Photonic Antiferromagnetic Analogue

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1. Introduction: Spin Angular Momentum (SAM) and Orbital Angular Momenta (OAM) are degrees of freedom shared by both electrons and photons and have become ubiquitous properties in modern physics. The SAM of light corresponds to the circular polarization, while the OAM is held by optical vortices. Although electrons and photons fundamentally differ, the prospect of mimicking a solid-state system with its photonic analogue is motivating significant research efforts. Among the potential platform candidates, photonic crystal distinguishes itself by its intrinsic analogy with atomic crystal. If standard Photonic Crystal Waveguides (PCWs), do not possess prominent circular polarization nor optical vortices, PCWs with broken mirror symmetry exhibit substantial SAM and OAM [1,2], that couple and organize into structural arrangements similar to antiferromagnets [3].

2. Results and Discussion*:* Transverse Electric (TE) modes of a PCW with in-plane mirror symmetry can be classified as odd or even. Such a pair of modes may intersect without interacting due to their different parities. However, if the mirror symmetry is substituted with a glide-plane axis (i.e. shift of one side of the PCW along the propagation direction), these modes couple to become hybrid (Fig.1(a)), with enhanced SAM at high electric field intensity points, (the Stokes Parameter S_0). Due to the emergence of zero-group velocity points inside the Brillouin Zone a sub-bandgap opens which have been probed by transmission experiment. 22.5µm-long PCWs, fabricated in 220nm thick silicon membrane, exhibit a measured 40dBm transmission drop at these points [1].

The polarization of the modes can be described by the Stokes Parameters S_1, S_2 and S_3, depicting the linear, diagonal and circular polarization basis respectively and represented on the surface of the Poincaré sphere (Fig.1(b)). Due to their parity, even and odd modes are dominantly polarized along the transverse and longitudinal direction respectively. On the other hand, breaking the mirror symmetry rotates the polarization and confer to the TE1+ and TE1- modes strong elliptical and circular polarizations [1,2]. If the right and left handednesses feature strong and identical electric field intensities, it is because the glide-plane symmetry conserves the refractive index profile.

The zero-group velocity of the modes, far from the Brillouin zone edge, is substantiated by the emergence of optical vortices holding the OAM. SAM density circulation is established between neighboring optical vortices with opposite topological charges (-l and l) to bond them together, thus forming spin-1/2 like lattices structure. As shown in Fig.1(c), The angular momenta of the TE_1^+ and TE_1^- modes organize as antiferromagnets in a honeycomb and chain lattices respectively [3].

3. Conclusions: Antiferromagnets lattices were synthetized in PCW by breaking the mirror symmetry. Interfacing photonic crystals with distinct optical properties may form other spin lattices, such as ferromagnets or ferrimagnets.

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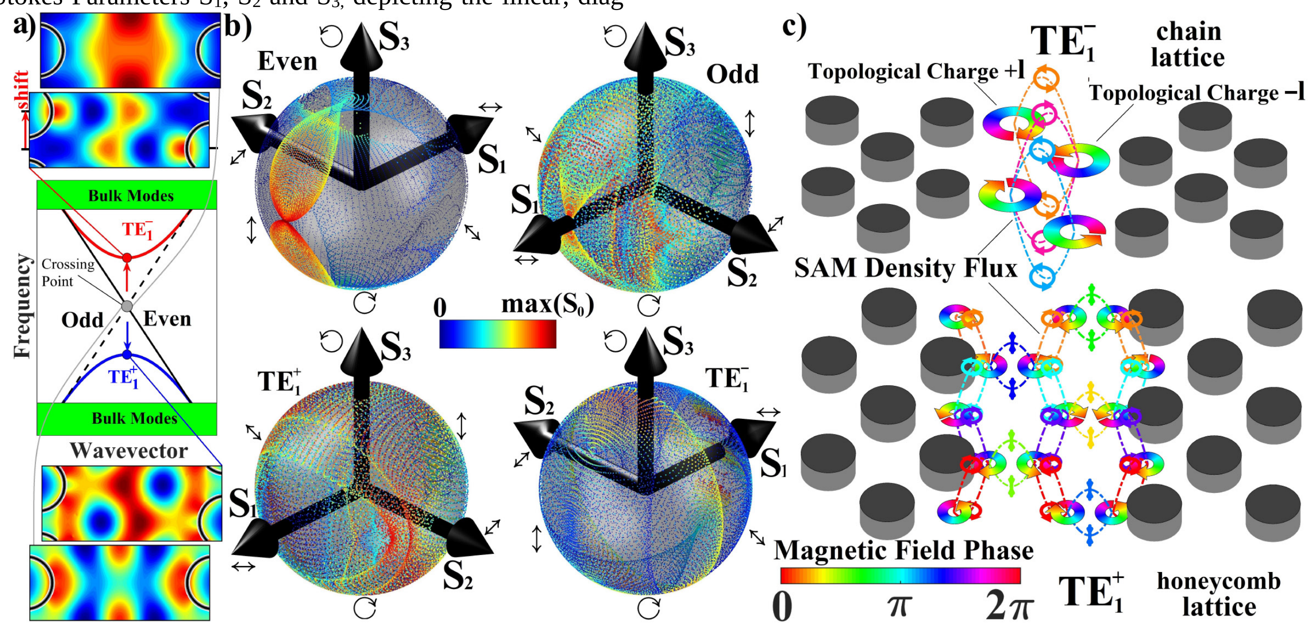

Figure 1: (a) Bandstructure and modal intensities, (b) Poincaré spheres, (c) Optical vortices and SAM density arrangements.