ULTRA-LOW TEMPERATURE AND HIGH MAGNETIC FIELD TUNNELING MEASUREMENTS IN YBCO SUPERCONDUCTOR

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Introduction

The mechanism responsible for high temperature superconductivity is considered to be one of the most investigated and difficult contemporary condensed matter physics issues. Many experimental results support evidence for a *d*-wave order-parameter symmetry [1] having nodes at 45^0 from the main principle axes. Theoretical works by Gor'kov-Schrieffer [2] and by Anderson [3] have pointed out that when a magnetic field is applied perpendicular to the c-axis, Landau-states could be probed in the vicinity of the nodes. The first Landau-state is in fact identical to the additional id_{xy} order-parameter symmetry as proposed by Laughlin [4] using a phenomenological free-energy argument. This is due to the id_{xy} symmetry, which breaks the time-reversal symmetry, thus including circulating currents on opposite sample faces, which give rise to a magnetic moment opposite to the magnetic field. However, Meissner screening currents Doppler shift these states, hence making its observation problematic [5]. Using a special experimental configuration, we were able to minimize the Doppler-effect and to probe the first nodal Landau-states.

Experimental

We investigated the tunneling junctions spectra of *In/insulator/* $YBa_2Cu_3O_{7-x}$(YBCO) when a magnetic field is applied parallel to the film and perpendicular to the CuO_2 planes. The junction has been shown previously to exhibit reproducible and clear results during many thermal cycles and over time scales of weeks. We measured the tunneling conductance (dI/dV *vs.* V) of optimally doped (110) oriented YBCO films at the milli-Kelvin DC magnet facility at the NHMFL, Tallahassee Florida. Our findings show that we are sensitive to the first nodal Landau state [2,3] and give experimental evidence for a phase transition in the order parameter symmetry at low temperature and high magnetic fields [4].

Results and Discussion

Using a special sample and field configuration we are able to probe the density of states with little interference of the screening currents. By measuring the tunneling conductance of the zero bias region at ultra-low temperature we could distinguish between the Doppler-shift of the zero bias conductance peak and the Landau nodal-states. The first is expected to produce a V-shape conductance [6], while for the latter a U-shape one is expected. As shown in Fig. 1, a U-shaped conductance is observed at zero bias. In addition, we followed the low temperature dependence of the spectral peaks at different low temperatures and magnetic fields and compared our results to the theoretical predications for a first order phase-transition [4] and a square root spectral peak behavior [2-4].

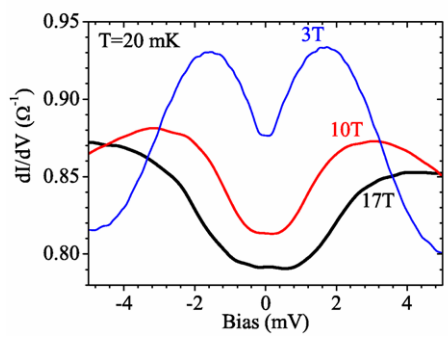

Fig.1: Tunneling conductance in high magnetic fields and at 20mK. Notice the U-shape conductace at zero bias.

Conclusions

Ultra-low temperature tunneling experiments support experimental evidence for the theoretical prediction of nodal Landau states in a *d*-wave superconductor [2-4]. Moreover, we find clear indication for a order-parameter symmetry phase transition, from a *d*-wave at high temperature to $d+id_{xy}$ at low temperature. This happens when a magnetic field is applied perpendicular to the CuO_2 planes, as predicted by Laughlin [4].

References

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