August 17, 2012

SCIENTIFIC REPORT

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Ref. Number 3980

ESF – POLATOM : Vortex arrays in polariton fluids

Purpose of the visit:

Excitons-polaritons are bosonic quasiparticles with intriguing properties like low masses and strong interactions which make them promising candidates to study quantum fluid effects. So far Bose Einstein condensation, superfluidity, half-vortices, solitons and half-solitons have been observed in polariton system. Vortices have been observed in polariton fluids, pinned to local potential variations or moving with the fluid, but never organized in a geometric network as it has been observed in cold atoms, although it has been theoretically predicted to occur in different configurations. Purpose of this project is to create a regular lattice of vortices and anti-vortices in a polariton fluid under resonant excitation and to study their dependence on the principal parameters of the system, which are the polariton density, the excitation energy and the shape of trapping region.

Description of the work carried out during the visit:

We resonantly inject polaritons at k = 0 just outside of a trap, allowing polariton currents to enter into the trap. The trap is created by a metallic mask on the path of the exciting beam, which originates in the sample a region outside of the mask with an high polaritons density and a region inside of the mask where polaritons get trapped. This is due to the energy shift which results from the polariton interaction outside of the masked region. The phase of the polariton field is imprinted by the continuous wave (cw) exciting laser only outside of the trap, while we can observe the formation of topological defects inside the masked region. The advantages of this experimental configuration are the control over the shape and size of the trap, the possibility to study the dependence on the energy of the exciting laser and, most important, the control over the polariton density which is adjusted by tuning the power of the exciting laser.

The microcavity is excited with a cw single-mode Ti:Sa laser resonant with the lower polariton branch. The output beam is interfered with a reference beam of constant phase and collected on a CCD camera, allowing the extraction of the phase of the polariton fluid.

Description of the main results obtained:

We experimentally observed the formation of arrays of vortices and antivortices inside the masked region: the pattern structure and the number of vortex-antivortex pairs have been successfully controlled by changing the shape and size of the trapping mask.

The detuning between the excitation laser and the lower polariton branch has been found to be a crucial parameter because it determines the velocity of the polariton currents and therefore the size of the unit cell of the vortex-antivortex array. We have studied this dependence demonstrating the possibility to control the pattern formation by changing the energy of the excitation laser or the energy of the lower polariton branch.

The intensity of the excitation laser determines the polariton density and therefore the amount of interactions between them. The control over this parameter resulted of crucial importance in the formation of topological defects in the phase of the polariton field. We studied the dependence on the excitation power finding a threshold-like behavior for increasing polariton densities related to the strong non-linearities of polariton fluids. Above this threshold, the strong polariton-polariton interactions allow the vortex formation only in specific areas of the masked region changing dramatically the structure of the vortex-antivortex array. We are analyzing the measured data to find the relationship between the polariton density (proportional to the speed of sounds in the fluid) and the velocity of the polariton fluid. Moreover, to confirm our results we have performed theoretical simulations based on the Gross-Pitaevskii formalism, finding a good agreement with the experimental data. The experimental data are currently under further scrutiny and will be presented in the complete form when properly analyzed.

Future collaboration with host institution:

The next step is to implement a time-resolved experiment to observe the dynamics of the formation of the vortex-antivortex array, which is planned to be performed in the laboratory of Lecce in collaboration with the host institution.

Projected publications / articles resulting or to result from the grant:

These results have been partially presented in the 31st ICPS 2012 (International Conference on the Physics of Semiconductors) held in Zurich, Switzerland, July 29th to August 3rd 2012 and will be presented in a manuscript to be submitted to a peer-review journal. The ESF will be acknowledged in the expected publication resulting from the work done during my visit and anticipated in this scientific report.