Vortices and vortex interactions in exciton-polariton condensates

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I will discuss the properties of topological defects (vortices) in exciton-polariton condensates. For linearly polarized condensates the vortices carry two winding numbers, k and m, which define the polarization and phase change after encircling the vortex core [1]. The winding numbers (k, m) can take integer or half-integer values simultaneously. In particular, the (0,1) vortex is the usual phase vortex with polarization being constant. The (1,0) vortex is the hedgehog with constant phase and the linear polarization rotating by 2π. Both polarization and phase can change together by encircling the vortex core and this is the case of half-vortices with $k,m = \pm 1/2$, where polarization and phase are changed by $\pm\pi$. The half-vortices are basic topological defects in linearly polarized polariton condensates formed in microcavities with cylindrical symmetry.

Four half-vortices can be divided by two pairs, left and right ones, depending on the sign of the product km, and they correspond to the singularities in right and lift circular component of the condensate wave function. In the simple case of isotropic parabolic dispersion the left and right half-vortices do not interact with each other. I will describe how the coupling between left and right half-vortex subsystem appears due to longitudinal-transverse splitting (also referred as TE-TM splitting) of polariton bands. Interestingly, with an account for TE-TM splitting the (1/2,-1/2) and (1/2,1/2) half-vortices start to interact logarithmically, while the other left and right half-vortices still remain decoupled in logarithmic approximation.

Real microcavities present a broken cylindrical symmetry. Namely, there is a small splitting between [110] and [1-10] polarized condensates, so that polarization is pinned to [110]-direction (x-direction). The preferential pinning of the condensate polarization to a specific direction in the microcavity plane has a pronounced effect on the half-vortex texture. When one encircles the half-vortex core polarization remains pinned to x-direction everywhere except a narrow region where it rotates by $\pm\pi$. This narrow region defines a string that goes from the half-vortex to an anti-half-vortex or to the system boundary. String connecting a pair of half-vortices carries additional positive energy, so that the energy of the pair acquires additional term linearly increasing with the distance between half-vortex and anti-half-vortex.

I will also present recent results [2] on the coherent excitation and dynamics of polariton condensates with embedded vortex lattices. Polariton condensates containing vortex lattices can be excited resonantly by the interference of several (three or more) optical pumps. Vortex-antivortex pairs can also appear in polariton condensates due to scattering with disorder. The dynamics of vortex lattices is strongly nonlinear and is characterized by interactions of vortex cores and vortex-antivortex recombination. This dynamics of vortices is studied by the numerical solution of the time-dependent Gross-Pitaevskii equation, both with and without static disorder in the microcavity plane.

References

[1] Yu. G. Rubo, Phys. Rev. Lett. **99**, 106401 (2007).

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