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Doping-dependence of the electronic state in the periodic Anderson-Holstein model

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We investigate the electronic state in the periodic Anderson−Holstein model, which includes both the electron−phonon interaction g and the electron−electron interaction U, by using the dynamical mean−field theory in conjunction with the exact diagonalization method. The model Hamiltonian is given by

$$\begin{aligned} H &= \sum_{\mathbf{k}\sigma} \epsilon_k c^\dagger_{k\sigma} c_{k\sigma} + \epsilon_f \sum_{i\sigma} f^\dagger_{i\sigma} f_{i\sigma} + V \sum_{k\sigma} \left(f^\dagger_{k\sigma} c_{k\sigma} + h.c. \right) \\ &\quad + U \sum_i n_{fi\uparrow} n_{fi\downarrow} + \omega_0 \sum_i b^\dagger_i b_i + g \sum_i \left(b^\dagger_i + b_i \right) \left(\sum_\sigma n_{fi\sigma} - 1 \right), \end{aligned}$$

where $c^\dagger_{i\sigma}$, $f^\dagger_{i\sigma}$ and $b^\dagger_i$ are creation operators for a conduction electron, for a f-electron and for a phonon, respectively, and $n_{fi\sigma} = f^\dagger_{i\sigma} f_{i\sigma}$. The density of f-electrons couples with the Einstein phonons with frequency ω_0. In the previous work [1], we studied this model in the case of half filling ($n_f = n_c = 1$) and found that: (1) In the strong electron−phonon coupling regime $g \gtrsim g_c$, the system shows an anomalous heavy fermion behavior which is accompanied by a large lattice fluctuation and an extreme phonon softening. (2) A simple harmonic potential for ions for $g \lesssim g_c$ changes into an effective double−well potential for $g \gtrsim g_c$. (3) The pairing interaction between the conduction electrons has a maximum at $g \approx g_c$. In the present study, as a extension to the previous work, we discuss the electronic state in the model away from half filling. We find that the heavy fermion state with large effective mass due to the electron−phonon interaction is realized in the wide range of n_f (see Fig.1(a)), on the other hand, that due to the Coulomb interaction is realized in the narrow range of $n_f \approx 1$ (see Fig.1(b)).

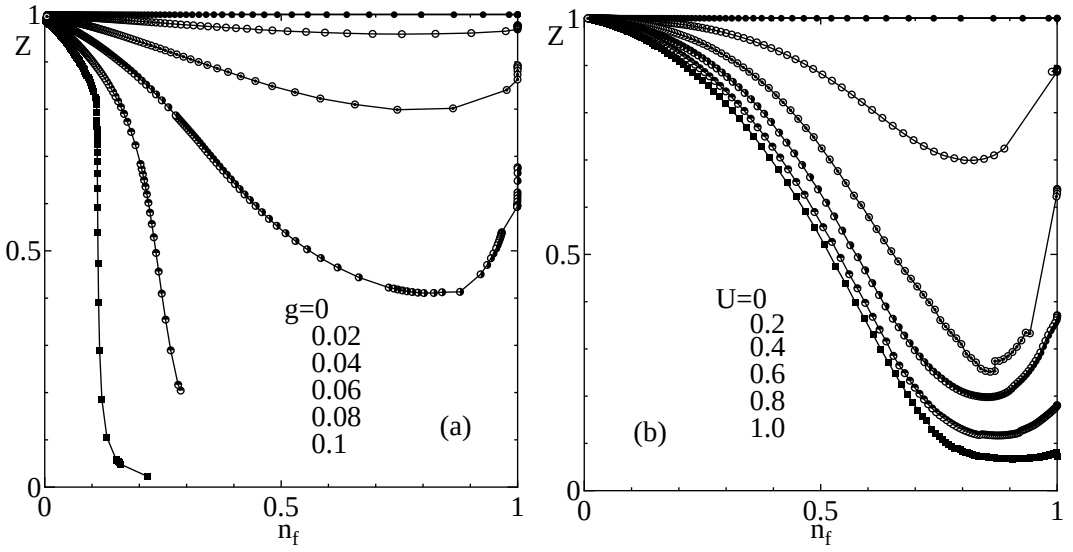

Figure 1: The quasiparticle weight Z as a function of f-electron number nf for various values of the electron-phonon interaction g (a) and for the Coulomb interaction U (b)

[1] K. Mitsumoto and Y Ōno, Physica C **426-431** (2005) 330.