Optical control of vortex-antivortex lattices of polariton quantum fluids

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In quantum fluids, such as liquid helium and atomic Bose-Einstein condensates, vortex lattices have been observed as a consequence of an externally induced rotation [1]. The generation of vortex-antivortex (AV) lattices with total angular momentum L=0 has instead been observed only recently in a solid state system: exciton-polaritons in semiconductor microcavities under non resonant excitation [2]. Here we report on the coherent generation of polariton quantum fluids which create lattices of AV pairs, allowing for a complete control over the size and shape of the lattice geometry. Moreover, the true interacting effect of a condensate of polariton is revealed once the density is sufficiently high to allow for superfluid flow.

Exciton-polaritons are bosonic quasi-particles formed by the strong coupling between exciton and photon, which have shown to behave as a macroscopic quantum state both under resonant and non-resonant excitation. In particular, resonant excitation allowed for the observation and control of the flow of AV pairs, hydro-dynamically generated by artificial defects [3]. Extending these techniques, we have been able to study the formation of triangular and squared lattices of AV pairs under resonant excitation, demonstrating the existence of a power threshold above which the AV lattice disappears due to the strong interactions between polaritons (as shown in Fig.1). Below this threshold, the size of the unit cell is controlled by changing the energy of the excitation laser beam. Moreover, thanks to the out-of-equilibrium nature of polariton condensation, we have explored the formation process of this kind of topological excitations, and their organization in ordered structures, with a time resolution of few picoseconds.

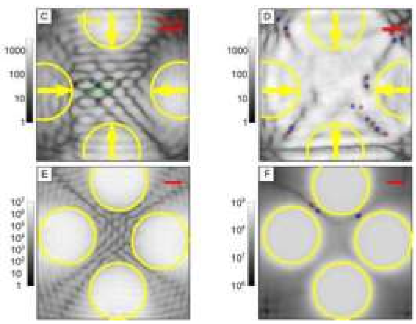

Figure 1. Four-pumps setup in the low power regime (C) and in the high power regime (D). A k=0.78μm^{-1} square lattice of vortex-antivortex pairs is formed in C and disappears in D. This nonlinear behaviour is due to the strong polariton-polariton interactions and it is correctly predicted by simulation based on the Gross-Pitaevskii formalism. E-F: Theoretical simulations run under the same conditions as in panels C and D, respectively.

[1] Yarmchuk et al, Phys. Rev. Lett. **43**, 214 (1979); Fetter et al, Rev. Mod. Phys. **81**, 647 (2009).
[2] Tosi et al, Nature Communications **3**, 1243 (2012).
[3] Sanvitto et al., Nature Photonics **5**, 610 (2011); G. Nardin et al., Nature Phys. **7**, 635 (2011).