PHOTONICS Research

Topological photonics and beyond: introduction

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Topological photonics has been opening exciting opportunities in recent optics research. In this feature issue, we present a collection of papers outlining state-of-the-art and application perspectives for this thriving field of research.

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Topological photonics has been raising significant interest in the past years, due to the exciting fundamental advances it has unveiled in the way we can control light with engineered materials, and for the broad opportunities it has opened for applications. This field of research has taken inspiration from recent advances in condensed matter physics highlighting the important connections between the topological features of the band diagram of an infinite medium and the electronic response of a finite sample of such material. In particular, topological insulators are a class of insulating materials whose bandgap has nontrivial topological features, based on which robust conduction properties are expected across the entire bandgap at the boundaries of any finite sample of such material. Their inherent robustness is rooted into these topological features, which are not affected by continuous perturbations and disorder, and by the underlying symmetry protection that drives the nontrivial topology.

In photonics, these concepts have spurred significant excitement in recent years, showcasing various ways to exploit pseudospins for photons in engineered metamaterials that can imprint similar topological order in tailored bandgaps, and therefore enable unusually robust light propagation along arbitrary boundaries, while forbidding propagation in the bulk. The key advantages enabled by topological photonic concepts are the inherent robustness to disorder and continuous perturbations, and the reconfigurability of their response by tailoring the pseudospin distribution across the device. Recent research in this area has shown how these analogies between condensed matter physics and photonics can be extended to implement various forms of topological order for photons, including higher-order topological insulators, Weyl points, Floquet topological insulators, and others. In turn, these discoveries have led to remarkable new nanophotonic devices with unusual robustness, such as reconfigurable waveguides, nonreciprocal transport robust to disorder, quantum optics, and robust lasing.

The intention of this feature issue is to provide a snapshot and overview of the recent advances in this thriving field of research. We feature six papers, by some of the leading experts in the field, covering various aspects of topological photonics research, with an outlook to future perspectives, showcasing different aspects in which these concepts are offering new degrees of freedom. These include topological phase transitions between small and large valley Chern numbers in a photonic crystal [1]; a weak-measurement scheme to enhance optical signatures in topological phase transitions [2]; dynamically modulated nonlinear ring resonators that can be designed to possess local interactions in a synthetic frequency dimension and may be used to study topological phases not accessible with non-interacting systems [3]; robust propagation of photonic quantum states through a coupled-resonator waveguide with helical spin-momentum locked dispersion by breaking time-reversal symmetry [4]; coherent energy transfer between distant donor and acceptor with topological edge states and corner cavities [5]; the photonic analogue of two-particle quantum walks in topological arrays [6]. In addition, Xuefan Yin and Chao Peng have contributed an invited review article introducing recent progresses on light manipulation in topological photonic systems [7].

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