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Cumulant Expansion in the Holstein model: Spectral Functions and Mobility

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Abstract. The cumulant expansion (CE) method presents an alternative to the usual Dyson equation approach for the calculation of spectral functions and quasiparticle properties of interacting quantum many-particle systems. We examine the range of validity of this method by implementing it in a system described by the simplest electron-phonon model Hamiltonian - the Holstein model [1]. For a benchmark, we use the dynamical mean-field theory (DMFT) [2] which gives, as we have recently shown [3], rather accurate spectral functions in the whole parameter space. The results are also compared to the one-shot and the self-consistent Migdal approximation. While CE is exact in both the weak-coupling and the atomic limit, we find that even in a regime of intermediate coupling in 1D, the CE resolves well both the quasiparticle and the first satellite peak of the spectral function. CE also gives promising results for high temperatures, but it is not exact in the limit $T \to \infty$, which is proved analytically by analyzing the spectral sum rules.

Charge mobility μ is also calculated, using the bubble approximation of the Kubo formalism. At high temperatures, we demonstrate that it assumes a power law, which is different in the limit of weak coupling $\mu \propto T^{-2}$, and in the case of somewhat stronger coupling $\mu \propto T^{-3/2}$.

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