Proposition de sujet de thèse

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Funding: ANR JCJC STLight (2022-2026)

Fluids of light in a complex environment

This project focuses on the experimental study of photonic fluids [1] in disordered environments. Superfluidity, the ability of a fluid to move without friction along a pipe or past an obstacle, is one of the most spectacular features of quantum fluids. In nonlinear optics, it manifests as light propagating without being altered by an inhomogeneous environment. The exact opposite happens in the linear case, where light undergoes spatial localisation in disordered media. The main ambition of the project is to study the transition from spatial localisation to superfluidity in complex, but fully controlled, environments, positioning the project at the edge between quantum hydrodynamics and waves in nonlinear complex media. Strong turbulence in complex media will naturally arise in the system and will be investigated. It will, besides addressing transport in disordered optical systems, significantly benefit in both the nonlinear optics and quantum hydrodynamics communities. The project relies on the main research hypothesis that the paraxial propagation of an optical field in a nonlinear transparent medium is formally analogous to the evolution of a two-dimensional quantum fluid. In this analogy, the spatial evolution of the optical field along the propagation direction is analogous to the temporal evolution of the wavefunction of a quantum gas. Simply put, each transverse plane in the nonlinear medium is equivalent to a "snapshot" of the temporal dynamics of a two-dimensional quantum fluid. To realise this analogy, photons need to acquire an effective mass and be in a fully controlled effective (repulsive) interaction – two features that are allowed in properly engineered photonic systems. For instance, a photorefractive crystal [2] in which the optical index can be structured in an arbitrary and reconfigurable way, is a perfect candidate for studying fluids of light [3, 4], notably in disordered environments, and is at the heart of our experimental apparatus.

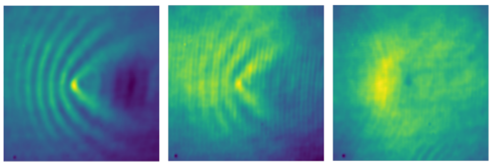

Fig. 1 – Transition from a dissipative (left) to a superfluid (right) regime for a fluid of light propagating in a nonlinear crystal.

The main expected results of the project include:

- Observing strong turbulence signatures in the presence of few obstacles,
- Unravelling the interplay between the spatial localisation and the superfluidity in a 2D disordered nonlinear landscape,
- Implementing a time-dependant full-optical disorder to study the transmission of a fluid of light through a scattering medium.

Profile.— This **experimental project** is at the interface between quantum hydrodynamics, nonlinear optics and transport in complex media. We are looking for highly motivated applicants with a broad outlook and knowledge in at list one of these topics.

[1] I. Carusotto and C. Cuiti, "Quantum fluids of light", Rev. Mod. Phys. **85**, 299 (2013).
[2] O. Boughdad et al, "Anisotropic nonlinear refractive index measurement of a photorefractive crystal via spatial self-phase modulation", Opt. Express **27**, 21, 30360 (2019).
[3] C. Michel et al, "Superfluid motion and drag-force cancellation in a fluid of light", Nat. Commun. **9**, 2108 (2018).
[4] A. Eloy et al, "Experimental observation of turbulent coherent structures in a superfluid of light," arXiv, arXiv:2012.13280 (2020).