Circular-Polarization Biased Topological Insulators

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Photonic topological insulators have attracted a lot of attention for their unique physical characteristics and their property to support edge states that are immune to backscattering. Although it is possible to make photonic topological insulators based on reciprocal media through bi-anisotropy or the valley degree of freedom, the edge states in these cases are robust against only specific types of scattering. Generation of edge states that are immune under all forms of discontinuities requires breaking of time reversal symmetry (breaking of reciprocity), which can be achieved with magneto-optical materials under biasing with a static magnetic field or spatiotemporal modulation. The first approach has the disadvantage of being difficult to be realized in an integrated platform and needing static magnets, which are usually heavy and bulky. The second approach is compatible with integration, but the implementation of spatiotemporal modulation over a large array, as in topological insulators, through application of distinct modulation signals to different elements of the array is practically intractable. For this reason, the majority of experimental efforts has focused to date on topological insulators that do not break time-reversal symmetry, which however as mentioned above do not provide full immunity against backscattering.

Here, it is proposed that robust nonreciprocal topological insulators are possible to be realized in a practically feasible fashion through biasing with circularly polarized waves. Circular polarization carries non-zero angular momentum, thus satisfying the conditions of Onsager-Casimir principle for breaking reciprocity. It will be shown that a system where this effect can be achieved is a hexagonal array of wye resonators with 120 deg rotational symmetry on top of a grounded dielectric substrate. Due to their rotational symmetry, resonators of this type support degenerate modes rotating in opposite directions. This fact combined with the hexagonal symmetry of the array, ensures the existence of a doubly-degenerate Dirac point. It will be shown that it is possible to break this degeneracy and achieve non-trivial topological properties, if the wye resonators are loaded with varactors and the array is illuminated with a circularly-polarized wave. It will be shown that this form of biasing results in modulation equivalent to the angular-momentum biasing approach, with modulation phases of 0, 120 and 240 deg on the three branches of the wye resonators, however without the need of an elaborate modulation network delivering different modulation signals to different parts of the array. Furthermore, it will be shown that the topological properties of the array can be fully reversed by reversing the polarization direction. The proposed approach constitutes a novel and practically feasible way to realize the exciting concept of topological insulators, with applications in the design of integrated nonreciprocal devices and tunable signal processing networks.