Synthetic magnets, spins, and dimensions: Topological phases in nanophotonics and nanophononics

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The fascinating properties of electronic topological insulators have inspired the investigation of analogous effects for bosonic degrees of freedom such as light and sound [1,2]. The idea of topological protection is especially appealing for photons and phonons in nanoscale, chip-based platforms, due to their rich application potential and the importance of disorder. However, the absence of magnetic-field interactions and Kramers degenacy necessitates the pursuit of alternative mechanisms for bosons than the well-known quantum (spin) Hall effects. In this tutorial, I will discuss several alternative mechanisms, placing special emphasis on experimental implementations.

First, I discuss the creation of topological insulators based on the tailored breaking of crystal symmetries [3]. As this requires only passive, structured media, it is especially suited to be realized in two-dimensional photonic and phononic crystals. With full control over unit cell geometries, this concept offers a lot of versatility to design effective material properties at will and observe various kinds of topological states [4,5], while their bosonic nature also presents some important limitations and differences with respect to electronic alternatives.

Second, we take a look at suitable forms of spatiotemporal modulation to effectively break time-reversal symmetry and create synthetic magnetic fields for light and sound [6]. As an interesting testbed, we consider optomechanical systems, where multiple coupled optical and mechanical resonators, interacting through radiation pressure and controlled through laser fields, can be configured to emulate physics similar to the quantum Hall effect [7,8]. I will discuss future opportunities in this area, and specifically highlight the special properties that emerge when combining breaking of time-reversal symmetry with controlled amplification and damping, to induce non-Hermitian topological phases with new properties.

References

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