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Title:

Thermal Hall effect in underdoped cuprates

Abstract:

In the quest to increase the critical temperature T_c of cuprate superconductors, it is essential to identify the factors that limit the strength of superconductivity. The upper critical field H_{c2} is a fundamental measure of that strength, yet there is no agreement on its magnitude and doping dependence in cuprate superconductors. Owing to its high sensitivity to vortex scattering, we show that the thermal conductivity κ_{xx} can be used to directly detect H_{c2} in the cuprates $YBa_2Cu_3O_y$, $YBa_2Cu_4O_8$ and $Tl_2Ba_2CuO_{6+\delta}$. Using resistivity measurements in high magnetic fields, we demonstrate that there is no vortex liquid phase at $T = 0$, allowing us to map out H_{c2} across the doping phase diagram [1]. It exhibits two peaks, located at dopings $p_1 = 0.08$ and $p_2 = 0.18$, where the Fermi surface of $YBa_2Cu_3O_y$ is known to undergo a transformation. Below $p2$, the condensation energy, obtained directly from H_{c2}, suffers a sudden 20-fold collapse. This reveals that phase competition – associated with Fermi-surface reconstruction and charge-density-wave order – is a key limiting factor in the superconductivity of cuprates.

In addition, we investigate the thermal Hall conductivity κ_{xy} in magnetic fields up to 35 T and show that the Wiedemann-Franz law is satisfied above H_{c2} in underdoped $YBa_2Cu_3O_y$. Thereby demonstrating the Fermi-Liquid normal state of underdoped cuprates, and moreover confirming no trace of long range superconductivity above H_{c2}. This also confirms that the Fermi surface is dominated by an electron pocket, as inferred from prior Hall [2] and Seebeck [3] data.

[1] G. Grissonnanche *et al.*, Nature Communications **5**, 1380 (2014).

[2] D. LeBoeuf *et al.*, Nature **450**, 533 (2007).

[3] F. Laliberté *et al.*, Nature Communications **2**, 432 (2011).