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Field-induced phase transition in the periodic Anderson model

Takuma. Ohashi, Akihisa Koga, Sei-ichiro Suga, and Norio Kawakami

Department of Applied Physics, Osaka University, Suita, Osaka 565-0871

Heavy-fermion systems with various ground states have attracted continued interest. It is known that some f-electron compounds are in the proximity of the antiferromagnetic (AF) instability, which results from the competition between the Kondo effects and RKKY interaction, or other instabilities to the charge ordering, superconductivity, etc. In such systems, external fields may possibly trigger the phase transition, realizing quantum critical phenomena. Some experiments on the Kondo insulator in magnetic fields have suggested a phase transition from the insulator to a correlated metal. More recently, a field-induced orbital order has been found in Pr-based filled skutterudite compounds.

We investigate here the field-induced phase transition in the periodic Anderson model at half filling. By combining the dynamical mean field theory with quantum Monte Carlo simulations, we clarify how the introduction of the field suppresses the formation of the Kondo singlet, thus driving the system to the AF ordered phase at low temperatures. Moreover, we point out that novel heavy-fermion states emerge in the paramagnetic phase just above the AF transition temperature. As shown in Fig. 1, at weak fields, the system is in the Kondo insulating phase characterized by a quasi-particle gap, which is smoothly connected to the high-temperature paramagnetic phase. Beyond a certain critical field, there is a second-order phase transition from the paramagnetic phase to the low-temperature AF phase with the decrease of temperature. The AF phase possesses a long-range order in the xy plane, namely, the transverse AF order. It is seen that the transition temperature T_c takes a maximum, when the Zeeman energy is nearly equal to the spin gap $B \sim 2\Delta_0$. An important point to be noticed is that around this field heavy-fermion behavior shows up in the paramagnetic phase just above T_c. To see this more clearly, we show the one-particle spectral function for f electrons at $T = 0.23\Delta_0$ in Fig. 2. At $B = 0$, the well-defined insulating gap exists. As the field is increased, the peak structure existing beside the gap is slightly shifted in the presence of the Zeeman splitting. For $B/\Delta_0 \sim 2$, the spectral gap almost disappears. A remarkable point is that f electrons get another sharp peak around $\omega = 0$, which implies that strong Kondo correlations still persist even in such fields, driving the system to a heavy-fermion metallic phase immediately after the quasi-particle gap is closed. If the field is further increased, the sharp quasi-particle peak disappears, and the system gradually changes to an ordinary paramagnetic metal with the spin polarization. Details of the phase diagram will be discussed at the workshop.

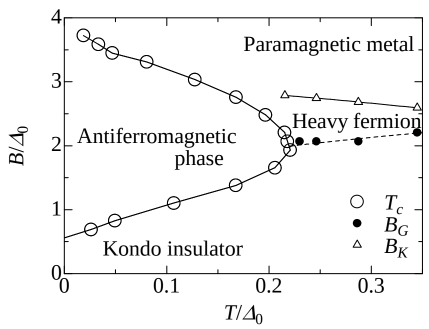

Figure 1: Phase diagram of the PAM.

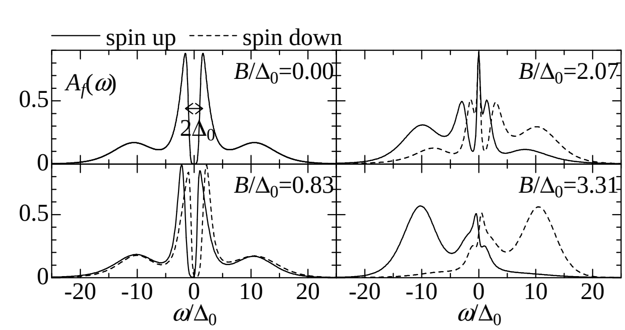

Figure 2: Spectral functions of f electrons.