Optimization of the polarization state of an ensemble of quantum dots for chiral emission

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Controlling the interaction of light and matter is the basis for many applications ranging from light technology to quantum information processing, many of which are based on nanophotonic structures. The confinement of light in such nanostructures imposes an inherent link between its local polarization and its propagation direction, known as spin-momentum locking of light [1]. This modifies the elementary processes of light-matter interaction: the emission and absorption of light of an appropriately polarized emitter becomes chiral, i.e., propagation direction-dependent. Placing a solid-state quantum emitter in a photonic crystal waveguide is promising for future applications because a very high fraction of the generated light can be injected into the waveguide guided mode [2]. Here, we focus on maximizing the directionality of chiral light emission from a quantum dots (QDs) placed within half core region of the photonic waveguide, as quantified by the fraction D of light emitted in the desired direction.

Most research so far has focused on placing the single emitter with circularly polarized transitions at a point of perfect circular polarization (a C point). These points are scarce. The photonic crystal structures support circular polarization at a few accessible locations, resulting in small area with high directional contrast D_{90} (top left panel in Fig. 1). That would require a precise embeding of QD in a waveguiding structure. To avoid this deposition requirement we consider ensemble of quantum dots and calculete net directionality. We find an optimal elliptical polarization of the QD transition dipole that maximizes the net directionality of the whole planar QD ensemble. We also calculate the Purcell factor and determine the area where $|D| \geq 0.9$ to explore the advantage of optimized elliptical polarization with respect to circular one. It is noticeable that optimizing the elliptical polarization state broadens the area of the waveguide core that may be used for unidirectional coupling with a single quantum emitter, while maintaining a high Purcell factor. We also perform $\mathbf{k} \cdot \mathbf{p}$ calculations to find geometrical parameters of the QD leading to the optimized polarization of the emission. This proves that optimal polarization is feasible if a small magnetic field of 0.2 T is applied.

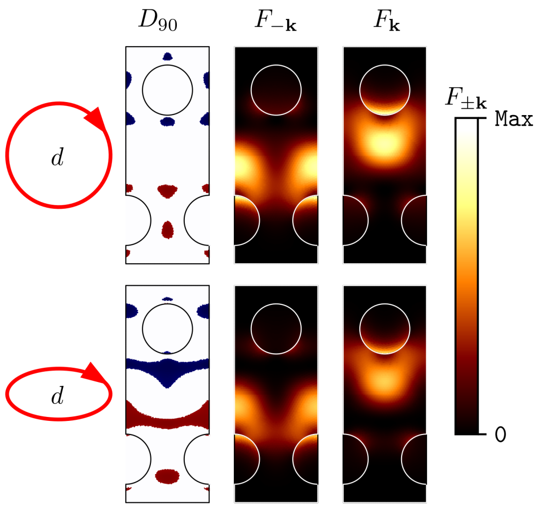

Figure 1: *The Purcell enhancement factor (right) and area where $|D| \geq 0.9$ (left) for an optimized elliptical polarization state (bottom) compared to the circular one (top) as a reference.*

[1] K. Bliokh et al., *Nat. Photonics* **9**, 796–808 (2015).
[2] A. Javad et al., *J. Opt. Soc. B* **35**, 514–522 (2018).