Chapter 5
Conclusions

We demonstrated that the Stiffnessometer can measure penetration depth two orders of magnitude longer, or stiffness four orders of magnitude smaller, than ever before. This allows us to perform measurements closer to T_c and explore the nature of the superconducting phase transition, or determine the stiffness at low T in cases where it is naturally very weak. The Stiffnessometer also allows measurements of very small critical current or long coherence lengths. The measurements are done in zero magnetic field with no leads, thus avoiding demagnetization, vortices, and out-of-equilibrium issues.

Using this new magnetic-field-free superconducting stiffness technique, we shed new light on the SC phase transition in LSCO $x = 1/8$. In this compound, there is a temperature interval of 0.7 K where SC current can flow in the CuO_2 planes but not between them. That is, in this temperature range, the in-plane stiffness if finite while the interplane stiffness is zero. When stiffness develops in both directions, the ratio of penetration depths obeys $\lambda_c/\lambda_{ab} \geq 10$.

Thus, studying superconducting properties with the stiffnessometer leads to new results. The most intruiguing one is two stiffness transition temperatures in the same sample.

Moreover, studying the relationship between spin and charge degrees of freedom in extrem underdoped LSCO, we found the bottom part of an hourglass dispersion inside the AF phase. The hourglass does not start from zero energy, but has a soft gap from the static SDW order. A CDW order seems to be absent in our sample. Upon cooling the system, a nodal gap in electronic excitations opens just when the strongest spin excitations start to diminish. It is therefore sufficient for the SDW fluctuations to slow down without completely freezing out in order to modify the band structure.

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