layer surrounding the bead is used to provide mechanical support and immunoprotection.

The goal of our present studies is to use MR microscopy and microspectroscopy to characterize and monitor cell growth in individual alginate beads of different types, and with varied coating designed to control chemical exchange through the bead. The development of high field MR and microcoil technology makes suitable data collection feasible in realistic timescales with respect to cell viability. Drs. Constantinidis and Simpson performed feasibility studies at the NHMFL on the 600 MHz wide bore magnet as outside users from Emory University, but have for the last year been employed at UF, continuing their studies in the AMRIS facility.

To date four types of alginate have been analyzed: a high molecular weight, high guluronic acid content alginate (MVG); a lower molecular weight, high guluronic acid content alginate (LVG); a high molecular weight, high mannuronic acid content alginate (MVM); and a lower molecular weight, high mannuronic acid content alginate (LVM). In the bead preparation, a $CaCl_2$ solution is used to gel the alginate droplets in concentrations ranging

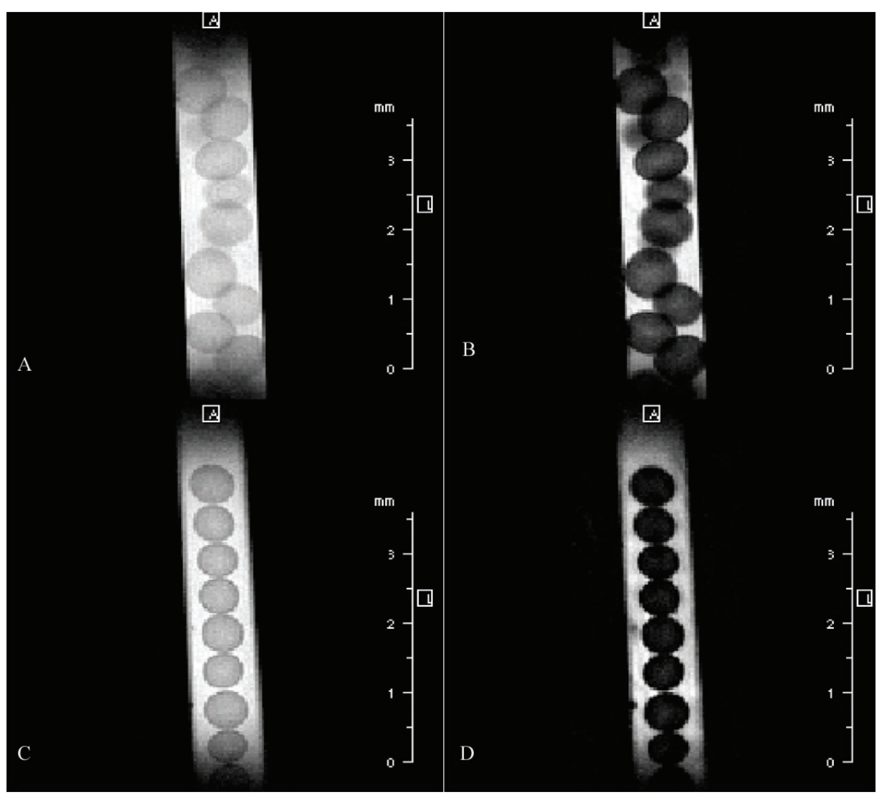


Figure 1: T2-weighted images for 2% LVG (top) and LVM (bottom) gelled with 100mM CaCl2. TE=15ms for A&C; TE=95ms for B&D. The darker signal from the LVM beads on the weighted images indicates a shorter T2.

10 to 100 mM. A few alginate beads were coated with poly-L-lysine (MW=19,200) to form alginate/poly-L-lysine/alginate (APA) beads in order to assess the effect of a PLL layer on the ability of alginate to re-gel in the presence of $CaCl_2$. NMR data were acquired using the 17.6 T Bruker wide bore system at UF. Alginate beads were loaded into a homebuilt, susceptibility-matched solenoidal microcoil having a diameter of 1.7 mm and length of 6 mm. T_2, T_1 and diffusion weighted image series yielded T_1, T_2 and ADC values using single bead ROI analysis.

The average T_1 of water in the beads showed no significant differences between alginates and only slight decreases compared to bulk water. The T_2, however, displays significant differences as a function of alginate and gellating Ca^{+2} concentration (see Figure 1). Higher concentrations of $CaCl_2$ result in a more tightly bound alginate matrix, while high guluronic content results in increased alginate order and structure. Because it is related more closely to the fraction of bound water, T_2 relaxation offers a good indicator of porosity and structure in the alginate bead. Interestingly, the addition of a PLL layer around the bead significantly alters the transverse relaxation of bead water by hindering the penetration of gellating Ca^{+2} into the liquefied core of the bead.

