Internship/Thesis

Molding complex wave propagation through space and time

Information

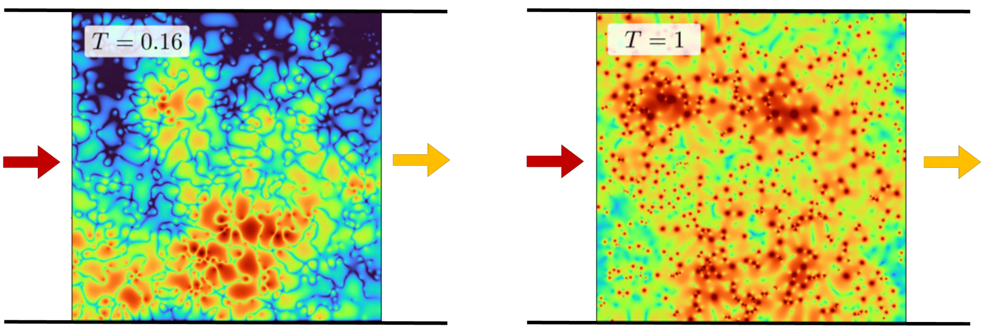
Nature of the internship : theoretical
Advisors : Arthur Goetschy (arthur.goetschy@espci.psl.eu), Romain Pierrat (romain.pierrat@espci.psl.eu)
Location : Institut Langevin, 1 rue Jussieu, 75005 Paris
Thesis possibility : Yes

Proposal

This project explores how waves (classical or quantum) interact with complex, disordered open materials. It lies at the crossroads of light-matter interaction, statistical physics, and the emergence of collective behavior in open systems. When a wave travels through a disordered material (like a cloudy medium or a random collection of atoms), it usually gets scattered in all directions, making the medium opaque. However, open channels are special states that can pass through such complex materials without being reflected. These states make it possible to focus light behind opaque layers, deliver energy precisely where needed, or even improve communication through disorder [1].

During the internship, the student will simulate how open channels propagate in two-dimensional disordered systems made of resonant scatterers (for example, atoms). Recent results show that the intensity pattern of these open channels depends strongly on the polarization of the wave, leading to very different transmission behaviors (see figure). The goal will be to explore these differences through numerical simulations and theoretical analysis, and to investigate whether a phase transition occurs between distinct propagation regimes controlled by disorder and polarization.

For students interested in continuing toward a PhD, this project naturally extends to the development of a microscopic theory of open-channel propagation in complex structures, building on the radiant field theory recently introduced by our group [2]. This work aims to provide first-principles predictions for how transmission eigenchannels behave in space and time, supported by simulations and experimental collaborations in 2D complex systems.



Open channels in disordered structures. Waves with out-of-plane polarization (left) tend to be trapped in long-lived modes and fail to reach full transmission, whereas in-plane polarized waves (right) can utilize all degrees of freedom to find a path through the structure.

[1] H. Cao, A. P. Mosk, and S. Rotter, Nature Physics **18**, 994 (2022).
[2] P. Gaspard and A. Goetschy, Physical Review Letters **135**, 033804 (2025).