Vortices in a dipolar superfluid of interlayer excitons in bilayer semiconductors

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Recent independent reports of observations of signatures of Bose-Einstein Condensation [1,2] and superfluidity [3] of dipolar excitons have drawn enormous attention to excitonic bilayer semiconductor systems in which electrons and holes are kept separated in different 2D conducting layers. We have predicted a transition from superfluid to an incompressible exciton supersolid in an experimentally accessible region of the phase space [4].

Here we investigate the time-dependent dynamic superfluid condensate by solving the full Gross-Pitaevskii equation for the 2D excitonic system with aligned dipole-like interactions that are long-range and everywhere repulsive. This makes the system in marked contrast with ultracold dipolar gases [5] in which the dynamics are driven by competition between the atomic dipolar repulsive interactions plus two attractive interactions, the contact interaction and the external harmonic confining potential.

The ground state solutions of the Gross-Pitaevskii equation can be experimentally tuned by changing the exciton dipole moments, here determined by the layer separation d, and by changing the density n of the dipoles with metal gates. Existence of vortices can be experimentally used to establish unequivocally the onset of Bose-Einstein Condensation [6]. We follow the formation of vortices in the system as functions of d and n, and the formation in the superfluid of a vortex lattice driven by the vortex-vortex interactions. Recall that the vortex cores depend on the ratio of the strength of the exciton dipole moment relative to kinetic energy. When we approach the phase space region of the supersolid where the dipole interactions are strong, we find the appearance of interesting maxima in the density redistribution around the edge of each vortex, leading to highly non-trivial behavior of the vortex-vortex interaction. This is associated with a roton minimum mixing with the ground-state [7] and so may be a precursor to the crystallization to a supersolid.

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