Testing of a Prototype Faraday Magnetometer

V. S. Zapf, N. Harrison, R. McDonald (NHMFL-LANL)

Introduction

A Faraday magnetometer was designed for use in dc magnet systems. This magnetometer relies on the fact that a force $F = \vec{m} \cdot \nabla H$ is generated when a magnetic moment is subjected to a gradient magnetic field. If the sample is mounted on a spring, the deviation of the spring due to the force can be measured capacitatively. This magnetometer is designed to measure macroscopic samples up to several mm and mg in length and mass in dc magnets. It will be eventually adapted to work in pulsed fields as well, e.g. in the 60 T long pulse.

Experimental

Our first design is meant to minimize the effects of magnetic torque on the sample. Thus the sample is mounted on a phosphor-bronze plate that is suspended by four 1 mil phosophor-bronze wires from posts. A second plate is similarly suspended underneath the first plate and connected to the first plate via a G-10 rod. This minimizes the ability of the system to respond to a torque. The second plate acts as one plate of a capacitor that measures the displacement of the sample. The magnetometer is designed to fit into a standard 4He sample holder in NHMFL-Tallahassee, as well as the dilution refrigerator and 3He systems in the superconducting magnets at NHMFL-LANL.

Results and Discussion

Initial tests were performed with the sample DTN ($NiCl_2$-$4SC(NH_2)_2$) since the magnetization of this sample is well-characterized at low temperatures [1]. This compound also experiences a very large torque in a magnetic field due to the single-ion anisotropy of the Ni moments, and thus is a good test whether the torque effects are minimized by this magnetometer design. Additional measurements were performed on the sample $(HPIP)_2$-$CuBr_4$. The magnetometer was mounted in the ^{3}He fridge of a 17 T DC magnet at NHMFL-LANL. The capacitance was measured as a function of magnetic field at temperatures down to 500 mK, with the sample out of the field center in order to induce a vertical gradient magnetic field. An example result is shown in Fig. 1. The gradient magnetic field is proportional to the applied magnetic field, and thus the magnetometer becomes more sensitive at high magnetic fields. The phase transition at H_{c2} = 12 T of DTN [1] can be clearly distinguished, however the phase transition at H_{c1} = 2.1 T is difficult to discern. Measurements at different gradient fields indicate that the torque effect is small but still measurable.

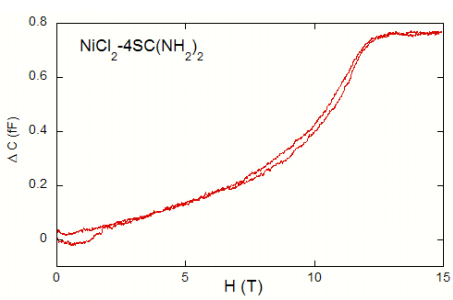

Fig. 1. Change in capacitance vs applied magnetic field for a sample of DTN at 500 mK. The sample is located 10 mm above the field center, resulting in a gradient magnetic field that is proportional to the applied magnetic field H of H*(0.009 cm^{-1}).

Conclusions

This prototype appears to work and gives a signal that is dependent on the magnetization of the sample. However, for the extreme example of the compound DTN, torque effects still occur. The magnetometer is also not quite sensitive enough for the applications we have in mind. We will therefore build a second prototype in early 2008.

Acknowledgements

This work was funded by the NSF through an IHRP grant (V. S. Zapf, principal investigator).

References

[1] A. Paduan-Filho et al, PRB **69**, 020405(R) (2004).