Transverse relaxation thus appears to be a valuable method of contrast in analyzing the structure and complexity of alginate gels used as a construct for encapsulating cells, and these data are being presented at a meeting[3] and have been submitted for publication[4]. Using T_2 methods, alginate structure and degradation can be monitored *in vitro* and *in vivo*, pre- and post-implantation. With regards to the construction of a bioartificial pancreas, these alginates have been used successfully to encapsulate islets and transformed cells. Initial studies at 17.6 T have shown that diffusion-weighted imaging is an excellent tool for monitoring the proliferation and distribution of these cells in alginate beads throughout the growth cycle. Figure 2 shows images of beads implanted with cells, clearly indicating the ability of the imaging to give and index of cell density and distribution. Additionally, preliminary results using spatially localized 1H spectroscopy indicate that the choline and lactate peaks may prove useful indicators of cell viability. By combining the imaging and spectroscopic information, it will be possible to monitor the viability and integrity of the entire construct noninvasively throughout the entire life of the artificial organ.

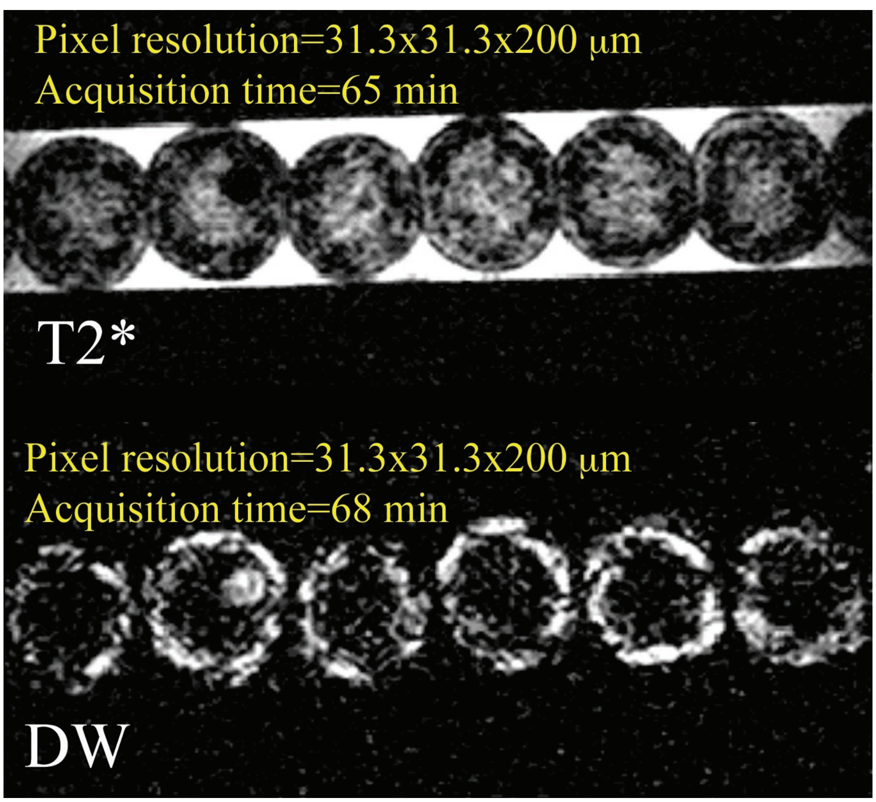


Figure 2. bTC3 cells in beads made from 2% LVG alginate & gelled with 1.1% CaCl2. The bright signal on the diffusion scans (bottom) indicate the presence of cells, and are complimented by dark signal on the T2* weighted images (top).

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PULSED FIELD USER PROGRAM

ATTENTION USERS: Alex H. Lacerda

The Pulsed Field Facility of the NHMFL continues to maintain its role as a world leader in the field of strong correlated electron systems at extreme conditions of high magnetic field, low temperature, and high pressure. The following research by Marcelo Jaime, Kee-Hoon Kim, and Neil Harrison of the NHMFL Pulsed Field Facility and John Mydosh of Leiden University represents significant results in this field. The resulting phase diagram of URu_2Si_2 was recently featured on the cover of *Physical Review Letters*, **90**, 096402 (2003). This is an excellent example of the valuable scientific collaborations constantly being made between the NHMFL users program and the outside scientific community. Furthermore, this experiment was also a joint project among facilities as research was conducted at both the Los Alamos andTallahassee campuses of the NHMFL.

Magnetic-Field-Induced Critical Behavior in the Hidden-Order Compound URu_2Si_2

M. Jaime *et al. Physical Review Letters*, ***89****, 287201 (2002)*
N. Harrison *et al., Physical Review Letters*, ***90****, 096402 (2003)*

Almost two decades have been passed and a clear understanding of the intriguing second order phase transition (T_0 ~ 17 K) of URu_2Si_2 is still missing. Recently, a great amount of experimental and theoretical work utilizing high magnetic field as an external parameter initiated a real renaissance of heavy fermion physics and particularly the physics related to URu_2Si_2.

