Role of nonlocal interaction in theory of a weakly non-ideal Bose gas with condensate

M.S. Bulakhov[a], A.S. Peletminskii[b], S.V. Peletminskii[b], Yu.V. Slyusarenko[a,b] and A.G. Sotnikov[b]

[a] *V.N. Karazin Kharkiv National University, 61022 Kharkiv, Ukraine*
[b] *Akhiezer Institute for Theoretical Physics, NSC KIPT, 61108 Kharkiv, Ukraine,*

In this work, we perform a consistent analysis of quadratic approximation of the Bogoliubov model [1] for a weakly interacting Bose gas with condensate employing different model potentials. The equilibrium properties of the system are described by two coupled equations [2]: the first equation provides a relation between the total number of particles and chemical potential and the second one represents the minimum condition for the grand thermodynamic potential. We demonstrate that the coupled equations have no solutions for contact (local) interaction potential, although they formally reproduce the well-known results for the chemical potential and condensate density. Therefore, we consider some nonlocal model interaction potentials with nontrivial dependencies of their Fourier transforms in momentum space [3]. In the regimes close to experimental realizations with ultracold atoms, the contribution of the terms originating from the quadratic part of the truncated Hamiltonian to the chemical potential can be of the same order of magnitude as from its c-number part. Therefore, the spectrum of single-particle excitations in the quadratic approximation acquires a gap. The issue of the gap is also discussed.

[1] N.N. Bogolyubov, J. Phys. USSR **11** 23 (1947).

[2] V.V. Tolmachev, *Theory of a Bose gas* (Moscow University Press, Moscow, 1969) [in Russian].

[3] M.S. Bulakhov, A.S. Peletminskii, S.V. Peletminskii, Yu.V. Slyusarenko and A.G. Sotnikov, J. Phys. B: At. Mol. Opt. Phys. **51** 205302 (2018).