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Cyclotron resonance and effective mass renormalizations in Sr_2RuO_4

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Abstract

Using a microwave cavity perturbation technique, we have succeeded in observing cyclotron resonances in the layered Perovskite superconductor Sr_2RuO_4. Three cyclotron masses are deduced, corresponding to $m_{c\gamma} = 9.7m_e$, $m_{c\beta} = 5.8m_e$ and $m_{c\alpha} = 4.3\,m_e$. A comparison between these values and the effective masses deduced from other techniques provides us with a unique means of gauging the role of Coulomb correlations in the title compound.

Keywords: Correlated electron system; Cyclotron resonance; Sr_2RuO_4

1. Introduction

The superconducting state in the layered perovskite, Sr_2RuO_4, is a strong candidate for p-wave pairing [1]. In spite of the structural similarities between this compound and the high-T_c superconductors (HTS), striking differences set them apart. For example: although strong electron correlations feature in both, the normal state in Sr_2RuO_4 conforms to the behavior expected of a 2D Fermi-liquid; meanwhile, the itinerant ferromagnetism (FM) in related ruthenates contrasts the antiferromagnetism found in close proximity to superconductivity in the HTS phase diagram.

The availability of high-quality single crystals of Sr_2RuO_4 has enabled extremely precise experiments, including the observation of magnetic quantum oscillations [2]. These studies have, in turn, enabled rigorous comparisons with theory. We report the observation of cyclotron resonance (CR) in the normal state of Sr_2RuO_4. By comparing CR masses with those deduced from de Haas–van Alphen (dHvA) measurements, we are able to gauge the strength of electron–electron interactions (EEIs) in the title compound, and to further test the applicability of Fermi liquid theory, which predicts that CR and dHvA measurements should differ in their sensitivity to EEIs [3].

2. Experimental results and discussion

We utilize a high sensitivity cavity perturbation technique [4] to probe the complex electrodynamic response of a single Sr_2RuO_4 crystal in the frequency range from 40 to 80 GHz, and in fields up to 33 T. The crystal was grown by a floating zone technique and has a T_c (mid point) of 1.44 K. The sample was situated in an AC H-field antinode within the cavity, thereby exciting both in-plane and inter-layer currents. Based on the conductivity anisotropy in Sr_2RuO_4, we expect similar contributions to the dissipation from both conductivity components ($\sigma_\perp$ and $\sigma_{||}$). From studies of layered organic conductors [4,5], it is known that resonances in both $\sigma_\perp$ and $\sigma_{||}$ can occur – the former due to Fermi surface (FS) warping – at the fundamental CR frequency, plus harmonics.

On cooling below 6 K, resonances ($\sim$Lorentzian peaks) are indeed observed in the field-dependent

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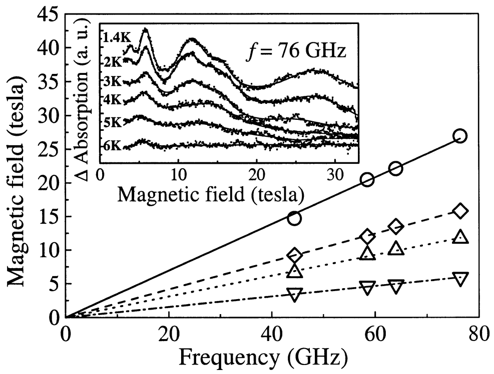

Fig. 1. Plot of the main CR positions versus frequency (see text for explanation of symbols). The inset shows the temperature-dependent cavity absorption (offset) versus magnetic field (the solid lines are lorentzian fits).

absorption within the cavity, as illustrated in the inset to Fig. 1, which shows data obtained at 76 GHz. The main CR positions are plotted versus frequency in the main part of Fig. 1. All of the data fall on straight lines passing through the origin, as expected for CR. We attribute each CR series to one of the established FSs: ○–γ, ◇–β, △–α first harmonic, and ▽–α second harmonic [6]. From the slopes of the data in Fig. 1, we assign CR masses $m_{c\gamma} = 9.7m_e$, $m_{c\beta} = 5.8m_e$ and $m_{c\alpha} = 4.3m_e$. With the exception of the α pocket, these values are significantly lower than the dHvA masses ($m^*_\gamma = 14.6m_e$, $m^*_\beta = 7.5m_e$ and $m^*_\alpha = 3.4m_e$ [2]).

The differences between the masses obtained by the two techniques (CR and dHvA) is not unexpected, since they effectively measure different dynamical averages [3]. The dHvA mass (m^*) includes enhancements due to EEIs which a CR measurement is insensitive to. It is interesting to note that the ratio of the mass enhancements for the γ and β pockets, $[(m^*_\gamma/m_{c\gamma}) - 1]/[(m^*_\beta/m_{c\beta}) - 1] = 1.73$, is similar to the ratio of the dHvA masses, i.e. $m^*_\gamma/m^*_\beta = 1.95$. This provides convincing evidence that the mass enhancements scale with the density of states at the Fermi energy ($\propto m^*$), as expected for a strongly interacting translationally invariant Fermi liquid [3]. Agreement for the α pocket is not so good. This may be attributable to the broken translational invariance due to the lattice [7].

3. Summary

We have observed CR in the Perovskite superconductor Sr_2RuO_4. We deduce CR masses for the α, β and γ FSs of $m_{c\alpha} = 4.3m_e$, $m_{c\beta} = 5.8m_e$ and $m_{c\gamma} = 9.7m_e$. Differences between these values and those deduced from dHvA studies are attributable to EEIs.

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