To that end, NHMFL – Pulsed Field Facility scientists, in collaboration with J. Mydosh (Leiden University), investigate the temperature and magnetic field dependences of the specific heat, magnetization and resistivity of URu_2Si_2 from $T \approx 0.5$ K to 20 K in continuous and pulsed magnetic fields up to 50 T. The specific heat vs. temperature at constant magnetic field shows that the transition at $T_0 = 17$ K is shifted to lower temperatures and sharpened when the magnetic field increases, and is completely suppressed at H ≈ 35.5 T. Between ~36 T and ~39 T we observe a new first-order anomaly in the specific heat vs. temperature. Above 40 T a Schottky-like contribution develops. Evidence is found of metamagnetism at $H \approx 38$ T. In the close proximity of the metamagnetic transition, *quantum critical* behavior is observed in the temperature dependence of the resistivity.

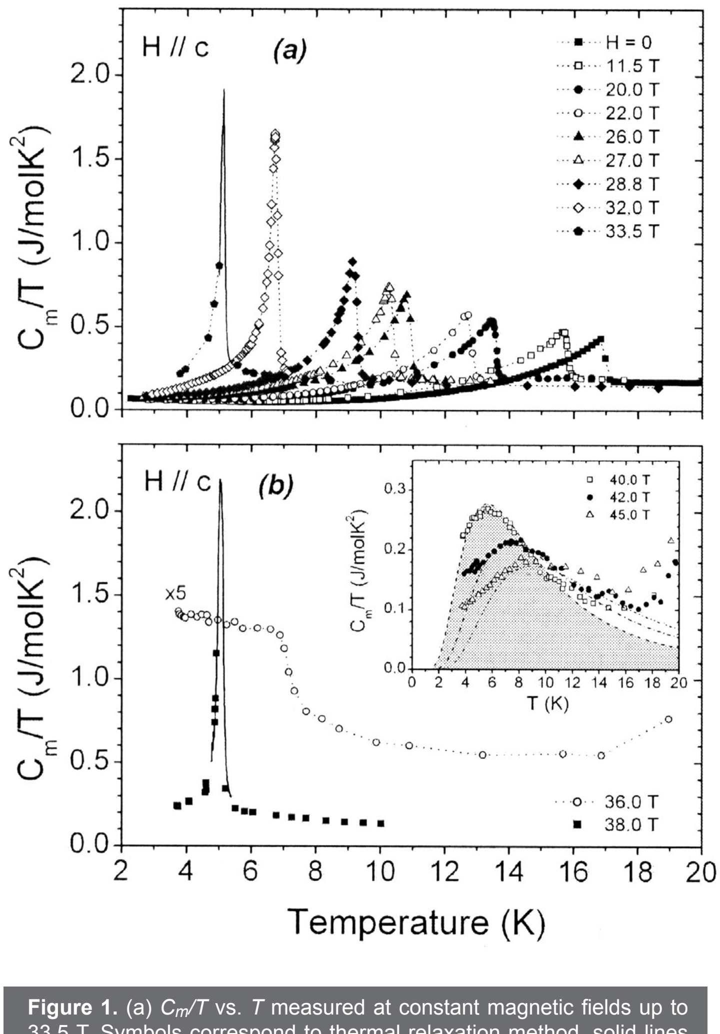


Figure 1. (a) C_m/T vs. T measured at constant magnetic fields up to 33.5 T. Symbols correspond to thermal relaxation method, solid lines to large delta T method [12], and dotted lines are guides to the eye. (b) C_m/T vs. T for H = 36 and 38 T. Inset: C_m/T vs. T for H = 40, 42, and 45 T. Dashed lines are fits with a Schottky expression.

