Probing Superconductivity and Elastic Constants of $PuCoGa_5$ with Resonant Ultrasound Spectroscopy

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Introduction

The superconductor PuCoGa5 is unique among the 115 compounds, having a superconducting transition temperature of 18.5 K-far greater than other 5f electron superconductors[1]. We perform resonant ultrasound spectroscopy (RUS) on a single crystal of PuCoGa5, and obtain all six elastic constants as a function of temperature, as well as thermodynamic information about the superconducting transition.

Experimental

RUS measures the mechanical resonances of a crystal by applying AC strain at one point on a crystal and measuring the response at another point. Because plutonium is radioactive, a unique probe was built that could easily be loaded with the sample in a glove-box. The probe was then inserted into a flow cryostat, also located in the glove box, for temperature control down to 10K. This apparatus was designed and built, and the measurements were made, at the NHMFL in Los Alamos.

Results and Discussion

The resonant frequencies follow the expected form down to 35K where they begin to soften (**Figure 1**), and then drop discontinuously at Tc. The origin of the softening may hold the key to the superconducting pairing mechanism, and further analysis is needed to sort out the symmetry of this behavior.

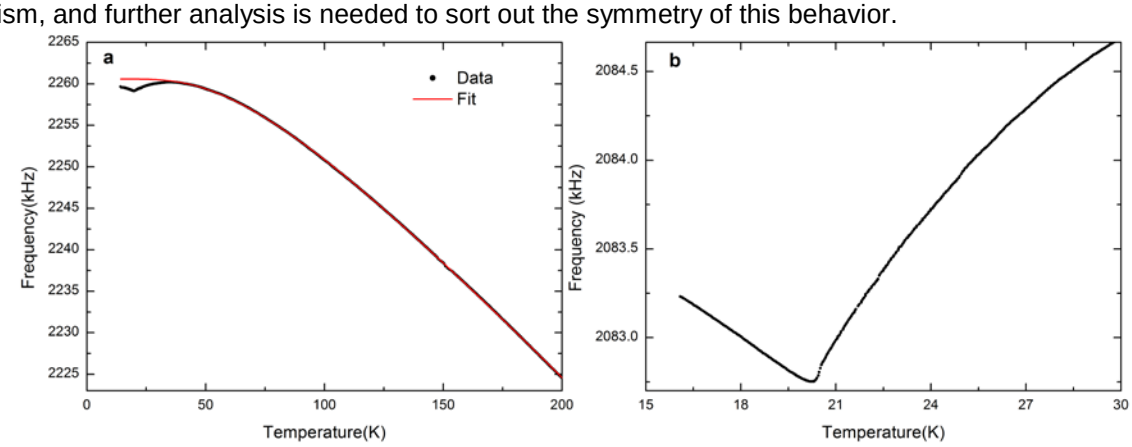

Figure 1: a. A resonant frequency from 200 to 15 K. The fit is to an Einstein-oscillator model[2], and the data shows the expected behavior down to 15 K above Tc, where the elastic constants begin to soften. **b.** The temperature dependence of a resonance near Tc. Note the sharp drop just before Tc: the magnitude of this drop is related to the size of the superconducting gap.

The elastic constants were extracted at room temperature, and found to be c11 = 1.68 GPa, c33 = 1.20 GPa, c23 = 0.29 GPa, c12 = 0.49 GPa, c44 = 0.59 GPa, and c66 = 0.60 GPa.

Conclusions

$PuCoGa_5$ shows a conventional jump in its resonance frequencies across Tc, and shows a more unconventional softening of its elastic constants 15K above the transition. Future measurements in a magnetic field should provide critical information to determining whether this softening is related to superconductivity.

Acknowledgements

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References

[1] Sarrao, J.L., *et al*., Nature, **420**, 297-299 (2002).
[2] Migliori, A., *et al.,* J. of App. Phys, **104**, 053512-(1-4) (2008).