Pulsed Field AMRO on $YBa_2Cu_3O_{6+x}$ Using High-Stability Cryogenics

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Introduction

The discovery of quantum oscillations in the underdoped high-temperature superconductor $YBa_2Cu_3O_{6+x}$ (YBCO)[1] generated much excitement in the field of high-Tc research, providing the first concrete evidence for a metallic Fermi surface in this region of the phase diagram. One of the remaining challenges in the cuprates is to determine the full symmetry of this Fermi surface and to understand the mechanism of Fermi surface reconstruction. To this end, we performed angular magnetoresistance measurements in the 45 T hybrid in Tallahassee in 2013. We found broken rotational symmetry in the magnetoresistance, and our goal in the 65 T pulsed fields was to extend these measurements and possibly observe magnetoresistance oscillations (AMRO).

The specific challenge was that resistance is a strong function of temperature in this material, and the samples self-heat during the pulse. As the liquid helium level drops in the cryostat over the course of a day, the gas pressure in the fridge changes, changing the cooling power near the sample. This produces a drift in the resistance that overwhelms the physics we are looking for (changes in resistance as a function of field angle).

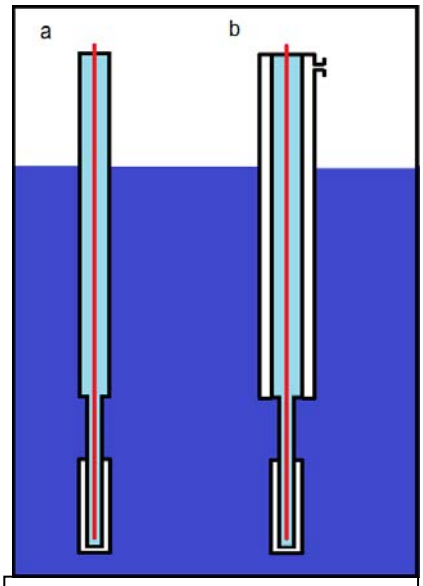

Figure1: Schematic of the fridge designs used in the pulsed-field magnets. a) Traditional fridge. b) Modified fridge. The probe and sample are red, exchange gas is light blue, liquid helium is dark blue, and vacuum is white.

Experimental

Traditional fridges used in the pulsed field magnets (item (a) in figure 1 consist of a stainless tube that is pumped out and filled with exchange gas, with a double walled section at the tail of the fridge to allow for temperatures other than that of the ^{4}He bath (i.e. 300 mK in ^{3}He, or higher temperatures with a heater). However, because the upper section is in direct contact with the bath, the density of exchange gas changes as the bath level drops. We added a secondary double-walled section to the fridge (item (b) in figure 1) that isolates most of the fridge from the bath. This leaves a single point of direct contact with the bath much lower in the cryostat (just the upper section of the tail), which should allow for better exchange gas stability. We performed pulsed field c-axis transport on a sample of $YBa_2Cu_3O_{6+x}$, which is particularly sensitive because of self-heating and a strong temperature dependence of the resistance.

Results and Discussion

With the traditional fridge design, over the course of 4 full-field shots (about 4 hours), the exchange gas increased from 93.1 mBar to 127 mBar. The resistance of the $YBa_2Cu_3O_{6.58}$ sample at 65 T and 15 K drifted by about 20% over this time period, and pumping the gas back down to 93.1 mBar only partially solved this issue (difference was still more than 10%).

With the new fridge design, the pressure stayed within 0.5 mBar of 90 mBar over 10 shots (a full day). The resistance of the $YBa_2Cu_3O_{6.58}$ sample at 65 T and 15 K was the same to within 1% over this period.

Conclusions

This fridge allows for high stability of the exchange gas around the sample, providing consistent cooling power during the pulse. This system will be useful for measuring other systems with strongly temperature dependent resistivity.

References

[1] Doiron-Leyraud,N. *et al*., Nature, **447**, 565 (2007).