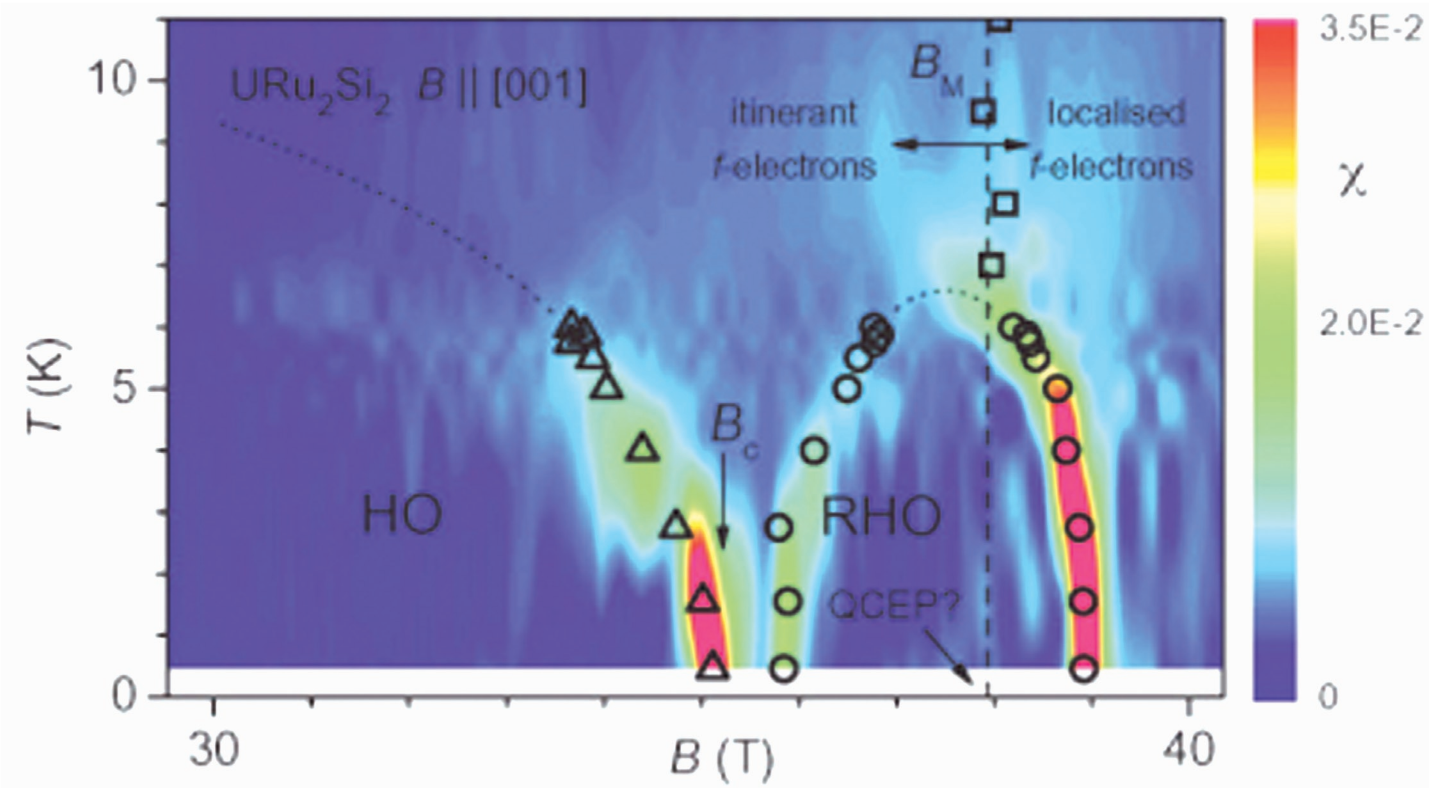


Figure 2. Color intensity plot of the magnetic susceptibility of URu_2Si_2 on traversing the hidden order (HO) and reentrant (RHO) phases measured in pulsed magnetic fields. The term "hidden order" refers to the low temperature phase in which the order parameter is yet to be identified. The RHO phase is believed to be created in the vicinity of a metamagnetic quantum critical end point. (Recently featured on front cover of *Physical Review Letters*, **90**, 096402 (2003)).

Figure 1 shows measurements of C/T vs. T in a single crystal oriented with the crystallographic *c*-axis along the magnetic field. Figure 1(a) displays $C_m/T=(C_{tot}-C_{ph})/T$ vs. temperature for magnetic fields up to 33.5 T. We observe the anomaly at T_0 shifting and becoming sharper and more symmetric with increasing external field. The sharpening of the anomaly indicates a gradual switch from second order to first order in temperature. Figure 1(b) displays C_m/T measured at 36 T and 38 T. At slightly higher field, $H = 38$ T yet another large anomaly develops in C_m/T, which in turn is suppressed with a magnetic field of 40 T. Figure 1 (b) inset shows C_m/T measured at $H = 40$, 42, and 45 T. For this extreme field regime all that is left in C_m is a Schottky-like anomaly.

Figure 2 shows a phase diagram of compiled of pulsed field isothermal magnetization (for H // c-axis) *M(H)*. *M*(*H*) at 7 K and 8 K show an inflection point (H_M), which we attribute to a metamagnetic transition indicating a crossover from itinerant *f*-electron behavior (low *H*) to localized *f*-electron physics (high *H*). When the temperature is reduced below 6 K the inflection point is replaced by a cascade of sharp transitions, one at each of several new phase boundaries. Combining the information obtained from *M(H), C(H),* and $\rho(T, H)$, a revised phase diagram for URu_2Si_2 displayed in Figure 2 in which the new phases are evident. It is interesting to notice that all these three lines seem to converge at a hypothetical quantum critical point at $H \approx 38$ T at $T = 0$.

The magnetic field induced quantum criticality in this material is an excellent example of where the right combination of low temperature and high magnetic field allows the authors to reveal new phases not possible to be observed before.

