Localized States in Nonlinear and Topological Photonic Systems

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We study nonlinear effects in topological photonic lattices of different configurations. First, we focus on the propagation of slowly-varying wavepackets along the topological domain walls in nonlinear photonic valley-Hall insulators [1]. As a specific example, we consider a dimerized graphene lattice composed of single-mode dielectric waveguides with local nondispersive Kerr nonlinearity. In the continuum limit, the evolution of a spinor wavefunction in such a system is governed by the nonlinear Dirac equations [2]. It is theoretically demonstrated that the evolution of finite wavepackets propagating along the domain wall is accompanied by steepening of the trailing wavefront up to the development of a gradient catastrophe. To illustrate this key effect, we also perform numerical modeling of the temporal dynamics of edge wavepackets. Taking the weak spatial dispersion into account stipulates the formation of stable edge quasi-solitons. Our results are validated by full-wave numerical modeling of beam propagation along a valley-Hall domain wall in realistic staggered honeycomb lattices of laser-written waveguides.

Next, we consider the nonlinear instabilities, developing in the presence of intense laser pulses in a topological photonic lattices [3,4]. We show that scenarios of the development of modulation instability in a chiral square lattice with the Kerr-type nonlinearity are determined by the topological properties of its energy bands [3]. Analysing the modulation instability makes it possible to distinguish the topology of the band structure (whether it is trivial or nontrivial). A number of vortex formations (singularities) emerging in polarization textures as a result of the instability development is quantized, that can be directly used to extract the topological invariant, namely, the Chern number. Finally, we study how to utilize the nonlinear propagation dynamics of bulk states to distinguish topological phases of slowly driven Floquet lattices [4]. We propose a scheme to identify dynamical symmetry inversion points using the nonlinear dynamics of nonstationary superposition states and, thereby, distinguish the anomalous Floquet phases from the trivial phase.

References

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