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Transmission Experiments on Photonic-Crystal Waveguides
With a Symmetry-Protected Dirac Point

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Abstract: Slow-light photonic-crystal waveguides suffer from Anderson localization and propagation losses due to fabrication imperfections. Here we investigate a novel photonic system exhibiting a symmetry-protected two-dimensional Dirac-point feature and observe a >50-fold group-velocity slowdown.

OCIS codes: (220.0220) Optical design and fabrication; (230.5298) Photonic crystals.

1. Introduction

Topological insulators holds promise of developing robust devices for various quantum applications. The highlight of these devices is the topologically protected degeneracy points (Dirac-points), which in special cases are immune to disorder-related backscattering. These concepts may find important applications in photonics [1] where backscattering from imperfections is prevalent in particular in one-dimensional systems, which suffer from Anderson localization [2]. Photonic-crystal waveguides have long been a contender for realizing slow-light phenomena. However, as light is slowed down, so is the sensitivity to inevitable fabrication disorder. Here we study a photonic system inspired by topological insulators. In this type of waveguide, the existence of the Dirac point is protected by a glide-plane symmetry, which exists along the propagation direction [3,4]. Although disorder would in general break the glide-plane symmetry, it remains an open question to what extent disorder-robust transmission can be observed in this system.

2. Design

A schematic of the glide-plane waveguide and the numerically calculated dispersion diagram are shown in Fig. 1. The key idea is to shift the lower half of the photonic-crystal cladding by half a lattice constant along the propagation direction, which leads to a Dirac point in the dispersion relation [3]. Further, a single-mode waveguide band has been constructed by engineering the photonic-crystal structure, i.e., by changing the size and position of the holes around the waveguide section [5].

Figure 1. (a) A schematic of the glide-plane waveguide configuration. Note that the lower half of the crystal lattice is shifted along the waveguide axis by half a lattice constant, indicated by blue arrows. The unit cell is highlighted in the red box. (b) The photonic-crystal waveguide dispersion curve incorporating the glide-plane symmetry design. The Dirac-point is highlighted by the red circle. (c) The group index versus frequency.
3. Results

Figure 2 shows a scanning electron micrograph of the dispersion-engineered glide-plane photonic-crystal waveguide fabricated using a silicon-on-insulator platform, which enables us to fabricate a membrane structure. This is done using 100 kV e-beam lithography for patterning the nanostructures, followed by dry and selective wet etching. The high refractive index of silicon and the photonic-crystal structure ensure a strong confinement of the waveguide modes both vertically and in-plane. The low material loss along with the mature fabrication techniques make silicon an excellent candidate to study slow-light effects.

We measure the transmission spectrum for various lengths of the waveguides and analyze the Fabry-Perot fringes. From this, we extract the group index, which is in line with theoretical predictions as seen in Fig. 3 although we note that the theoretical curve has been shifted by 19.5 nm to take a nanometer-scale offsets in hole radii and membrane thickness into account. Notably, we observe a 50-fold increase in the group index.

4. Conclusion and future work

In conclusion, we have demonstrated significant slow-down of light in photonic-crystal waveguides with glide-plane symmetry, which makes them promising candidates for slow-light technology. The high group indices observed in our samples highlights the promising prospects of using glide-plane waveguides for studying chiral quantum optics [6], where the slow-light effect translates into an enhanced light-matter interaction. We are currently carrying out systematic investigations of the losses in the glide-plane waveguides to facilitate a direct comparison to conventional waveguides.

5. References


