Research Networking Programmes

Short Visit Grant ☐ or Exchange Visit Grant ☒

(please tick the relevant box)

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online within one month of the event. It will be published on the ESF website.

Proposal Title: Berry phase effects in exciton-polaritons

Application Reference N°: 4914

1) Purpose of the visit

The main purpose of my stay in Trento was to study the effects of an external harmonic trapping potential on the Harper-Hofstadter model on a 2D lattice, in the context of a linear driven-dissipative photonic system. Besides the fundamental understanding of topological effects in this system, the focus is on the experimental verification of such effects in state-of-the-art devices like arrays of Si-based coupled ring resonators.

2) Description of the work carried out during the visit

We have extended the model of Price, Ozawa and Carusotto (Phys. Rev. Lett. 113, 190403 (2014)), originally conceived for equilibrium systems like ultracold atomic condensates, to the case of a driven dissipative bosonic system. Price et al. show that the eigenspectrum of a particle hopping on a 2D square lattice in the presence of an artificial gauge field (Harper-Hofstadter model) and under the influence of an external harmonic trapping potential can be understood as the Landau levels of a particle moving in constant magnetic field on the surface of a torus. In particular, the Berry curvature of the Harper-Hofstadter energy bands can be seen as the

effective momentum space magnetic field, in a fully quantum description.

The work carried out had both an analytical and a numerical component. We have first implemented driving and dissipation by adding the relevant extra terms to the Heissenberg equation of motion. In a second phase, the equation of motion was numerically solved for each point of the 2D grid, adjusting the parameters to closely follow the ones used in current state-of-the-art experiments.

3) Description of the main results obtained

We have found that readily-available experimental platforms, such as the arrays of Si-based coupled ring resonators currently in use in Mohamed Hafezi's (Nat. Photonics 7, 1001 (2013)) could already be used for observing toroidal Landau levels in momentum space, provided one implements the harmonic trapping potential by modulating the resonator size. In our forthcoming publication, we detail a spectroscopic protocol for probing these levels.

More generally, we have shown that the results of Phys. Rev. Lett. 113, 190403 (2014)) also carry over in a non-equilibrium system.

We have also found that non-Abelian effects are important when looking at the energy offset of momentum-space Landau levels, causing an overall shift. Making use of this fact, we propose a method of experimentally asessing the contribution of these non-Abelian effects

Last but not least, we are currently working on including mean-field interactions into our current model. This leads to a nonlinear Gross-Pitaevskii type equation for the bosonic condensate on a 2D square lattice under an artificial magnetic field. We expect that increasing the value of the field would eventually lead to the break-down of superfluid behaviour and formation of vortices, analogous to type-II superconductors.

4) Future collaboration with host institution (if applicable)

5) Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)*

We are currently in the process of submitting a publication which summarises the above-mentioned results.

6) Other comments (if any)