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PROGRESS REPORT FOR 1993

Statics and Dynamics in Systems with Frustration and or Randomness

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Introduction

Over the past year we have finished some projects as anticipated in our recent three year proposal, and we have started some new projects, some of which were not anticipated in our proposal. I will describe briefly our status with regard to students first. Then I will report on the current equipment situation in our UCSC labs. The projects completed or very close to being completed will be described. Projects which we are currently pursuing will be described next. Finally, our proposed budget, only slightly modified from the one in the proposal, will be justified. The budget itself is detailed at the end of this report. All manuscripts published since the recent proposal was submitted are included with this progress report. I have submitted a revised vitae as well.

Students

I have been supporting one student, Jiahua Wang, and he is expected to finish his thesis in the Spring quarter of 1994. He has worked on a variety of experiments, including the specific heat of stacked triangular lattice antiferromagnets and structural random-field transitions, and neutron scattering studies of thin films and multilayered films. He has also been the computer manager for our experimental and theoretical condensed matter group. I expect him to obtain his permanent residence within a few months and should have no problem finding a postdoctoral research position. He is widely regarded as one of our finest students.

Beginning in August, I will have another student, Zoran Slanic, begin his research in my group. I expect to concentrate his training in neutron scattering techniques. He came from Clark University where he worked with Prof. Stan Geschwind and has come with outstanding recommendations.

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Equipment

Our equipment for optical and specific heat measurements is in relatively good shape. Although we have not been able to make upgrades in this apparatus, the current setup is adequate to pursue the projects necessary to keep us very busy. We have only one significant problem which is a leak in our superconducting solenoid cryostat. We anticipate that we will locate and repair the leak soon and continue the measurements on the structural random-field phase transition that were interrupted by the leaking cryostat.

We upgraded our computing facilities by purchasing a Sun Sparc Classic. Jiahua Wang has it running very well. We have already begun to have success in analyzing our data and in running Monte Carlo simulations as will be described below.

Completed Projects

We completed two projects on neutron scattering in thin films, both to be published in the proceedings of the April 1993 MRS meeting in San Francisco. The first experiment reported is the neutron scattering study of a pure FeF_2 thin film grown on a ZnF_2 substrate. The experiment showed that using a thin film eliminates the extinction problems which plague the Bragg scattering experiments in the bulk samples. It opens up the possibilities of using the thin films for critical behavior characterizations. The second project involves neutron scattering in the multilayers $(FeF_2)_m(CoF_2)_n$ with the number of monolayers being $n=m=4.5$ in one sample and $m=26$ and $n=28$ in the second sample. The thin layered sample shows only one transition, whereas the thick one shows two distinct features associated with the two transitions of the bulk materials. The details of these behaviors are now being studied in our group using Monte Carlo techniques.

Over the past year we have continued to obtain data and analyze the behavior of excitations in $Fe_xZn_{1-x}F_2$ at low temperatures. The behavior of the fundamental excitation in such random-exchange systems is only crudely understood. Past attempts have been made to argue that the behavior can be described in terms of a crossover from a magnon excitation at the zone center to an overdamped fracton excitation as the zone boundary is approached. Our work and that of Prof. Ikeda, et al. in Japan, show definitively that such an interpretation is for the most part untenable. A simple cluster model works for the gross behavior, but the observed fine structure cannot be described within current theoretical frameworks. We believe that our experimental work should motivate a more serious examination of the theory. We anticipate submitting this work

to Physical Review B in September.

We completed our work on the specific heat of the stacked triangular lattice Ising antiferromagnet CsCoBr_3 . Although this is an Ising system, it shows the critical behavior of the classical XY universality class, as predicted by theory. This is a consequence of the frustration inherent in the three sublattice structure. All aspects of this study, which is a first of its kind, are compatible with theory except for the lack of tricritical crossover effects. A manuscript is nearly complete and will be submitted in August to the Physical Review. Neutron scattering studies by Prof. Gaulin, et al. at McMaster University, when published in the near future, will complement our study.

