Particle correlations in a quantum degenerate trapped dipolar exciton fluid

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Dipolar excitons in bilayers are expected by many to exhibit a thermodynamic phase transition, in the quantum degenerate regime, to a macroscopic coherent state. It is generally assumed that such a state would most likely be similar to a Bose-Einstein condensate of weakly interacting particles, however it is not clear if and how the repulsive dipole-dipole interactions between excitons would affect the nature of their ground state [1].
Recent advancements in trapping techniques of cold dipolar excitons [2] allow studies of such systems under more controlled conditions and indeed various results suggest that spontaneous phase transitions do occur to some new ordered state [3].

Here we present experimental evidence and an accompanied theoretical model that suggest that the dipole-dipole interactions of trapped exciton fluids induce strong particle pair correlations. These correlations affect the measured interaction energy dependence on the fluid density that shows significant deviations from the linear mean field behavior.

The measurements where performed on dipolar exciton fluids optically excited with short optical pulses inside electrostatic traps in a GaAs/AlGaAs bilayer system. The spatial and spectral dynamics of the exciton fluid following its excitation were monitored and analyzed under different conditions to deduce the dependences of the exciton-exciton interaction-induced spectral blue shift on the fluid density and temperature. These measurements show substantial deviations from the mean field predictions at high fluid densities. The calculation of the exciton – exciton interaction energy reveals significant pair correlations between excitons, the main element of which is a depletion region near each of them [1,4], a region which is temperature dependent and grows fast as the excitons become quantum degenerate. The results of the calculation of the luminescence intensity and blue shift are in qualitative agreement with the experimental data. The pair correlation significantly reduces the blue shift and shows that exciton concentration values based on the mean field theory might be an underestimate. Strong correlations also suggest that the exciton system is not a weakly non-ideal Bose gas but rather a quantum liquid.

References

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