DC FIELD USER PROGRAM

ATTENTION USERS: Bruce Brandt

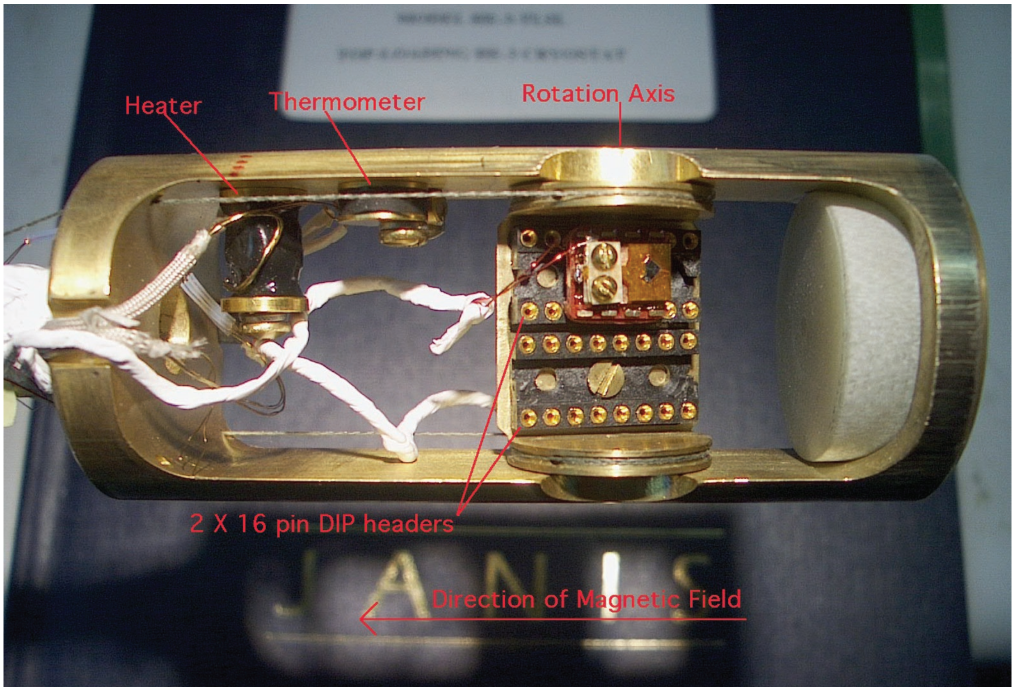
The users and staff of the DC High Field Facility in Tallahassee have wanted for some time to provide improved sample holders for helium three temperatures. Lower temperatures, longer hold times, and a sample-in-vacuum system were all considered highly desirable. Users, Instrumentation and Operations Staff, and engineers at Janis Research collaborated on the specifications and designs. The results are described below by Tim Murphy, who spearheaded the effort.

New ^{3}He Capabilities

Three sorbtion pumped ^{3}He systems were purchased recently from Janis Research Inc. for use in the DC magnets at the NHMFL. One of the systems has been received, tested, and configured and is ready for users. The other two systems are in the final stages of testing at Janis prior to shipment to the NHMFL. Notice will be given to the users when the second and third systems are available for use.

System A is a top-loading-into-liquid cryostat that is used with the 17.5/19.5 T magnet (SCM2). The available sample space is 36.8 mm (1.45 inches) in diameter. There are two probes available for the system, each wired with 16 twisted pairs and 4 S1 isolated coax. A separate group of 4 twisted pairs is used for a thermometer and heater on each probe. One probe is configured with a rotating sample holder, as shown in the photo. The second probe will be available for general use, non-rotating experiments and will have the ability to be reconfigured for specialized sample holders. Samples may be mounted on 16 pin DIP headers that plug directly into the sockets. The photo shows the rotating sample holder with a cantilever magnetometer mounted on it. The temperature range of this system is 225 mK to 70 K (0 field). The cooling power is 400 µW at 318 mK. Hold time at base temp is approximately 60 hours.

System B is also a top-loading-into-liquid cryostat that will be used in the 50 mm bore resistive magnets (presently 25 T). The available sample space is 24 mm (0.945 inches) in diameter. There are two probes available for this system, each wired the same as the probes for System A. Upon delivery one probe will be configured with a rotating sample holder while the second probe will be available for general use. The base temperature, hold time, etc. are the same as System A.



System C is a bottom-loading, sample-in-vacuum system that will be used in the 32 mm bore, 33 T resistive, and 45 T Hybrid magnets. The available sample space is 17.15 mm (0.7 inches) diameter. Mounting to the ^{3}He pot is accomplished by means of a 10-32 OFHC Cu cold-finger extending from the bottom of the pot. The available experimental wiring consists of 16 twisted pairs and 4 S1 isolated coax. The temperature range is expected to be 300 mK to 70 K.

For further information, contact Tim Murphy, tmurphy@magnet.fsu.edu, 850-644-0682.

NHMFL SIGNS INTERNATIONAL AGREEMENTS WITH TWO IMPORTANT KOREAN RESEARCH INSTITUTES

Dr. Hans Schneider-Muntau of the NHMFL was instrumental in initiating agreements with the Strategic Electrotechnology Research Laboratory of the Korea Electrotechnology Research Institute (SERL-KERI) and the Korea Basic Science Institute (KBSI) to promote cooperation in modern technologies and scientific exchange.

