PHOTONIC STRUCTURES

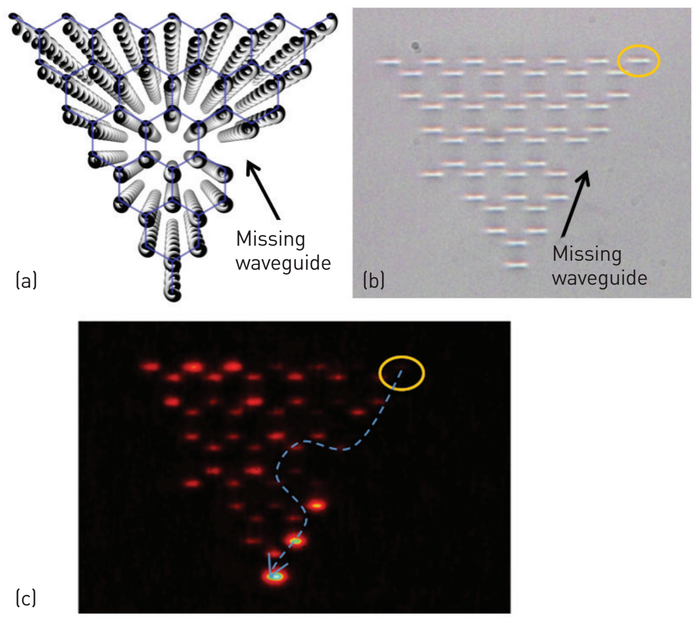
Photonic Topological Insulators

Topological insulators (TIs) insulate in their bulk and conduct electricity on their surfaces. In 2-D TIs, the edge current has scatter-free propagation, making it extremely robust. Perhaps the most intriguing feature of this new class of solids is that their physical properties are related to topological quantities rather than geometric ones, meaning they are not affected by small perturbations. Besides their impact on fundamental science, TIs may lead to sophisticated applications in quantum devices and spintronics.

Earlier this year, we formulated a proof-of-concept experiment demonstrating topological robustness in optical physics.[1] The concept of topological protection of electromagnetic radiation was put forward by Haldane, and experimentally demonstrated by Soljacic's group.[3] However, their approach relied on the strong gyromagnetic response only achievable in the microwave regime.[2] We needed a new methodology in order to scale down and observe the topological protection of light. That is why we used Floquet TIs. Pioneered by two condensed matter physics groups, Floquet TIs temporally modulate a solid in order to give a preferred direction in time—i.e., to break time-reversal symmetry or Lorentz reciprocity.[3,4] Fan's group proposed similar concepts in order to make optical isolators.[5]

We used waveguides in a honeycomb lattice. The propagation dynamics therein can be described by a paraxial Schrödinger equation, where the spatial coordinate, z, takes the place of time. By making the waveguides helical instead of straight, we effectively broke z-reciprocity and allowed for scatter-free edge states, and thus, we could directly observe light transport around corners without backscattering. We also observed light travel around strong defects without disruption. Furthermore, our experiments showed edge confinement consistent with topological insulation. This constituted a remarkable demonstration of a Floquet TI in a physical system as well as an optical topological insulator.

The proof-of-concept experiment has raised many more questions: How much can we perturb these systems before we break topological insulation? Do solitons exist in the TI gap? Are delocalized states possible in a disordered photonic TI? How will entangled photons behave? These are questions that are easier to answer or only possible to answer in photonic systems. We can see many applications and fundamental phenomena for this strange robustness for photons. OPN



(a) Observation of photonic topological protection in a honeycomb array of waveguides with a 15 μm neighbor distance and 8 μm helix radius. (b) A missing waveguide at the edge acts as a defect; yellow indicates the waveguide with injected light. (c) Injected light moves clockwise and avoids the defect. Backscattering is suppressed due to topological protection.

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