Observation of Edge States in Nanoscale Topological Photonic Crystals

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1. Introduction

Topological photonics is a burgeoning subfield of optics, inspired by the discovery of topological insulators in condensed matter [1]. A striking feature of such materials is the existence of edge modes robust against disorder. Such modes are particularly attractive for chip-scale nanophotonic systems for telecommunications [2]. Another appeal is that directional edge states can be interfaced with quantum emitters to realize novel many-body systems such as the fractional quantum Hall state [3]. Building upon previous work [4], we present a new design for an all-dielectric nanoscale topological photonic crystal and present experimental results consistent with the existence of edge states.

2. Theory and Simulations

Our proposed photonic crystal design starts with a honeycomb lattice of triangular air holes in a dielectric material [Fig. 1(a)]. This can be considered a triangular lattice of hexagonal clusters of six holes, whose band structure gives rise to Dirac points. From this base design, shrinking and expanding the hexagonal clusters opens a band gap at the Dirac point [5]. The eigenstates at this point shows a band inversion, indicative of non-trivial band topology.

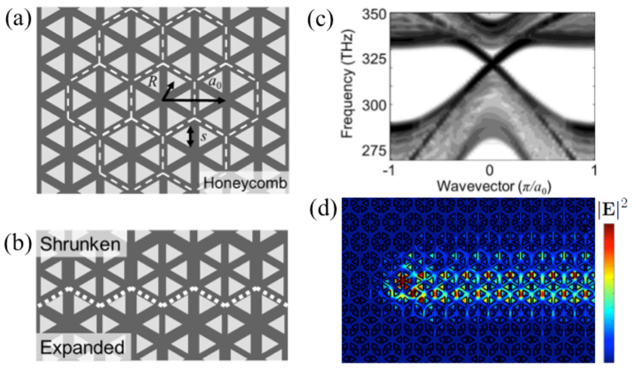

Figure 1: (a) Honeycomb lattice of triangular holes. (b) Boundary of shrunken and expanded region supports topological edge states. (c) Band structure of the geometry in (b). (d) Finite-difference time-domain simulation shows directional edge states.

Such a non-trivial band topology means that the boundary between shrunken and expanded regions [Fig. 1(b)] gives rise to topological edge states. A band structure calculation of this system [Fig. 1(c)] shows edge bands crossing the band gap. We further performed finite-difference time-domain simulations and showed that it is possible to excite directional edge states, where the in-plane polarization of the electric field acts as the pseudo-spin [Fig. 1(d)]. The parameters used are a_0=445 nm, s=140 nm, dielectric constant ε=13.1 and thickness h=160 nm.

3. Experimental Results

We nanofabricated our proposed design in an InP wafer embedded with InAs quantum dots [Fig. 2(a)]. The dimensions are a_0=900 nm, s=300 nm, and thickness h=280 nm. We then measured the transmission spectrum of the topological photonic crystal waveguide by shining 780 nm light at the grating G1 to excite the InAs quantum dots, and collected the transmission of the emitted light at the second grating G2 [Fig. 2(b)], where the edge transmission band is consistent with simulation results.

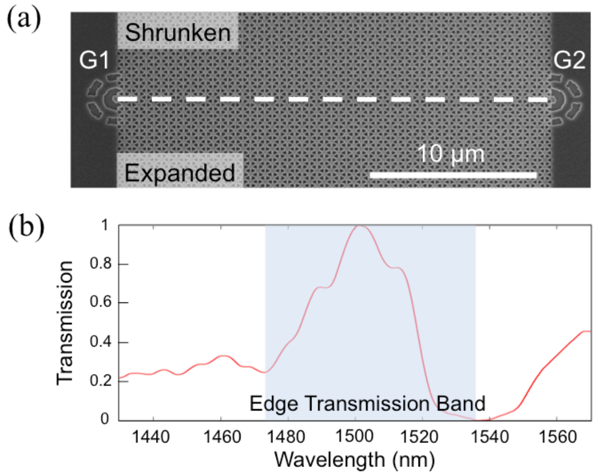

Figure 2: (a) Scanning electron microscope image of a nanofabricated topological photonic crystal waveguide in InP. White dashed line indicates the waveguide region. (b) Transmission spectrum of the structure in (a), consistent with edge states.

4. Conclusions

We present a novel all-dielectric nanoscale photonic crystal design that gives rise to topologically robust edge states, and show experimental transmission spectra consistent with such states.

References

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