The Cooperative Research Agreement involves three partners; besides SERL-KERI and NHMFL, it also includes the Center for Advanced Power Systems (CAPS). It is focused on the development of high temperature superconductors (HTS), such as BiSCCO and YBCO conductors, and their technical applications in HTS transformers and HTS motors. The cooperation will be very effective since there is already a very strong and successful cooperation between NHMFL and CAPS on the development of HTS, and the inclusion of a third partner will advance progress considerably. KERI and CAPS will combine their efforts on the applications of HTS technology in transformers and motors. The research agreement foresees, among others, the exchange of scientists and students and their training, exchange of results, mutual participation in interesting and advanced experiments, and the organization of workshops for detailed discussions of the results and definition of future programs. The photograph shows Dr. Kang-Sik Ryu (right), Executive Director of SERL-KERI, and Dr. Hans J. Schneider-Muntau, NHMFL, during the signing ceremonies on December 10, 2001, in Changwon, Korea.

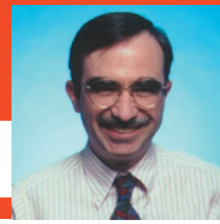
Dr. Hans J. Schneider-Muntau of the NHMFL (left) and Dr. Kang-Sik Ryu of SERL-KERI sign Cooperative Research Agreement on December 10, 2001 in Changwon, Korea.

The principal objective of the Memorandum of Understanding between the Korean Basic Science Institute (KBSI) and NHMFL is more directed toward science in high magnetic fields, although there is also an expressed interest of establishing a pulsed magnetic field facility with help and advice of the NHMFL. It has been agreed to provide opportunities to exchange ideas, information, skills, and techniques and to collaborate on various areas of research in high magnetic fields and high field magnet technologies of mutual interest. The agreement will also encourage the exchange of scientists and engineers between the two research institutions in biosciences, materials science, and geochemistry. Educational outreach is an important aspect of the new agreement with the exchange of university students and postdoctoral researchers. The Memorandum of Understanding was signed at the NHMFL on October 28, 2002. At the signing ceremony were President Dr. Jung-Soon Lee for the Korea Basic Science Institute and Director Dr. Jack Crow and Chief Technology Officer Dr. Hans Schneider-Muntau for the NHMFL.

Dr. Schneider-Muntau commented about the Korean memoranda of understanding, "International science and engineering cooperation is a critical part of the overall mission of the National High Magnetic Field Laboratory. These formalized agreements with the two Korean institutes will open new avenues to share not only science and technology, but also to involve graduate students who will be the next generation in their fields. Korea is an exciting place for science with a booming economy and a strong interest in new technologies."

PEOPLE IN THE NEWS


G.Boebinger


T.Cross


E.Dagatto


K. Hakansson

Greg Boebinger, NHMFL Principal Investigator at LANL, has been invited to present a talk on high-magnetic-field science at the spring meeting of the Board on Physics and Astronomy of the National Academy of Sciences on April 26. The Board is interested in this particular topic because they anticipate conducting a study of high-magnetic-field science for the National Science Foundation in the near future. Dr. Boebinger's talk is expected to present the status of high-field magnet design, featuring the contributions of the NHMFL to the state-of-the-art and as a magnet technology resource; materials research for high-field magnets; recent scientific accomplishments at the NHMFL; and a look toward the future of Nobel prizes in high-field research.

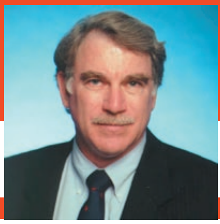
Timothy Cross, director of the NHMFL NMR Spectroscopy and Imaging Program, has been awarded a Named Professorship by Florida State University for his pioneering the development and application of solid-state NMR spectroscopy of uniformly aligned samples for the three-dimensional structural and dynamic characterization of peptides and proteins in a membrane environment. Today, this technology has joined the ranks of x-ray crystallography, cryoelectron microscopy, and solution NMR as methodologies for high resolution structural characterization. Professor Cross chose Earl Frieden for his Professorship title. Frieden was one of the initiators of the Chemistry graduate program in 1949 at FSU. During his illustrious career as a metallo protein chemist, he published several books and more than 150 research papers. He was also chairman of the department between 1962 and 1968 when the Dittmer Laboratory of Chemistry was built.

Elbio Dagatto of the NHMFL Condensed Matter/Theory Program has written a book entitled Nanoscale Phase Separation and Colossal Magnetoresistance: The Physics of Manganites and Related Compounds (2003, approx. 400 pp., 100 figs., Springer).

Abstract: The study of the spontaneous formation of nanostructures in single crystals is rapidly developing into a dominant field of research in the subject area known as strongly correlated electrons. The structures appear to originate in the competition of phases. This book addresses nanoscale phase separation, focusing on the manganese oxides with colossal magnetoresistance (CMR). The text argues that nanostructures are at the heart of the CMR phenomenon. Other compounds are also addressed, such as high-temperature superconductors, where similar nanostructures exist. Brief contributions by distinguished researchers are also included. The book contains updated information directed at experts, both theorists and experimentalists. Beginning graduate students or postdocs will also benefit from the introductory material of the early chapters, and the book can be used as a reference for an advanced graduate course.

