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

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Based on the fundamental interplay between spatial wavefronts and polarization degrees of freedom, spin-orbit interactions (SOI) of light constitute a novel tool for optical control at the nanoscale. While well described in simple geometries, SOI of light in disordered environments, where only a partial knowledge of the microscopy of the material is available, remain largely unexplored.

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 which arise as a result of the coupling between the light polarization and the random variations of the 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 of the coherent mode, 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 case, the disordered system exhibits an analogue of the magneto-optic Voigt effect, here occurring without any magnetic field but as a consequence of SOI. Transverse shifts, subwavelengths effects, can be amplified to the macroscopic scale thanks to the method of weak quantum measurements.

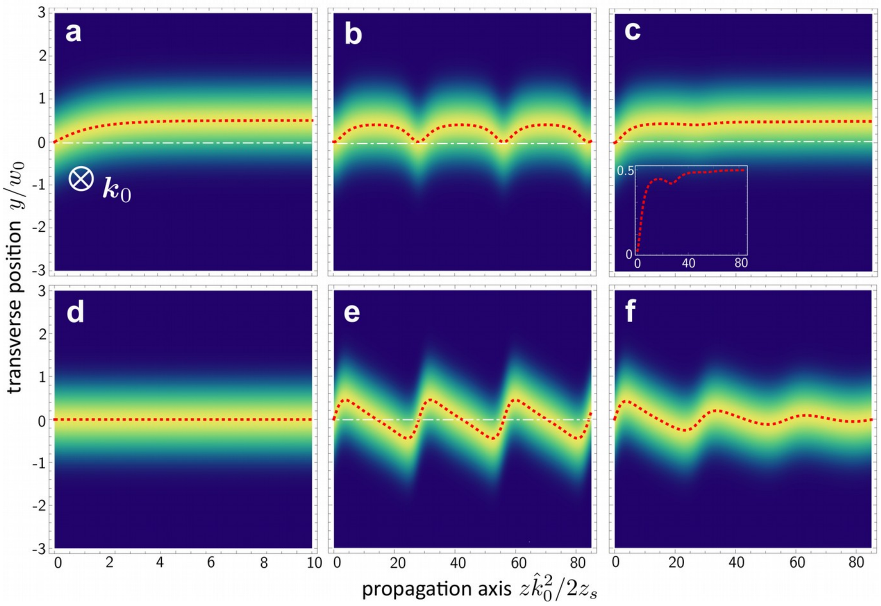

Figure Panels show different transverse trajectories of the coherent mode for light propagating along the axis z in a medium with disorder in the plane (x,y). $\mathbf{k_0}$ is the incident transverse wavevector and ω_0 is the beam waist of the incident beam. Each column stands for a different choice of disorder correlation. Panels **a**, **b**, **c** refer to shifts related to the spin-Hall effect, while panels **d**, **e**, **f** refer to shifts related to the spin-orbit Voigt effect. In panel c the inset shows a zoom of the beam centroid along y.