Minicolloque n° PMQ31 • **Oral x**

Tailoring propagation of coherent light via spin-orbit interactions in controlled disorder

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The physics of spin-orbit interactions (SOI) of light has recently become a novel and appealing research field in modern optics and nano-photonics. Indeed, spin-orbit interactions constitute a fundamental interaction that couples the polarization and spatial degrees of freedom of optical fields and, as such, opens wide perspectives in terms of spin-controlled photonics, from the control of light trajectories at the nanoscale to the optical manipulation of nano-objets or precision metrology.

While many progresses have recently been made in the understanding and characterization of SOI of light in simple optical structures, such as interfaces, graded-index fibers or non-paraxial beams in free space, much less is known about the manifestation of this physics in disordered systems, where only a partial information on the material’s microscopy is available. Clarifying this question is important for at least two reasons. On the one hand, disordered materials are in general more the rule than the exception and, when present, disorder may play a more prominent role at the nanoscale where SOI typically operate. On the other hand, recent progresses in wave control or imaging have shown the great potential of using disorder as a tool rather than as a nuisance in general. Pushing this potential to the realm of spin-orbit physics is one of the main motivations of our study.

In our work, we theoretically demonstrate that in specific materials displaying in-plane disorder, the propagation of coherent light can be tailored to a large extent using spin-orbit interactions. In the presence of disorder, SOI arise as a result of the coupling between the light polarization and the random variations of refractive index. We discover that by controlling the level of randomness via the disorder correlation or simple macroscopic parameters such as the beam polarization or inclination, one can trigger original transverse optical motions in the disordered environment, from “simple” beam shifts to trajectories oscillating around the geometrical-optics prediction. While some of these motions can be interpreted as an optical spin Hall effect (the analogue of the electronic spin Hall effect known in electronic conductors) where a circularly polarized beam is transversally shifted, we also unveil the emergence of non-trivial motions even for linearly polarized light. In this situation the disordered system exhibits an analogue of the magneto-optic Voigt effect, here occurring without any magnetic field but as a consequence of SOI.