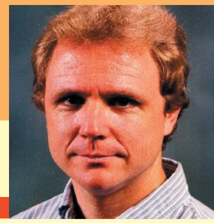
Kristina "Kicki" Hakansson, a postdoctoral fellow in the ICR Program, has accepted a position as Assistant Professor in Chemistry at the University of Michigan (Ann Arbor), beginning in August, 2003. Dr. Hakansson will be pursuing FT-ICR mass spectrometry research on posttranslationally modified proteins.

NHMFL-AFFILIATED FACULTY AT UF RECOGNIZED FOR EXCELLENCE



A.Marshall

S.Hershfield



C. Stanton

D. Talham

Alan Marshall, director of the NHMFL Ion Cyclotron Resonance Program, has been chosen to receive the 2003 Charles Holmes Herty Medal. The medal has been presented annually since 1933, and Dr. Marshall appears to be the first FSU chemist to receive this distinction. The Herty Medal is a solid gold medallion awarded annually by the Georgia Section of the American Chemical Society. It gives public recognition for the work and service of outstanding chemists who have contributed significantly to their chosen fields. All chemists in academic, government, or industrial laboratories in the 11 southeastern United States are eligible. Charles Herty was the first President of the American Chemical Society (in 1915-1916), and was also the South's first football coach (at University of Georgia in 1891). He was a natural products chemist, who is best known for developing a non-destructive method for harvesting tree resin, thereby saving much of the pine forest of the southeastern United States.

Selman Hershfield, Physics, was recognized by the College of Liberal Arts and Sciences for excellence, innovation, and effectiveness in advising. Dr. Hershfield's research interests include transport theory and many body physics of condensed matter systems. Particular emphasis is given to transport in nanostructures such as quantum dots, magnetic multilayers, and tunneling through single atoms or defects. These systems are easy to drive far from equilibrium and frequently have novel many body effects because of the reduced dimensionality, in addition to being important technologically.

The College of Liberal Arts and Sciences awarded six Term Professorships to outstanding faculty who excel in both scholarship and teaching. The recognition comes with a $6,000 one-time salary supplement and an additional $5,000 for research. We are pleased to note that two of the six honored professors are affiliated with the NHMFL and named Jean and Robin Gibson Term Professors.

Christopher Stanton, Physics. Dr. Stanton specializes in theoretical condensed matter physics. He teaches a broad range of courses, including applied physics, introductory solid state physics, optics and statistical mechanics. His research involved theoretically calculating and modeling the electronic, transport, and optical properties of bulk and quantum confined semiconductors.

Daniel Talham, Chemistry. Dr. Talham specializes in hybrid organic and inorganic materials with organic and inorganic interfaces. He teaches general chemistry, inorganic chemistry, and a graduate course he developed in materials chemistry. He is involved in two research projects, one developing new lightweight magnets, and the other, studying how organic interfaces can be used to template inorganic objects.

CONFERENCES & WORKSHOPS

SPIE's First International Symposium on Fluctuations and Noise Conference on Noise as a Tool for Studying Materials
http://spie.org/conferences/Calls/03/fn/conferences/index.cfm?fuseaction=FMo3
June 1-4, 2003
La Fonda Hotel
Santa Fe, New Mexico

The first meeting on Fluctuations and Noise (FaN) *http://spie.org/conferences/calls/03/fn* comprises six parallel conferences focusing on Biological, Biophysical, and Biomedical Systems; Photonics and Quantum Optics; Materials; Devices and Circuits; Complex Systems and Stochastic Dynamics; and Nano-electronics, Sensors, and Standards. The NHMFL is pleased to support the conference on Noise as a Tool for Studying Materials.

Contact: Conference Chair Michael B. Weissman, University of Illinois/Urbana-Champaign (*mbw@uiuc.edu*, 217-333-7897). Dragana Popovic of the NHMFL Condensed Matter/Theory group is serving on the Program Committee.

XIIth International Quantum Atomic and Molecular Tunneling in Solids Workshop (QAMTS)
http://www.clas.ufl.edu/QAMTS/
June 22-25, 2003
Reitz Union Hotel and UF Hotel & Conference Center
Gainesville, Florida

This important international meeting 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. Topics 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; Tunneling in Glasses and Amorphous Systems; and others. Sponsors include the NHMFL, LANL, Spallation Neutron Source, National Institute of Standards and Technology, and UF.

Contact: Conference Coordinator Carol Binello (*cbinello@clas.ufl.edu*; 352-392-0780).

33rd Southeast Magnetic Resonance Conference and Symposium (SEMRC)
http://semrc2003.magnet.fsu.edu
October 17-19, 2003
Ramada Inn & Conference Center
Tallahassee, Florida

SEMRC provides an ideal opportunity for scientists in all areas of magnetic resonance to come together and share new applications and technique developments. 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).

