Spin-orbit interactions of light in evanescent waves: from theory to experiments

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In quantum physics it is well known that the spin of a particle can determine its motion: this is known as spin-orbit interaction. It is not so well known that Maxwell's equations can show the same effect with electromagnetic radiation. Contrary to the approximate assumptions of ray optics, in which rays propagate independently of light polarization, Maxwell's equations tell us that the spin of photons (their polarization) can affect their motion, under certain conditions[1]. Although these spin-orbit effects of light are usually small, recent advances in nanotechnology have found ways to enhance them dramatically. This opens up very interesting applications in nanophotonics for light generation and switching of light through the control of its polarization.

In this work we will summarize a collection of relatively recent experiments that we performed based on structures that enable the unidirectional excitation of electromagnetic modes by simply controlling the incident polarization of light, exhibiting a strong spin-orbit coupling of light. These structures include slits etched on gold films[2], gold nanoparticles on plasmonic surfaces[3], radio-frequency antennas emitting near two dimensional hyperbolic metamaterial circuits[4] and silicon nanoantennas[5]. All these different scenarios can be explained using the same unified fundamental explanation of spin-momentum locking of evanescent waves[1,2,6,7]: evanescent near fields are characterised by elliptically polarized fields whose rotation sense is directly determined by their propagation direction. Therefore, any electromagnetic mode which possesses an "evanescent tail" can be excited unidirectionally if the appropriate polarization is used for its excitation.

We also describe experiments involving the reciprocal scenario, in which the direction of propagation of an electromagnetic mode can be used to determine the polarization of radiated light[3]. We show how this can be used to design dual-input nanoantennas that synthetize arbitrary light polarizations in the radiated light[8].

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