Superfluidity and quantum turbulence in cavity polaritons

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Polariton fluids can be generated in a planar optical cavity through strong coupling between light and matter. Polaritons are mixed light-matter quasi-particles coherently excited by an external laser field, which propagate in the plane of the cavity and decay into photons outside the cavity, thus forming a driven dissipative system. We have studied the properties of polaritons in semi-conductor microcavities, where the active matter particles are bound electron-hole pairs, called excitons. Importantly, due to their excitonic component, polaritons interact with each other (Coulomb and Fermi interaction). Polaritons have an effective mass, inherited from the parabolic dispersion shape of the cavity. In view of these properties, it was proposed that such out-of-equilibrium fluids could be described by Gross-Pitaevskii equations with some similarity to superfluid Helium or Bose Einstein condensates, and superfluid behaviour was predicted for these two-dimensional fluids [1].

We have for the first time observed the superfluid motion of resonantly excited polaritons based on the Landau criterion, which states that scattering disappears when superfluidity appears [2]. We have also observed a variety of quantum fluid effects, such as the formation of dark solitons in the wake of an obstacle [3] and of vortex-antivortex pairs due to colliding flows of polaritons [4].

As in ultra-cold atoms condensates, orbital angular momentum can be injected into a polariton fluid. We have demonstrated the formation of ensembles of same-sign quantized vortices when orbital angular momentum is injected by one or several exciting laser beams. In the first case the angular momentum is injected by a Laguerre-Gauss beam, and vortices nucleate in the fluid [5]. In the second case four coherent lasers arranged in a square resonantly create four polariton populations propagating inwards. The lasers are tilted in order to inject a controllable non quantized amount of optical angular momentum, which result, in the superfluid regime in an integer number of vortices with the same sign [6].

These properties of polaritons open the way to a new understanding of quantum phenomena, and to promising methods for quantum simulation.

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