Tracking the Conduction Electron Spin Resonance Signal in the Heavy Fermion Metal YbRh$_2$Si$_2$

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**Introduction**

Previous low temperature magnetization studies of YbRh$_2$Si$_2$ indicate that for magnetic fields applied perpendicular to the c-axis there is a field-induced transition from an itinerant to localized 4$f$ state at 9.9 T [1]. Interestingly, low frequency (9.4 GHz and 34.1 GHz) Electron Spin Resonance (ESR) measurements [2,3] indicate that an ESR spectra characteristic of the Kondo ion Yb$^{3+}$ is observable well below the Kondo temperature, $T_K \approx 25$ K. This is unusual in that the observed EPR linewidth, $\Delta B$, is about 3 orders of magnitude smaller than that inferred from thermodynamic measurements, which predict a linewidth due to spin fluctuations of the order of the Kondo temperature $k_B T_K / g\mu_B \approx 10$ T [2]. These studies [1,2,3] report a strong magnetocrystalline anisotropy evident in both the susceptibility, about a factor of 20 larger for the field applied in the basal plane than along the c-axis, and the spectroscopic g-factor, $g_\perp = 3.5$ for the easy plane vs $g_\parallel = 0.17$ for the c-axis [1,2].

The asymmetric ‘Dysonian’ lineshape of the ESR absorption is typical of the dispersive contributions from Conduction Electron Spin Resonance [4]. For magnetic fields applied in the easy plane the field dependence of magnetization undergoes reduction in slope at the 4$f$ itinerant to localized transition. This ‘kink’ occurs at a magnetization of 1$\mu_B$/Yb. Tracking the CESR signal as a function of frequency and magnetic field thus provides a unique opportunity to study the dynamics of the localization-delocalization transition. This is expected to be evident in the intensity, reflecting the change in the susceptibility; the line shape, reflecting the change in screening; and the g-factor reflecting the change in the correlations in an analogous manner to ‘Heavy Fermion’ mass renormalization.

**Experimental**

To date, we have measured the CESR spectrum of YbRh$_2$Si$_2$ in the temperature range between 4 K and 0.6 K, and at frequencies between 11 GHz and 120 GHz. This has enabled measurement of the CESR absorption at magnetic fields up to 2.5 T $\approx \frac{1}{4}$ that of the transition for the field perpendicular to the c-axis. All the measurements employed high Q-factor (Q $> 5000$) resonators to provide the necessary sensitivity; a closed cylindrical resonator at the lower frequencies, and an open etalon resonator at frequencies above 60 GHz. Both resonators were measured in transmission using a millimeter-wave vector network analyzer. Standard $^3$He and $^4$He cryogenic techniques were used to control the temperature and the magnetic field applied using a superconducting solenoid. Refinements to the microwave electronics, resonators and waveguide coupling are underway to extend these measurements to the $\approx 500$ GHz frequency / 10 T magnetic field range.

**Results and Discussion**

In the frequency range between 11 GHz and 120 GHz the magnetic field of the absorption has a linear dependence upon frequency yielding a g-factor of 3.48. Within experimental error the g-factor is independent of temperature between 4 K and 0.6 K. Further experimental refinement is necessary to draw any conclusions about possible changes in linewidth or asymmetry.

**Conclusions**

These preliminary investigations indicate the feasibility of tracking the CESR spectrum to higher frequencies and hence fields, with further experiments planned in magnetic fields exceeding the 4$f$ itinerant to localized transition.

**References**