Self-similarity of critical phenomena and their dependence on the boundary conditions and shape of trapping potential for BEC in various mesoscopic traps

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We theoretically show that the thermodynamic parameters of the mesoscopic Bose systems in the critical region of Bose-Einstein condensation depend on the fine features of a trapping potential such as the boundary conditions and cuts of the trap. We suggest particular trap configurations which could be used to demonstrate the predicted effect experimentally [1].

The described effect cannot be accounted for by the macroscopic theories which consider the thermodynamic limit and operate only with the density of states. Such models exclude the analysis of the critical region where the statistics and thermodynamics is largely determined by a relatively small number of the lowest occupied energy states. The point is that these states could be strongly modified by changing the boundary conditions or cutting the trapping potential.

We employ the analytical mesoscopic theory of critical phenomena developed recently for an ideal gas [2,3]. In particular, we present the exact results for the specific heat of an ideal gas. We analytically show how the λ-curve describing the specific heat evolves noticeably with relatively small changes in the trapping potential which do not affect the macroscopic density of states. We also point out that the situation remains qualitative the same even in the presence of a weak interaction.

For an experimental verification of the predicted effect, we suggest to study the ring traps in which the azimuthal boundary conditions can be switched over from the periodic to zero ones as well as the box traps cut by the "laser knife" in which a whole layer of states could be excluded by controlling the light intensity of the cutting laser. In such traps, the predicted effect of variation in the thermodynamic parameters (like the heat capacity) and their λ-structure are well pronounced even for sufficiently large dimensions of a system and large, $10^3 - 10^5$, number of atoms.

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