COLLECTIVE ELEMENTARY EXCITATIONS OF TWO-DIMENSIONAL MAGNETOEXCITONS INTERACTING WITH PLASMONS UNDER THE INFLUENCE OF EXCITED LANDAU LEVELS

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The collective elementary excitations of two-dimensional magnetoexcitons in a Bose-Einstein condensate (BEC) with wave vector $\vec{k}=0$ were investigated in the framework of the Bogoliubov theory of quasiaverages. The Hamiltonian of the electrons and holes lying in the lowest Landau levels (LLLs) contains supplementary interactions due to virtual quantum transitions of the particles to the excited Landau levels (ELLs) and back. As a result, the interaction between the magnetoexcitons with $\vec{k}=0$ does not vanish and their BEC becomes stable.

The equations of motion for the exciton operators $d(P)$ and $d^{\dagger}(-P)$ are interconnected with equations of motion for the density operators $\hat{\rho}(P)$ and $\hat{D}(P)$. Instead of a set of two equations of motion, as in the case of usual Bose gas, corresponding to normal and abnormal Green's functions, we have a set of four equations of motion. Changing the center-of-mass wave vector of a magnetoexciton from 0 to $\vec{P}$, for example, implies changing its internal structure, because the internal distance between the Landau orbits of the quantized electron and hole becomes equal to $|\vec{P}|l^2$, where l is the magnetic length. The separated electrons and holes remaining in their Landau orbits can take part in the formation of magnetoexcitons as well as in the formation of collective plasma oscillations. Such possibilities were not included in previous considerations of the theory of structureless bosons or in the theory of Wannier-Mott excitons with a rigid relative electron-hole motion structure without the possibility of the intra-series excitations. The internal structure of magnetoexcitons is much less rigid than that of Wannier-Mott excitons, and the possibilities for electrons and holes to take part simultaneously in many processes are much more diverse. This means we have to deal simultaneously with four branches of the energy spectrum, the two supplementary branches being the optical plasmon branch represented by the operator $\hat{\rho}(P)$ and the acoustical plasmon branch represented by the operator $\hat{D}(P)$.

The energy spectrum of the collective elementary excitations consists of two exciton-type branches (energy and quasienergy branches), each of them with an energy gap and a roton-type region, from the gapless optical plasmon branch and from the acoustical plasmon branch, which reveals an absolute instability in the range of small and intermediary wave vectors.

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