# PROBING THE SUPERCONDUCTING STATE IN $PuCoGa_5$

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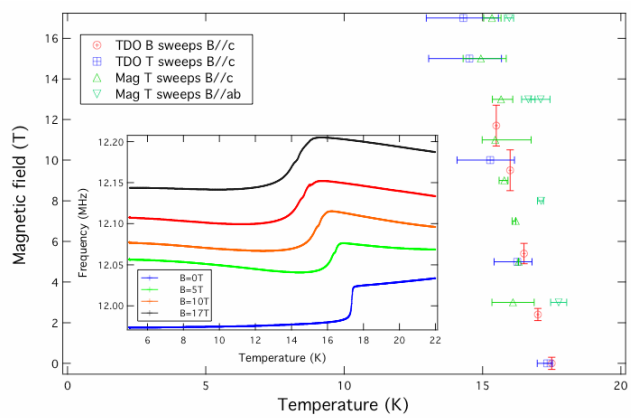
For a material that consists of heavy elements and in which *f*-electrons are expected to play a significant role, $PuCoGa_5$ has a unusually high transition temperature $T_c$ of 18.5 K, and an upper critical field expected to exceed 60 T [1]. Because $H_{c2}$ is so large, it cannot easily be measured. We have nevertheless made some preliminary measurements in a superconducting magnet at NHMFL, LANL.

Two measurement techniques were used, one in which the sample was placed on a torque magnetometer and another in which the sample is located in a small coil which is the inductive element in a resonant tank circuit driven by a tunnel diode oscillator (TDO). The magnetometer measurement requires that the sample be cooled into the superconducting state in zero magnetic field. A finite field is then applied causing flux to be trapped in the sample, as the temperature is raised above $T_c$ the flux ceases to be trapped and there is an abrupt change in the torque. The TDO method is sensitive to changes resonant frequency of the circuit. The exclusion of flux from the sample, and hence also the measurement coil, causes the inductance of the circuit to change and the resonant frequency to shift. A significant change in frequency is observed when the sample moves from the skin depth to penetration depth regime as it passes through the superconducting transition.




The figure above shows the superconducting transition as a function of magnetic field and temperature. The data includes $H_{c2}$(T) measured using the TDO method and $T_c(\mu_0 H)$ measured using both the TDO method (see inset) and torque magnetometry. The magnetometer measurements were performed on two samples, one with the c-direction parallel to the applied field, and another with the field in the ab-planes. That all the data lie on a common curve shows not only that there is good agreement between the two measurement techniques, but also that $H_{c2}$ appears to be isotropic despite the tetragonal symmetry of the crystal structure. Extrapolation of the data using a mean-field model suggests that $H_{c2}(T=0)$ is in excess of 60 T.

Through simple geometrical relations [2] it can be shown that for a TDO measurement $\delta - \lambda = R^2 \Delta f / r_s f_0$, where $\delta - \lambda$ is the difference between the skin and penetration depths that leads to a change in resonant frequency $\Delta f$, $R$ is the effective radius of the coil, $r_s$ is the effective sample radius and $f_0$ is the unperturbed resonant frequency. We find that for $PuCoGa_5$ $\delta - \lambda \approx 7\mu m$.

## References

[1] Sarrao J. L., *et al*., Nature **420**, 297 (2002).
[2] Mielke C. H., *et al*., J. Phys. C.M., **13**, 8325 (2001).