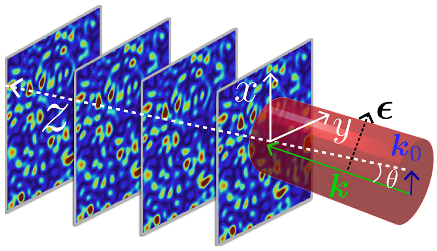
PhD project :

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
Contact : cherroret@lkb.upmc.fr
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).

Posdoc position in theoretical physics :

Spin-orbit interactions in fluids of light

Location : "Complex Quantum Systems group", Laboratoire Kastler Brossel (LKB), Sorbonne Université, Paris 05

Duration : 24 month minimum (ANR funding)

Expected date of employment : October 2019

Salary : 2695 to 3841 euros per month before tax depending on experience (2201 à 3135 net)

Description : Fluids of light constitute novel and flexible systems of effectively interacting photons that exhibit many fascinating properties of quantum gases : superfluidity, condensation or topological effects to cite a few [1]. To achieve a fluid of light, a very simple approach consists in propagating a quasi-monochromatic beam of light in a nonlinear Kerr medium. In the paraxial limit, the evolution of the beam is then described by an effective nonlinear Schrödinger equation. The post-doctoral researcher will theoretically study these systems beyond the paraxial approximation, in configurations where a spin-orbit coupling of light [2, 3, 4] shows up and modifies the physics of the fluid of light. The position is funded by the ANR project "CONFOCaL", and it might involve collaborations with the "Quantum optics" team at LKB and the "Cold atoms" group at Institut de Physique de Nice. The problems tackled will concern (not exclusively) the effect of spin-orbit interactions on light superfluidity, on the dynamics of (pre-)thermalization or on the Casimir forces induced by a fluid of light.

Tasks : The hired postdoc will develop a theoretical description of spin-orbit interactions in fluids of light, study the superfluidity, the non equilibrium dynamics and (pre-)thermalization of light in the presence of spin-orbit coupling. He/she is also expected to supervise a PhD student.

Skills : The candidate is required to have an excellent knowledge of the quantum physics of cold atoms and of the associated theoretical approaches. An expertise of non-equilibrium systems would be a strong asset. The hired postdoc will be highly dynamic, creative and motivated, both able to work independently and to regularly communicate with the team.

Application modalities : : Candidates are requested to send a detailed CV and a motivation letter (in pdf) to Dr. Nicolas Cherroret : cherroret@lkb.upmc.fr.

[1] I. Carusotto, C. Ciuti, *Quantum fluids of light*, Rev. Mod. Phys. **85**, 299 (2013).

[2] K. Y. Bliokh, F. J. Rodriguez-Fortuño, F. Nori and A. V. Zayats, Nature Photon. **9**, 796 (2015).

[3] N. Cherroret, *Coherent multiple scattering of light in (2+1) dimensions*, Phys. Rev. A **98**, 013805 (2018).

[4] T. Bardon-Brun, D. Delande, N. Cherroret, *Spin Hall effect of light in a random medium*, arXiv 1903.05447, Phys. Rev. Lett. (in press).