Critical temperatures of the model of hard-core bosons on a square lattice in the Bethe approximation

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We consider the inclusion of short-range correlations for a two-dimensional model of hard-core bosons[1] on a square lattice within the Bethe approximation for clusters of 2 and 4 sites. Hamiltonian of the model of hard-core bosons has the following form:

$$\mathcal{H} = -t \sum_{\langle i,j \rangle} \left(b_i^+ b_j + b_j^+ b_i \right) + V \sum_{\langle i,j \rangle} n_i n_j - \mu \sum_i n_i, \tag{1}$$

where b^+, (b) - hard-core boson creation (annihilation) operators, $n_i = b_i^+ b_i$ - operator of the number of hard-core bosons at a site, t and V - transfer integral and parameter of charge-charge correlations between nearest neighbors, μ - chemical potential required to take into account the condition of constant boson concentration.

We obtain explicit equations for the critical temperatures of charge and superfluid ordering for 2- and 4-site Bethe clusters and explore their solutions for various V/t ratios.

It is shown that the short-range correlations lead to the appearance of a critical concentration of bosons, limiting the region of existence of charge-ordered phase. For superfluid ordering, taking into account short-range correlations reduces the critical temperature to zero values at half filling.

The phase diagram of the model is constructed with allowance for phase separation, and it is shown that taking into account short-range correlations within the Bethe approximation quantitatively approximates the form of the phase diagram to the results of the quantum Monte Carlo[2].

References:

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[2] G. Schmid, S. Todo, M. Troyer, A. Dorneich, Phys. Rev. Lett. **88**, 167208 (2002).

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