Controlling superfluid vortices in polariton fluids

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Exciton-polaritons, microcavity half-matter half-light quasi-particles, when resonantly driven exhibit a superfluid regime. Accordingly, topological excitations similar to those predicted in equilibrium superfluids may spontaneously appear [1,2,3,4]. However, the non-equilibrium nature of polaritons requires the system to be continuously pumped in order to compensate for losses. This driving plays a key role in the formation and dynamics of such topological excitations. Excited through a resonant pumping, the coherent field driving the system imposes a phase on the polariton fluid which inhibits the formation of vortices or solitons [1]. This unique feature of coherently driven polariton superfluids has been used to trap vortices. To that purpose an engineered pumping profile, alternating between spatial driven and non driven regions was proposed and successfully implemented [1,2].

Based on this same idea of spatially engineered pumping profils, many works done lately focused spontaneous formation of vortices in polariton superfluids. For practical experimental reasons, such as high speeds, small propagation length and a short lifetimes, the hydrodynamics of these vortices propagating were largely ignored.

I will present a recent investigation of an optical method allowing us to overcome these difficulties, together with giving the unique opportunity to directly control and manipulate the properties of the vortices. The general idea is to sustain the superfluid polariton flow, something which generally does not last long outside the excitation region, with a secondary supporting excitation of low intensity. This way the flow may propagate over a much longer distance. The vortices formed in the superfluid are still permitted due to the weakness of the support pump. This allows their propagation along large distances and the observation of their hydrodynamic behaviour. However, the secondary coherent driving acting as a support, allows for some other rich and unique features. At the same time as increasing the propagation length, the same support driving gives direct control over the vortex-antivortex pair properties, offering a unique opportunity to manipulate vortex locally and accurately.

The new approach proposed allows for the observation of hydrodynamic behaviour of superfluid vortices, and initiates a new step regarding the control of such fundamental entities, thus paving the way toward their practical use.

Références

1. S. Pigeon, I. Carusotto and C. Ciuti, "Hydrodynamic nucleation of vortices and solitons in a resonantly excited polariton superfluid," *Phys. Rev. B*, **83**, 144513 (2010).
2. A. Amo, S. Pigeon, D. Sanvitto, V. G. Sala, R. Hivet, I. Carusotto, F. Pisanello, G. Leménager, R. Houdré, E. Giacobino, C. Ciuti and A. Bramati, "Polariton superfluids reveal quantum hydrodynamic solitons," *Science* **332** 1167 (2011).
3. G. Nardin, G. Grosso, Y. Léger, B. Piętka, F. Morier-Genoud and B. Deveaud-Plédran, Benoît "Hydrodynamic nucleation of quantized vortex pairs in a polariton quantum fluid," *Nat. Phys.* **7** 635 (2011).
4. D. Sanvitto, S. Pigeon, A. Amo, D. Ballarini, M. De Giorgi, I. Carusotto, R. Hivet, F. Pisanello, V. G. Sala, P. S. S. Guimaraes, R. Houdré, E. Giacobino, C. Ciuti, A. Bramati and G. Gigli, "All-optical control of the quantum flow of a polariton condensate," *Nature Photon.* **5** 610 (2011).