Electronic Grüneisen Parameter in $PuRhIn_5$

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Introduction

The electronic Grüneisen parameter is the ratio of the volume expansion of a material to its specific heat. This parameter is expected to diverge at a quantum critical point [1]. Hints of quantum criticality were observed in the heavy fermion superconductor $PuRhIn_5$. To elucidate the nature of the quantum critical point and to probe the superconductivity, optical dilatometry provides a unique way to measure the thermal expansion while the $PuRhIn_5$ sample is encapsulated for the experiments.

Experimental

Optical fibers containing two sets of diffraction gratings were used. Samples are glued to one of the gratings and one is left free as a reference. The frequency of the light reflected back to a spectrometer depends upon the period of the grating. Thermal changes in the length of the sample strain the grating and change the diffracted frequency. By analyzing this difference in frequency between the two gratings, a resolution of 10^-6 m can be obtained. The fibers are epoxied into brass cans containing the sample and local thermometry, in this way isolating the radioactivity from the rest of the system. The samples were run in an 18T DC oxford magnet at ^{3}He temperatures.

Results and Discussion

The dilatometry, along with specific heat data, was used to calculate the electronic Grüneisen parameter. Figure 1 shows the superconducting transition in both axies of the crystal. The superconducting transition is seen as a break in the slope near 1.6 K. In figure 2 the change in sign of the Grüneisen parameter Γ can be seen from the application of a 10 Tesla magnet field. These data suggest that pure $PuRhIn_5$ is located close to a quantum critical point. Furthermore, the 1/T – dependence of Γ (left inset of Fig. 2e) suggests that the unusual properties of $PuRhIn_5$ arise from proximity to a three-dimensional antiferromagnetic QCP.

Conclusions

The fiber optic method to determine sample dilatometry was successful in resolving the superconducting transition as well as the Grüneisen parameter when combined with specific heat data. The change of the Grüneisen parameter with applied magnet field is consistent with proximity to a quantum critical point. The nature of this change in sign is being compared to theoretical predictions to provide information about the type and/or dimensionality of the QCP.

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References

[1] Gegenwart, P., et al., J Low Temp Phys, **161**, 117-133 (2010).

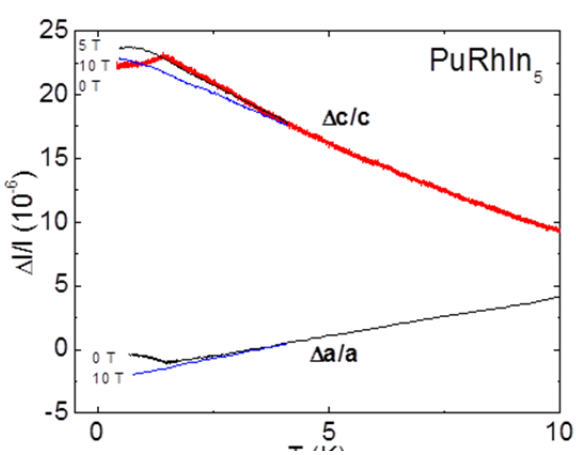

Fig.1 a- and c-axis thermal expansion data of $PuRhIn_5$ showing the superconducting transition as a break in slope near 1.6 K as well as its suppression in 5 and 10 tesla fields.

Fig. 2 c) Electronic specific heat C_{el}/T of $PuRhIn_5$ in 0 and 8 T. d) Volume thermal expansion β obtained from polynomial fits to the a-axis and c-axis thermal expansion data in Fig. 1, plotted as β/T. The Grüneisen parameter at 0 T and 10 T. The change in sign due to magnetic field is clear, indicating proximity to a quantum critical point.