Measuring the speed of sound of light

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Bose-Einstein condensation (BEC) of Lithium, Caesium and Rubidium atoms was achieved by evaporative cooling of atomic gases in magnetic traps (Science, 269, 198 (1995)). A decade later several groups claimed BEC of mixed light-matter quasiparticles (exciton-polaritons) at much higher temperatures (Nature 443, 409 (2006), Science 316, 1007 (2007)). Cooling of exciton-polaritons has been realised through their interaction with the crystal lattice in these works. The low efficiency of polariton cooling remains a main obstacle on the way to creation of a new generation of ultrafast optoelectronic devices based on exciton-polariton BECs: polariton lasers, optical switches, integrated circuits etc. widely discussed in the literature (Nature Physics 6, 860 (2010), Science 336, 704 (2012)).

Here I will describe a new method for obtaining polariton condensation through evaporative cooling, the same method used for the cooling of atomic gases and formation of atomic BECs. Recently we engineered a highly efficient evaporative cooling technique of exciton-polaritons using an optically induced parabolic dipole trap, which allows for the spontaneous formation of polariton BEC spatially separated from the excitation laser and at an order of magnitude lower excitation densities compared to previous experimental configurations. Unlike all previous manifestations of polariton BEC, including our past works, we have now observed polariton condensation prior to the build-up of coherence in the form of photon or polariton lasing at the excitation area on the sample, conclusively resolving the debate on the phase relation between excitation laser and polariton BEC.

The advantage of polariton BECs formed through evaporative cooling is its spatial separation from the optically injected exciton reservoir, a source of strong scattering and therefore dephasing in the system. The "purity" of polariton BECs in terms of coherence but also localisation within the optically induced trap allowed us to access the fundamental dependence of the renormalized polariton BEC dispersion on the number of condensed polaritons as in atomic BECs (PRL 79, 5053 (1997)). We image the Bogoliubov excitation in the absence of polariton diffusion and for the first time measure the superfluid sound velocity as a function of the number of polaritons in the condensate.

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