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Topological Classification of Dispersive Photonic Crystals

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In recent years there has been a great interest in topological systems and in their peculiar properties. The application of topological methods to optics was largely inspired by the physics of the quantum Hall effect [1]. Topological optical systems may allow for the propagation of light with suppressed back-scattering and may enable a more efficient light transport weakly sensitive to imperfections and non-idealities.

The Chern topological numbers of a material system are usually written in terms of the Bloch eigenmodes. The calculation of the Chern invariants can be a rather challenging computational problem. It generally requires finding the photonic band structure and all the Bloch states in the Brillouin zone. The problem is especially complex in the case of periodic systems, e.g., nonreciprocal photonic crystals. In a recent work [2] it was demonstrated that the gap Chern numbers can alternatively be written in terms of the system Green's function. This theory does not require any detailed knowledge of the band structure or of the Bloch eigenstates [2-4].

Photonic systems are characterized by a few peculiar features not found in their electronic counterparts. The first of such properties is related to the unavoidable material dispersion, as the dielectric function varies with frequency. The second relevant property is the particle-hole symmetry inherited from the reality of the electromagnetic field: the spectrum is formed by positive and negative frequencies. In this talk, we will highlight that these properties may lead to situations where the usual topological methods break-down and the Chern topology becomes ill-defined. We will discuss two different regularization methods to fix the ill-defined topologies of dispersive photonic crystals. It will be shown using the Green's function method that the regularized topologies may depend critically on the response of the bulk materials for large wave vectors and that it is essential to take into account the nonlocal effects in the bulk-materials to have a well-defined photonic topology.

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3. F. R. Prudêncio, and M. G. Silveirinha, "First Principles Calculation of the Topological Phases of the Photonic Haldane Model," *Symmetry*, **13**, 11, 2021, pp. 2229 - 2229, doi: 10.3390/sym13112229.

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