PhD project :

Quantum transport in artificial gauge fields : from atom to photon gases

Location : Laboratoire Kastler Brossel, Sorbonne Université, Paris (50 to 60%)
Laboratoire Majulab, Center for Quantum Technologies, Singapour (50 to 40%)

Nature of the project : theoretical

Principal advisor : Nicolas Cherroret ; Co-advisor : Christian Miniatura

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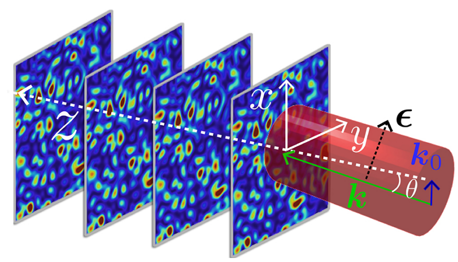
Funding : CNRS scolarship

Description

The ability to control quantum atomic gases in different types of optical potentials has recently led to cornerstone achievements, like the observation of Anderson localization with cold atoms [1, 2] or the first realization of artificial gauge fields for neutral atoms [3]. In parallel, over the past years many scenarios usually encountered in cold-atom or condensed-matter systems have been transposed to optics. For example, in photonic waveguide arrays, the analogy between paraxial photons and quantum particles was used to achieve Anderson localization of photons (figure) [4]. In a similar spirit, by conveniently guiding optical beams or structuring dielectric media, it is now possible to simulate artificial gauge fields for photons and induce optical topological phases. At the nanoscale, "spin-orbit interactions" of light in heterogeneous materials are even more the rule than the exception [5] and become an important ingredient in the field of nanophotonics.



A paraxial beam of photons propagating in a 2D, longitudinally invariant disordered refractive index landscape behaves as an effective quantum gas of massive particles.

The goal of this PhD project is to theoretically study the quantum transport of atoms and photons subjected to artificial gauge fields in the presence of disorder or interactions. In the atomic case, we will examine how artificial magnetic field and spin-orbit coupling affect Anderson localization. A particular attention will be paid to the "coherent forward scattering" peak, a novel signature of Anderson localization discovered by us [6, 7]. In the optical case, we will explore the quantum transport of photons in waveguide arrays beyond the paraxial approximation, a regime where photons experience a spin-orbit coupling [8, 5]. We will examine its interplay with both photon superfluidity in nonlinear media and with Anderson localization in disordered materials.

The PhD candidate will be supervised by Nicolas Cherroret at Laboratoire Kastler Brossel. 40 to 50% of the PhD time will be spent at the CNRS Majulab in Singapore, where the PhD candidate will be co-supervised by Christian Miniatura. The PhD project will involve both analytical and numerical approaches.

[1] F. Jendrzejewski *et al.*, Nature Phys. **8**, 398 (2012).
[2] J. Choi *et al*, Science 352, 1547 (2016).
[3] J. Dalibard, F. Gerbier, G. Juzeliunas, P. Öhberg, Rev. Mod. Phys. **83**, 1523 (2011).
[4] T. Schwartz, G. Bartal, S. Fishman, and M. Segev, Nature **446**, 52 (2007).
[5] K. Y. Bliokh, F. J. Rodriguez-Fortuño, F. Nori and A. V. Zayats, Nature Photon. **9**, 796 (2015).
[6] T. Karpiuk, N. Cherroret, K. L. Lee, B. Grémaud, C. A. Müller, C. Miniatura, Phys. Rev. Lett. **109**, 190601 (2012).
[7] S. Ghosh, C. Miniatura, N. Cherroret, and D. Delande, Phys. Rev. A **95**, 041602 (2017).
[8] N. Cherroret, Physical Review A **98**, 013805 (2018).