Contactless Measurement of Magneto-Conductivity of the Cuprate High-T_c Superconductor $HgBa_2CuO_{4+\delta}$

Chan, M.K.; Ramshaw, B.J.; McDonald, R.; Modic, K. (NHMFL, LANL); Geven, M. (Minnesota U., Physics); Harrison, N. (NHMFL, LANL)

Introduction

Underdoped cuprates are characterized by an enigmatic pseudogap phase defined by the opening of a gap in the antinodal regions of the Fermi-surface at a characteristic temperature T^*[1], which is typically larger than the superconducting temperature T_c. The ground state in the cuprates can be accessed by the application of a sufficiently large magnetic field to suppress superconductivity at low temperatures. Recent work revealed quantum oscillations (QO) in underdoped $YBa_2Cu_3O_{6+y}$ (YBCO) with a periodicity consistent with a small *electron*-like pocket[2,3] (corresponding to ~3% of the Brillouin zone). This should be contrasted with the large *hole*-like Fermi surface (~65% of the Brillouin zone) expected from band-structure calculations and from measurements in the overdoped regime of $Tl_2Ba_2CuO_{6+\delta}$ (Tl2201)[4]. These results can be taken as evidence of a reconstruction of the Fermi-surface in the pseudogap phase, which would likely have to involve an order parameter that breaks the translational symmetry of the crystal lattice. Therefore, whether the particular Fermi-surface reconstruction observed in YBCO is a universal and essential property of the cuprates or merely a consequence of a compound specific peculiarity remains a pivotal open question. Our work focuses on the study of quantum oscillations in $HgBa_2CuO_{4+\delta}$ (Hg1201), which has a simple crystal-structure (one copper-oxygen plane per unit cell and tetragonal crystal symmetry) while exhibiting a high maximal T_c of 98 K.

Experimental

Experiments were performed by coupling the Hg1201 sample to a proximity-diode-oscillator (PDO) circuit. A change in the sample's conductivity is manifested in a change of the PDO circuit's characteristic frequency, *f*. Fig. 1a shows the change in PDO frequency with applied magnetic field of a Hg1201 single crystal. Experiments were performed with 65 T pulsed field facility at the NHMFL, LANL.

Results and Discussion

The large swing in *f* at approximately 35 T is due to the suppression of superconductivity by the applied magnetic field. It is difficult to resolve small shifts in f due to QO from the raw data. Instead, we show in Fig. 1b the derivative of the raw data, which reveals QO at high fields. We have therefore successfully measured QO in Hg1201 using a contactless method. This paves the way for future studies as a function of doping, angle, and extensions to the 100T magnet.

Acknowledgements

A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy. We also acknowledge funding from DOE-BES SC0006858 and "Science at 100T".

References

[1] T. Yoshida et al., J. Phys. Soc. Jpn. **81**, 011006 (2012). [2] N. Doiron-Leyraud et al., Nature 447, 565 (2007). [3] S. E. Sebastian et al., Proc. Natl. Acad. Sci. 107, 6175 (2010). [4] N. E. Hussey et al., Nature 425, 814 (2003).

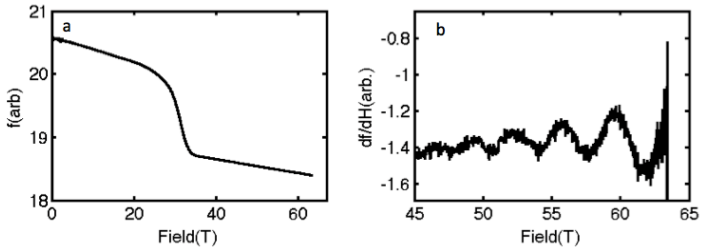

Fig.1 (a) Change in PDO circuit frequency as a function of applied magnetic field. (b) close up of the derivative with respect to applied field of the high field data revealing quantum oscillations in Hg1201