QUANTUM CRITICALITY AND HIGH FIELD PHASE DIAGRAM OF $HgBa_2Ca_3Cu_4O_x$

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Competing orders with superconductivity have been proposed[1] to explain several properties of high-T_c superconducting cuprates such as the pseudo-gap and the abnormal pairing symmetry. These competing orders can result in an unusual excess of low energy excitations which cause quantum fluctuations in the cuprate, altering the vortex dynamics[2,3]. The magnitude of the fluctuations could also indicate the cuprate is in the vicinity of a quantum critical point. To investigate this conjecture and the nature of the possible competing order, we have chosen to study the optimally holed-doped $HgBa_2Ca_3Cu_4O_x$ (T_c= 125 K) system, synthesized by the group of Prof. S.-I. Lee at the Pohang University of Science and Technology in Pohang, South Korea. This cuprate shows the smallest ab-plane irreversibility field (H_{irr}) versus the paramagnetic field (H_p) ratio when low field data is extrapolated to 0K among several other cuprates (See Figure 1a), suggesting proximity to a quantum critical point. Further probing of the irreversibility over critical field ratio at lower temperatures (and therefore higher fields) is necessary to validate the extrapolation. Low temperature vortex behavior is particularly important since thermal fluctuations are suppressed and the quantum fluctuations are more apparent. Preliminary tests of such measurements were conducted at the National High Magnetic Field Lab in Tallahassee.

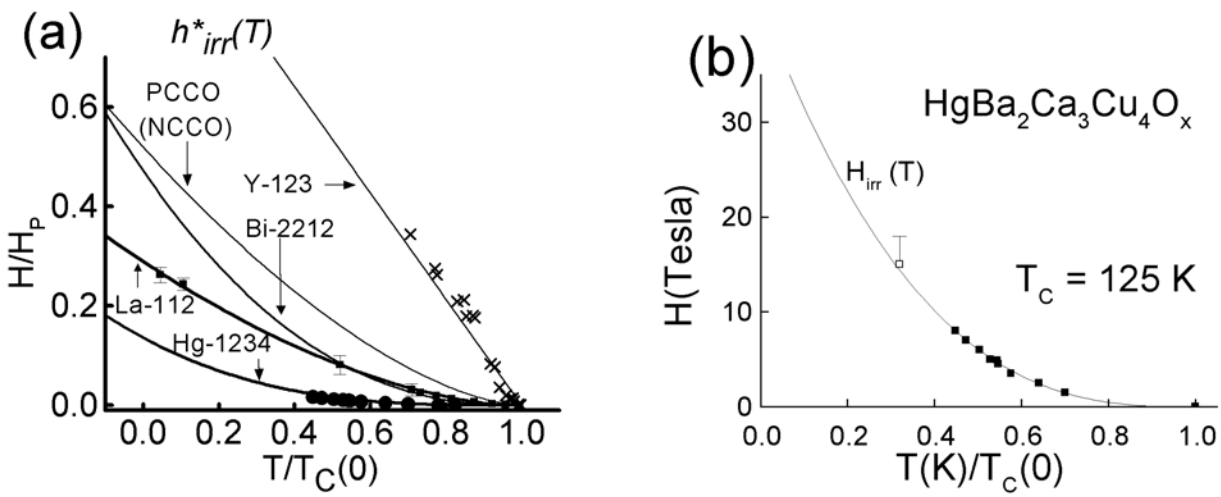

Fig 1. a) A comparison of the ab-plane irreversibility field $h_{irr}^*(T) = H_{irr}/H_p(T = 0K)$ for various cuprates[2,3], where H_p is the paramagnetic field. b) Irreversibility field data for $HgBa_2Ca_3Cu_4O_x$ including low field data taken at Caltech (closed squares) and preliminary high field data from the NHMFL (open square).

Magnetization measurements were conducted in a 33T resistive magnet using cantilever magnetometry. Measurements centered and off-centered on the magnet were required to eliminate the torque component of the signal due to the isotropic nature of our polycrystalline sample. The resulting datum does agree well with the low field extrapolation of the irreversibility line (See Figure 1b), further confirming the fluctuating nature down to 40 K. Additional data at higher fields and lower temperatures using cantilever magnetometry and third-harmonic susceptibility will be acquired in the future to verify the low temperature vortex dynamics of $HgBa_2Ca_3Cu_4O_x$ and other cuprates.

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References

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[2] N.-C. Yeh et al., to appear in Int. J. Mod. Phys. [cond-mat/0408100]
[3] N.-C. Yeh et al., to appear in Chinese J. Phys. [cond-mat/0408105]