NMR Investigation of the High-Field Phase in YbInCu$_4$

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Introduction

YbInCu$_4$ is one of the few heavy fermion (HF) metals that show an intriguing first-order valence transition, which can be controlled by applying pressure or magnetic fields. Recent high pressure experiments have shown that a pressure-induced ferromagnetism occurs in YbInCu$_4$ near the critical pressure (~25 kbar) and a quantum critical point (QCP) for the valence transition temperature $T_V = 0$ is ruled out.$^{(1)}$ Whether a similar magnetism or a QCP can be induced by a high magnetic field near the critical field (~34T) is an interesting question. We therefore have conducted the high-field NMR experiments in YbInCu$_4$ in order to explore the nature of the critical phenomena in this first-order valence transition.

Experimental

YbInCu$_4$ has two good NMR nuclei, $^{63}$Cu and $^{115}$In. Since our sample is a polycrystal, we have chosen $^{115}$In as the primary probe nucleus because it gives a single $^{115}$In NMR line without any quadrupolar satellite broadening.$^{(2)}$ We have measured the $^{115}$In NMR spectra and spin-lattice relaxation rate $1/T_1$ at various magnetic fields up to 35 tesla and down to 2 K. All the experiments were conducted at Cell 7 31.5 T and Cell 8 35 T magnets.

Results and Discussion

Figure 1 shows the plot of the NMR linewidth and peak frequency as a function of magnetic field at 4 K in the Fermi liquid (FL) state. The linewidth starts to increase dramatically above 30 tesla, which suggests that the electronic state becomes very inhomogeneous near $H_c$. Above 33 tesla, the Fermi liquid undergoes a paramagnetic (PM) spin liquid. As for the spectra from the PM state, we do not find any signature of field-induced magnetism in our present temperature window because neither line broadening nor change of the Knight shift are observed at 2 K when approaching $H_c$. Figure 2 gives the temperature dependence of $1/T_1$ at various fields. A field enhancement of $1/T_1$ is observed for both the FL and PM states. This is different from the high-pressure experiments where the $1/T_1$ in the FL and PM states are insensitive to the pressure.$^{(3)}$ This suggests that the mechanisms for the magnetic field and pressure on tuning the valence transition in YbInCu$_4$ are different. In the former, the Zeeman effect is involved in the competition between the Kondo and RKKY interactions, whereas in the latter, the inter- and intra-site coupling is directly controlled by the pressure effect.

Conclusions

Our results show that the FL state in YbInCu$_4$ is strongly perturbed by magnetic fields and become inhomogeneous as approaching the critical field. No signature of the field-induced magnetism is observed for $H$ up to 35 tesla and $T$ down to 2K.

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References