Research Networking Programmes

Short Visit Proposal – Scientific report

Proposal title:
Participation to the International School of Physics "Enrico Fermi" - Varenna, Lake Como, Italy Course on: "Quantum Matter at Ultralow Temperatures"

Project description

I am a PhD student at EPFL under the supervision of Benoit Deveaud and my research topic is on the study of spinor properties of exciton-polariton condensate under a magnetic field. Hence, the quantum properties of matter and light-matter interactions are at the center of my project. The goal of attending this summer school was first to improve my understanding of quantum fluids through the views of ultracold atoms physicist but also to stimulate new ideas for experiments on the polariton system, inspired by the lectures. Since many key experiments done on polariton fluid were inspired by experiments achieved in cold atoms, it seems logical to continue in that direction.

School description

The school consisted entirely of lectures and was held for nine days with one day break in the middle. The program was from 9am to 19pm with a three hour break for lunch and discussion. Each day consisted of four lectures of 1h15 and one invited talk of 1h. Appart from the invited speakers, each lecturer gave two or three lectures during the school, not more than one per day. It allowed them to cover related topics but also to go deeper in the explanations. The extended lunch break was quite beneficial because it allowed enough time to discuss either with the lecturers or with the other students. Being from the polariton community and not from the cold atom, these turned out to be really stimulating and useful, especially for learning more on the basics and the experimental subtleties related to this field.

Description of specific topic studied

The first topic covered in details by four lecturers is regarding the realization of synthetic gauge fields in 1D or 2D using atoms in an optical lattice. The goal of these experiments is to simulate non-trivial magnetic fields with atoms hopping between lattice sites. Like a charged particle in a magnetic field, an atom can acquire a phase when in circular motion in the lattice. This phase shift can be mapped to a specific magnetic field interaction (more precisely a vector potential) as a function of the shape of the lattice. The size of the lattice site, which dictates the hopping strength, is controlled by one or two laser beams of either same of different frequency in order to get equivalent or non-equivalent lattice sites. For the actual hopping, it is forced either by shaking the lattice or using additional laser beam to trigger optical transitions allowing overcoming the potential barrier.

Another topic was on the observation of weak and strong localisation using a 1D or 3D condensate. The observation of weak localisation occurs through a backscattering caused by destructive interference in the propagation direction. In the case of strong localisation, the destructive interference of propagating paths in a highly disordered landscape forces the particles to be localised on sites. The latter case was observed by imprinting a weak speckle pattern onto a condensate and releasing it from the trap. When there is no disorder, the condensate normally expand but, when the speckle is present, the diffusion does not occurs and the condensates stays localised on the weak disordered potential.

Two sets of lectures were devoted to dipolar gases. When atoms in an ultracold gas have a strong dipole moment, the dipolar interaction must to by included in order to properly study the system. This additional interaction can lead to drastic effect for the condensate. The dipolar interaction is strong and long range but also highly directional as it depends on the relative dipole orientation. Therefore, depending on the shape of the trap for the atoms, it is possible to get attractive or repulsive interactions. For this reason, the stability of the condensate will be dependent on the shape of the trap, more precisely on its aspect ratio. These studies can also be done in an optical lattice.

Outlook

After all these lectures, many ideas are starting to flourish to link the concepts and ideas seen in these lectures and the possibility to apply them to the polariton system. The best possibility will be related to the work done using optical lattice and synthetic gauge fields either in 1D or 2D. It is possible to pattern the semiconductor microcavity in order to get an additional confinement potential for the polariton. As we are currently optimising the process to realize this, the idea would be to extend the pattering to lattices and look for the possibility to create synthetic gauge field using polariton fluids. So far, it looks quite promising because we can engineer the potential landscape with great accuracy. The generation of synthetic gauge fields rely on phase shift when hopping from site to site. For the polariton, it means a polarization shift on each site of the lattice, which can be achieved geometrically or with additional laser beam on sites. Although we are still far from obtaining this regime, I can safely say that my goals to attend this summer school have been met.