Polariton Superfluidity in Microcavities

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Abstract: A semiconductor microcavity polariton fluid, injected by a nearly-resonant continuous wave pump laser, can exhibit collective excitations which deeply modify its propagation. When the polariton density is large enough, a superfluid behaviour of the polariton fluid is observed and manifests itself as the suppression of scattering from defects. In other conditions Cerenkov-like patterns are observed. Due to their exciton-photon mixed nature, polaritons are thus very good tools for exploring the physics of non-equilibrium quantum fluids.

In a very thin semiconductor quantum well, the motion of excitons, which are bound electron-hole systems, is quantized perpendicularly to the well, while it is free in the plane of the well. When the quantum well is placed in a high finesse microcavity, the strong coupling regime between excitons and light is reached at low temperature (4K), forming polaritons that are exciton-photon mixed quasi-particles. Polaritons can be coherently excited by an incident laser field and detected through the emitted light. At the same time polaritons have binary interactions due to their excitonic component, which can modify their dispersion curve. These properties have allowed in the past to demonstrate nonlinear and quantum optical effects[1] and optical spin Hall effect[2] in a semiconductor microcavity. Very recently, we have observed quantum fluid properties of the polariton ensemble[3].

We have studied the motion of the polariton fluid injected into a planar microcavity by a nearly resonant laser. In the presence of static defects, the response of the system is predicted using a Bogoliubov model similar to the one for a weakly interacting Bose gas[4]. Superfluidity of the polariton fluid should manifest itself as a quenching of the usual resonant Rayleigh scattering intensity when the flow velocity imprinted by the exciting laser is slower than the sound velocity in the polariton fluid (Landau criterion).

By varying both the flow velocity and the density of polaritons, we have demonstrated superfluidity in a quantum fluid of exciton-polaritons. In the subsonic regime, when the pump laser intensity is increased, we have observed that the system goes from a non-superfluid regime in which a static defect creates a perturbation in the moving fluid to a superfluid one, in which the polariton flow is no longer affected by the defect. In the supersonic regime, superfluid propagation is replaced by the appearance of a Čerenkov-like perturbation produced by the defect, in agreement with theoretical predictions.

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[1] J.P. Karr, A. Baas, R . Houdré, E. Giacobino, Phys. Rev. A69 031802(R) (2004); Romanelli M., Karr J.-Ph, Leyder C., Giacobino E., Bramati A., Phys. Rev. Lett **98** 106401 (2007)

[2] Leyder C., M. Romanelli, J. Ph. Karr, E. Giacobino, T. C. H. Liew, M. M. Glazov, A.V. Kavokin, G. Malpuech, A. Bramati Nature Physics 3, 628 (2007)

[3] A.Amo, J.Lefrère, S.Pigeon, C.Adrados, C.Ciuti, I.Carusotto, R.Houdré, E.Giacobino, A.Bramati, Nature Phys.5, 805 (2009)

[4] Carusotto, I. & Ciuti C, Phys. Rev. Lett. 93, 166401 (2004).