Projects Proposed or in Progress

Jiahua Wang and I will be traveling to the Oak Ridge National Laboratory in August for two weeks of neutron scattering experiments. The first objective of the experiments is to complete the Bragg scattering study of a thin film of $\text{Fe}_{0.5}\text{Zn}_{0.5}\text{F}_2$. The behavior in zero field has been adequately studied and is just what is expected, i.e. the critical behavior is compatible with the random-exchange Ising model. In a field, we have the random-field Ising model and a technique for finally studying the order parameter directly. Our preliminary studies showed unexpected and unusual behavior in the order parameter indicating a long wavelength modulation in the staggered magnetization. These experiments should shed light on the puzzling results obtained by Birgeneau, et al. at Brookhaven. They observed a peculiar and unexplained sample dependent behavior in bulk $\text{Mn}_x\text{Zn}_{1-x}\text{F}_2$ samples that depended on whether they observed with neutrons or x-rays. The claim is that x-rays see only the surface whereas neutrons see only the bulk. Since we have a thin film, we can study with neutrons the behavior they claim to observe with x-rays. In contrast to their results, our carefully prepared thin film sample shows behavior of a thin layer compatible with that of the bulk crystals! We are also planning to study the same thin films with x-rays sometime in the future in collaboration with Prof. Brown (UCSC).

We also hope to study a multilayered thin film $(\text{FeF}_2)_m(\text{ZnF}_2)_n$ with $m \approx n \approx 6$ during our August trip. This is a system with alternating antiferromagnetic and diamagnetic layers. With this thickness, we should be able to observe crossover from three to two dimensional critical behavior as the correlation length grows upon the approach to the critical temperature. The crossover should occur when the correlation length becomes

comparable to the layer thickness.

Finally, if we have sufficient time, we hope to do inelastic measurements on another sample of the random-exchange system $Fe_xZn_{1-x}F_2$ to verify the rather mysterious three peak structure we observed for $x=0.59$ which is described in the manuscript on magnetic excitations mentioned in the previous section. At this time, we do not have an explanation for the three peak structure and it would be helpful to know if it is a concentration dependent effect.

With regard to our recently finished study of $(FeF_2)_m(Co_2)_n$ multilayers, we believe we may learn more about correlations between and within the two kinds of anti-ferromagnetic layers by using polarized neutron scattering. We are now in contact with Dr. Ross Erwin and hope to do some experiments at NIST using the apparatus they used for a similar study on oxide multilayers.

I will be collaborating with Dr. F. Montenegro, from the Physics Department at the Universidade Federal de Pernambuco, Recife, Brazil on an experiment to be done with Dr. R.M. Nicklow at ORNL. He has shown that his samples of $Mn_xZn_{1-x}F_2$ exhibit the same spin-glass like phase diagram as our $Fe_xZn_{1-x}F_2$ system for concentrations near the percolation threshold. He used magnetization measurements. To complete the characterization, we will use neutron scattering techniques. The measurements are tentatively scheduled to take place in November.

Jiahua Wang has begun specific heat experiments of the random-field structural phase transition in $Dy(As_xV_{1-x})O_4$ in collaboration with K. Reza, who visited UCSC this Spring, and Prof. D. Taylor, both from Queen's University. This system should complement the magnetic phase transitions we have previously studied. The sensitivity of the sample to strains necessitates a special sample holder which contains the sample in a helium atmosphere but is small enough not to add undue background to the specific heat data. While perfecting this technique, the cryostat developed a leak which we are presently attempting to fix. These experiments will resume as soon as the leak is repaired.

I have begun a collaboration with Dr. M. Marinelli from the Mechanical Engineering Department at the University of Rome who has developed an apparatus for studying the thermal conductivity and diffusivity critical behavior of magnetic systems. We may test current theories for the behavior of these systems using his techniques. I am

providing prepared crystals of the three dimensional Ising model system FeF_2 and the three dimensional Heisenberg model system $RbNiF_3$ and the measurements will be done in Rome. If these experiments are successful, we will try the dilute systems to study the effects of randomness on the transport properties.

I had a senior thesis student, Mario Viani, this past academic year who wrote a Monte Carlo program to simulate the Bragg scattering in the multilayered thin film anti-ferromagnets $(FeF_2)_m(Zn_2)_n$. He compared his results quite favorably with our neutron scattering data. Jiahua Wang and I hope to pursue this investigation further and determine, for example, the staggered magnetization as a function of distance from the layer interfaces, which may have bearing on the planned polarized neutron scattering measurements at NIST. These investigations have been made possible by our new Sun Sparc Classic computer.

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