Fast vortices in the Cuprates? A vortex plasma model analysis of the THz conductivity and diamagnetism in $La_{2-x}Sr_xCuO_4$

L. S. Bilbro[1], R. Valdés Aguilar[1], G. Logvenov[2], O. Pelleg[2], I. Bozovic[2] and N. P. Armitage[1*]

[1]The Institute for Quantum Matter, Department of Physics and Astronomy, The Johns Hopkins University, Baltimore, Maryland 21218, USA
[2]Brookhaven National Laboratory, Upton, New York 11973, USA.
*e-mail: npa@pha.jhu.edu.

The nature of the underdoped pseudogap regime of the high-temperature copper oxide superconductors has been a matter of long-term debate. On quite general grounds, we expect that, owing to their low superfluid densities and short correlation lengths, superconducting fluctuations will be significant for transport and thermodynamic properties in this part of the phase diagram. Although there is ample experimental evidence for such correlations, there has been disagreement about how high in temperature they may persist, their role in the phenomenology of the pseudogap and their significance for understanding high-temperature superconductivity. Here we use THz time-domain spectroscopy to probe the temporal fluctuations of superconductivity above the critical temperature (T_c) in $La_{2-x}Sr_xCuO_4$ (LSCO) thin films over a doping range that spans almost the entire superconducting dome (x=0.09–0.25). Signatures of the fluctuations persist in the conductivity in a comparatively narrow temperature range, at most 16 K above T_c. We compare our results with measurements of diamagnetism in a similarly doped crystals of LSCO and show through a vortex-plasma model that if the fluctuation diamagnetism solely originates in vortices, then they must necessarily exhibit an anomalously large vortex diffusion constant, which is more than two orders of magnitude larger than the Bardeen-Stephen estimate. This points to either the extremely unusual properties of vortices in the under-doped d-wave cuprates or a contribution to the diamagnetic response that is not superconducting in origin.

Published in:

L. S. Bilbro, R. Valdés Aguilar, G. Logvenov, O. Pelleg, I. Bozovic, N. P. Armitage, ``Temporal correlations of superconductivity above the transition temperature in $La_{2-x}Sr_xCuO_4$ probed by terahertz spectroscopy", Nature Physics 7, 298–302 (2011).

L. S. Bilbro, R. Valdés Aguilar, G. Logvenov, O. Pelleg, I. Bozovic, N. P. Armitage, ``Fast vortices in the Cuprates? A vortex plasma model analysis of the THz conductivity and diamagnetism in $La_{2-x}Sr_xCuO_4$, To be published in Phys. Rev. Lett. (2011).