DOCTORATE THESIS

Fluctuating superconductivity and pair-density wave order in the cuprate superconductors

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High-temperature superconductors are some of nature's most enigmatic materials. Besides carrying a supercurrent, these materials manifest a range of electronic and structural orders. A state of modulated superconductivity, called a pair-density wave (PDW), has been suggested to occur in copper-based (cuprate) high-temperature superconductors, with the possibility of explaining these various orders, and perhaps even superconductivity itself. This thesis is based upon four appended papers and concerns the nature of the PDW state and the cuprate superconductors.

In the first two papers, we consider a so-called pair-hopping interaction that can stabilize a (mean-field) PDW state. In the first paper, we use this interaction to study the supercurrent carried by a PDW state, which, due to it being a multiple-component order, can lead to phase-separation and additional symmetry breaking. In the second paper, we study the competition between a PDW state and an ordinary uniform superconducting state in the context of a BCS-BEC crossover. We find a suppressed superfluid stiffness in the vicinity of a PDW instability, with implications on the nature of the underdoped cuprates.

The third paper includes an experimental study on thin films of $La_{2-x}Sr_xCuO_4$, which above T_c develops a highly anisotropic resistive response, especially pronounced for underdoped samples, pointing towards an exotic pseudogap phase in the underdoped cuprates with quasi-1D phase superfluid stiffness. We interpret these results in terms of nematic order manifested in the superconducting fluctuations. In the last paper of this thesis, we consider a scenario where the cuprate pseudogap phase consists of a thermally disorder PDW state with vestigial order. We show that a vestigial PDW nematic order coexisting with a uniform superconducting order yields an anisotropic superconductor on a form consistent with the fluctuations seen in $La_{2-x}Sr_xCuO_4$.

Finally, in addition to providing background for the appended papers, this thesis contains an introduction to the general phenomenology of the cuprate superconductors.

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