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

Future Events

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).

Sanibel Symposium

The 43rd annual Sanibel Symposium arranged by the faculty and staff of the University of Florida Institute for Theory and Computation in Molecular and Materials Sciences was held February 22 through March 1, 2003 at the Ponce de Leon Conference center close to the North Gate of the city of St. Augustine, Florida. This year's meeting gathered close to 300 scientists from about 20 different nations.

The topics covered by the fifteen plenary and seven poster sessions included, in addition to Advances in Electronic Structure and Dynamics Theory, the following:

- Density Functional Theory and Applications
- Advanced Materials
- Molecular Electronics
- Coherent Control
- Computer Simulations of Bio-Nano Systems
- Energy Transduction
- Membrane Proteins
- Carbohydrate Modeling

The University of Florida, the IBM Corporation, the Office of Naval Research, and the Department of Energy sponsored the meeting. A one-day short-course on "Force Fields and Molecular Dynamics" with hands on computer applications, sponsored by the CACHe Group of Fujitsu, was part of the program and participation of graduate and undergraduate students from several U.S. colleges and universities.

Professor John A. Pople (Nobel laureate in Chemistry, 1998) shares discussions with Peter Gill of Nottingham University and others at the 43rd Sanibel Symposium.

NHMFL HOSTS NEUTRON SCATTERING WORKSHOPS

The inherent interface been high magnetic fields and neutron scattering research has forged natural collaborations between 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.

The workshops will be held at the Turnbull Florida State University Conference Center. See the Web site, *http://www.sns.gov/jins/jins.htm*, for contacts and up-to-date information.

Joint Institute for Neutron Sciences (JINS) Workshop: Neutron Scattering for Chemistry and the Chemistry-Biology Interface

September 23-25, 2003

The U.S. neutron users' community is eagerly anticipating the commissioning and operation of beamlines at the SNS, currently under construction at ORNL. Many opportunities exist for wonderful scientific advances with neutron scattering and spectroscopic investigations by chemists and by biologists working at the chemistry-biology interface. The number of active neutron users among these communities, however, is currently small, and the communities as a whole have had little opportunity to communicate their interests and needs. A series of talks on scientific grand challenges and the role neutrons can play are planned in areas such as: catalysis; compounds with exotic magnetic and electronic properties; materials for energy production and storage; structure and dynamics in liquids, glasses, complex fluids; molecular behavior under confinement/near interfaces; complex self-assembled materials of molecular and macromolecular components, studied at multiple length scales.

The goals of this workshop are to: (1) inform the chemistry and chem-bio communities of instrumentation and supporting facilities currently planned for the SNS; (2) solicit ideas on the needs for instrumentation, for detector development, for sample environment development (addressed by the overlapping workshop, SENSE), for time-resolved neutron scattering, for deuteration facilities for both low- and high-molecular compounds, for data analysis suites that integrate modeling and simulation and for educational efforts in designing, executing, and analyzing scattering experiments; (3) identify the tools needed and outline a path to realization via the formation of concept teams to develop science cases and funding proposals for instrumentation, sample environments, supporting lab facilities, and best practices for education of new users in the chemistry and chem.-bio communities.

Sample Environments for Neutron Scattering Experiments (SENSE) Workshop

September 24-26, 2003

A joint venture of the Center for Nanophase Materials Science (CNMS), the Spallation Neutron Source (SNS), and the Joint Institute for Neutron Sciences (JINS).
NHMFL Director Jack Crow and Dr. Paul Sokol of Pennsylvania State University, co-chairs

Many of the most exciting neutron science initiatives hinge upon the development of advanced sample environments. Examples include *in situ* studies of catalysis, self-organizing nanostructures, pressure-induced phase transitions, dynamic mechanical stress, and high-field studies of magnetic excitations and structures. There is presently a lack of advanced sample environments for conducting such studies, particularly in the United States, which jeopardizes the advancement of neutron science and growth of the user-community. SENSE is an action-oriented workshop devoted to solving this problem.

The SENSE workshop will include advanced tutorials on the latest sample environment techniques and designs; review of user-facility sample environment programs; and a symposium on launching user-driven development projects. The workshop will culminate in the commissioning of several highly focused working groups, charged with developing concepts and ultimately submitting viable funding proposals. Advanced tutorials will prepare graduate students and junior scientists to participate on these working groups and help shape the future of neutron science. Other major components of the workshop will be a review of user-facility sample environment programs, that will be designed to give the participants a clear sense of present and emerging capabilities worldwide. Thus, the working groups will have a good basis for evaluating and refining their concepts, and introducing designs that are compatible with user-facility standards.

Moving the 900 MHz MAGNET

See page 3 for more info.

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Fax: 850 644-8350
www.magnet.fsu.edu

On April 9, 2003 the 900 MHz High Resolution NMR Magnet was moved from the OPMD building to its new home a quarter mile away in the NMR building.