Hysteretic Quantum Oscillations in Underdoped Cuprates from Nesting Driven Charge Order

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Introduction

Quantum oscillation experiments on underdoped YBCO have revealed a Fermi surface that is dramatically transformed from the overdoped side. In contrast to a large Fermi surface yielded by bandstructure calculations and observed from quantum oscillation and angle resolved magnetoresistance oscillation experiments on overdoped Tl2201 [1], a small Fermi surface is observed in underdoped YBCO [2].

Various explanations have been proposed as the origin of the small Fermi surface observed in underdoped YBCO. Experiments such as x-ray diffraction, nuclear magnetic resonance, and ultrasound experiments have observed signatures of charge order. It remains an open question, however, as to the origin of the small Fermi surface in the underdoped cuprates, and a potential relation to a charge density wave. The physical origin of the charge density wave such as potential Fermi surface nesting, or other many body effects is also under debate.

Experimental

Here we report ultra-high magnetic field experiments of the in-plane resistance in underdoped YBCO measured using a PDO (proximity detector oscillator) technique in pulsed magnetic fields up to 92 T at NHMFL, Los Alamos. Experiments reveal the intriguing phenomenon of a shift in phase between quantum oscillations observed when the magnetic field is increased compared to quantum oscillations observed when the magnetic field is decreased (Fig. 1).

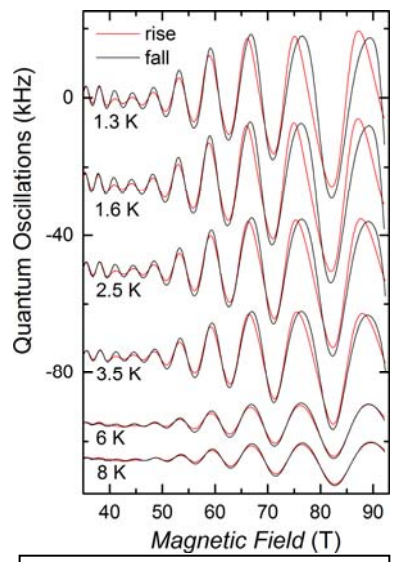

Fig. 2: Phase shift between quantum oscillations measured as a function of rising and falling field up to 92 T in underdoped YBCO.

Discussion

Previous measurements in the organic family of materials α-(BEDT-TTF)$_2$KHg(SCN) (Fig. 2) has revealed a similar evolution in quantum oscillation frequency with magnetic field as a function of direction, which is related to a field-induced phase transition between charge density waves of different quantised periods [3]. In this case, the evolution of nesting wavevector with magnetic field in quantised steps is proposed to yield an evolution in quantum oscillation frequency as the magnetic field is increased.

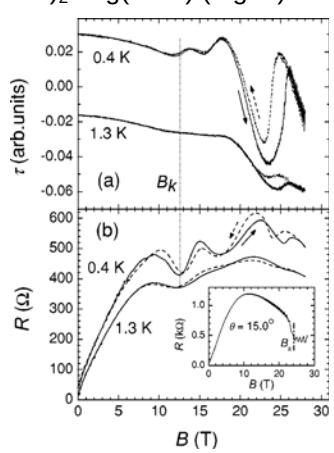

Fig. 2: Up (solid lines) and down (dashed lines) field sweeps of (a) the magnetic torque and (b) the interlayer resistanceof α-(BEDT-TTF)$_2$KHg(SCN)$_4$, which exhibits a field-induced charge density wave transition, reproduced from [3].

Conclusions

A field-induced charge density wave transition is suggested in the underdoped cuprates, which points to a nesting induced charge density wave origin of the small Fermi surface pocket in the underdoped cuprates. For further evidence for a field induced charge density wave, theoretical modelling and additional quantum oscillation measurements of the magnetic torque at these ultra-high magnetic fields are underway.

References

[1] B. Vignolle et al., Nature 455, 952 (2008)
[2] Doiron-Leyraud, N. et al. Nature 447, 565-568 (2007)
[3] D. Andres et al. Phys. Rev. B 68, 201101 (R) 2003