Quantum phase transitions and intermediate magnetization plateau of 1D Heisenberg spin systems

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According to the extended Lieb-Schultz-Mattis theorem, 1D periodic Heisenberg spin 1/2 systems with odd number of spins per unit cell have the gapless lowest energy excitation spectrum. This may leads to non analytical behavior of their ground state energy as a function of Peyerls distortions of the distances between neighbor unit cells (dimerization) and the appearance of spin-Peierls instability of the corresponding spin systems when they are coupled to three-dimensional phonons. The systems with even number of spin per unit cell usually have gapped energy spectrum and do not demonstrate spin-Peyerls instability.

We propose a special type of 1D spin systems with even number of spin per unit cells formed by weakly interacting segments of two different types. The first order of perturbation theory in the interaction between neighbor segments gives the gapless character of the lowest part of the energy spectrum. Using the density-matrix renormalization group method we studied numerically the dependence of spin-Peierls critical exponents for the ground-state energies of above systems on the value of the coupling between neighbor segments. Perturbative treatment also demonstrates the existence of gapped excitations which corresponds to the excitations inside the weakly interacting segments. This leads to the appearance of intermediate plateau in field dependence of magnetization at low temperatures. The stability of this plateau against the increase of coupling between segments and temperature is studied using the quantum Monte-Carlo method.

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