Phase Structure of the t-J Model of Hard-Core Bosons in Three-Dimensions at Finite Temperatures

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In relation with the t-J model of strongly correlated electrons, it is interesting to study its bosonic counterpart, the bosonic t-J model. It has two versions, (i) the canonical bosons with anisotropic spin coupling, and (ii) the hard-core bosons with isotropic spin coupling. In the paper, we consider the version (ii) which describes a system of isotropic antiferromagnet with doped bosonic holes, and is closely related to systems of two-component bosons in an optical lattice. The bosonic "electron" operator $B_{x\sigma}$ at the site x with a two-component spin $\sigma(=1,2)$ is treated as a hard-core boson operator, and represented by a composite of two slave particles; a spinon described by a Schwinger boson (CP^1 boson) $z_{x\sigma}$ and a holon described by a hard-core-boson field ϕ_x as $B_{x\sigma} = \phi_x^\dagger z_{x\sigma}$. By Monte Carlo simulations we study its phase diagram in the density-temperature plane and the possible phenomena like appearance of antiferromagnetic long-range order, Bose-Einstein condensation, phase separation, etc. Obtained results show that the hard-core bosonic t-J model has a phase diagram that suggests some interesting implications for high-temperature superconducting materials, although the difference of statistics is still crucial.