Quantum crystal induced by interparticle repulsive interaction

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Superfluid behavior in solid ^{4}He has attracted the interest of both theoreticians and experimentalist. This counterintuitive behavior is observed only in solid ^{4}He, which has the large quantum effect. Path Integral Monte Carlo (finite temperature method) and Diffusion Monte Carlo (zero temperature method) calculations have shown that the perfect commensurate ^{4}He crystal has neither finite superfluid density nor condensation fraction. It may be premature to conclude that a perfect quantum crystal never exhibits superfluid behavior; the quantum fluctuations much stronger than those in ^{4}He may favor superfluid behavior even in a solid phase. We study the quantum crystal phase with much stronger quantum fluctuations, using the DMC method. The strength of the quantum effect can be parametrized by the so-called quantum parameter, the ratio of the zero point energy to the interparticle attractive interaction energy. Here, we consider boson systems where only interparticle repulsive interaction works; the quantum parameter may be considered to be infinity. It has been known that quantum hard spheres[1] crystallize at much lower density than classical hard spheres[2]. This result implies that the quantum effect can help crystallization of bose gas. In this work, we calculate the ground state energy of bosons interacting with hardcore-like potential and obtain the phase diagram describing the gas-solid phase transition.

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[2]B. J. Alder and T. E. Wainwright, J. Chem. Phys. **33**, 1439 (1960).