Silicon Topological Photonic Bandpass/Notch Filter

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Abstract: By constructing waveguides and triangular microloops with two types of valley photonic crystals, we experimentally demonstrate a topological photonic bandpass/notch filter in the telecom band on the SOI platform.

OCIS codes: (160.5298) Photonic crystals; (130.3120) Integrated optics devices.

1. Introduction

Topological photonics provides a novel approach to implement topologically robust transport of light. In the early days of topological photonics, it was realized in the gyrotropic photonic crystals (PCs) under a strong magnetic field [1] and in the bianisotropic PCs composed of metamaterials [2] at the microwave wavelengths. Recently, valley photonic crystals (VPCs) emerge as a promising platform for studying topological photonics with non-magnetic all-dielectric structures and most importantly in the telecom band [3]. In this paper, we propose and experimentally demonstrate a silicon topological photonic bandpass/notch filter by employing the VPCs proposed in [4], and utilizing the edge modes in the topological photonic crystals (TPCs) that can pass sharp bends without backscattering.

2. Results and Discussions

Figure 1(a) presents the TPC edge formed by two types of VPCs. VPC1 and VPC2 share the same band structure as shown in Fig. 1(b). The band gap covers a wavelength range of 1504.4-1593.7 nm. The H_z field distribution of the edge mode in one period along the x direction is calculated and depicted in Fig. 1(c). By using topological waveguides and triangular microloops based on the edges between the two VPCs, we can build a TPC resonator as shown in Fig. 1(d). To investigate its function, we first simulate the resonator using 3D FDTD methods and plot the on-resonance electric field distribution in Fig. 1(e).

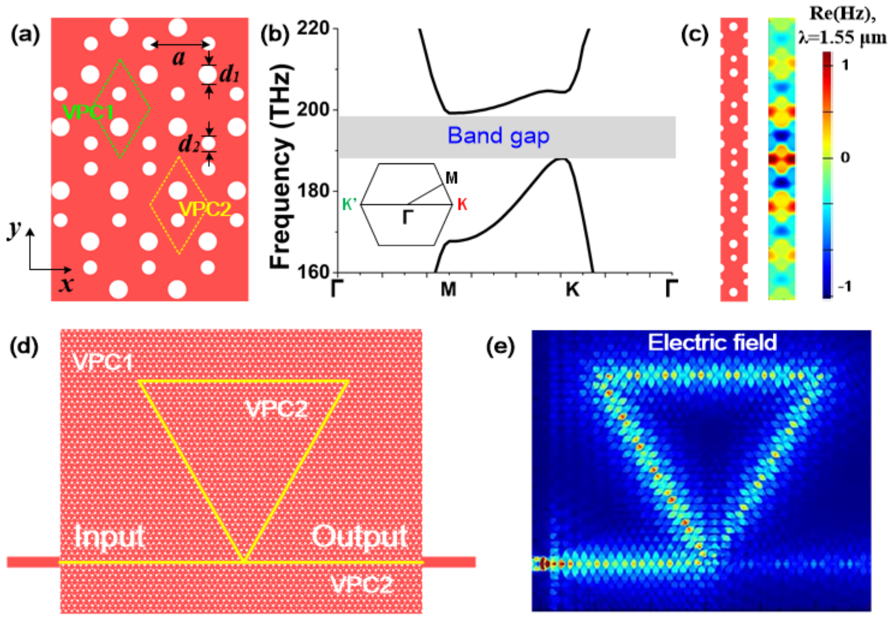

Fig. 1. (a) Topological waveguides formed by two types of VPCs, VPC1 (in the green dashed rhombic circle) and VPC2 (in the yellow dashed rhombic circle). The red and white colors represent silicon and air, respectively. The lattice constant is a = 490 nm. The radii of the big and small holes are $d_1 = 0.26a$ and $d_2 = 0.19a$, respectively. (b) Band structure of the VPCs with the reciprocal space shown in the inset. The band gap is shaded in grey. (c) H_z field distribution of the edge mode in one period along the x direction. (d) Schematic of the topological resonator which consists of a triangular microloop coupled to a straight waveguide (highlighted in yellow). The VPC1 and VPC2 areas are indicated in the figure. The perimeter of the triangular microloop is 96a. The edge mode in the TPC is excited by the TE mode in a 900 nm-wide silicon strip waveguide. (e) Simulated electric field distribution in the TPC when the triangular microloop is on resonance.

Then we construct the TPC bandpass/notch filter by adding a branching edge to the resonator. The micro photo and the SEM image of the device are shown in Fig. 2(a) and 2(b), respectively. The device was fabricated on a SOI wafer (220 nm-thick silicon on 3 μm-thick BOX) by E-beam lithography (Vistec EBPG 5200+) and inductively coupled plasma dry etching (SPTS DRIE-I). The SEM images of the interface between different waveguides and the nanoholes are magnified and shown in Figs. 2(c) and 2(d), respectively. TE-polarized light from a tunable laser (Keysight 81960A) was coupled into and out of the chip by grating couplers. An optical power meter and a photodetector (Keysight 81636B) were employed for optical calibration and receiving the transmitted power, respectively. Figure 2(e) presents the measured transmission spectra at the bandpass and notch ports of the filter, which are normalized to that of a reference grating coupler pair fabricated on the same wafer. The transmission spectra clearly show the bandpass and the notch filtering characteristics wider than C band in a wavelength range of 1520 nm – 1580 nm. The overall insertion losses are lower than 15 dB.

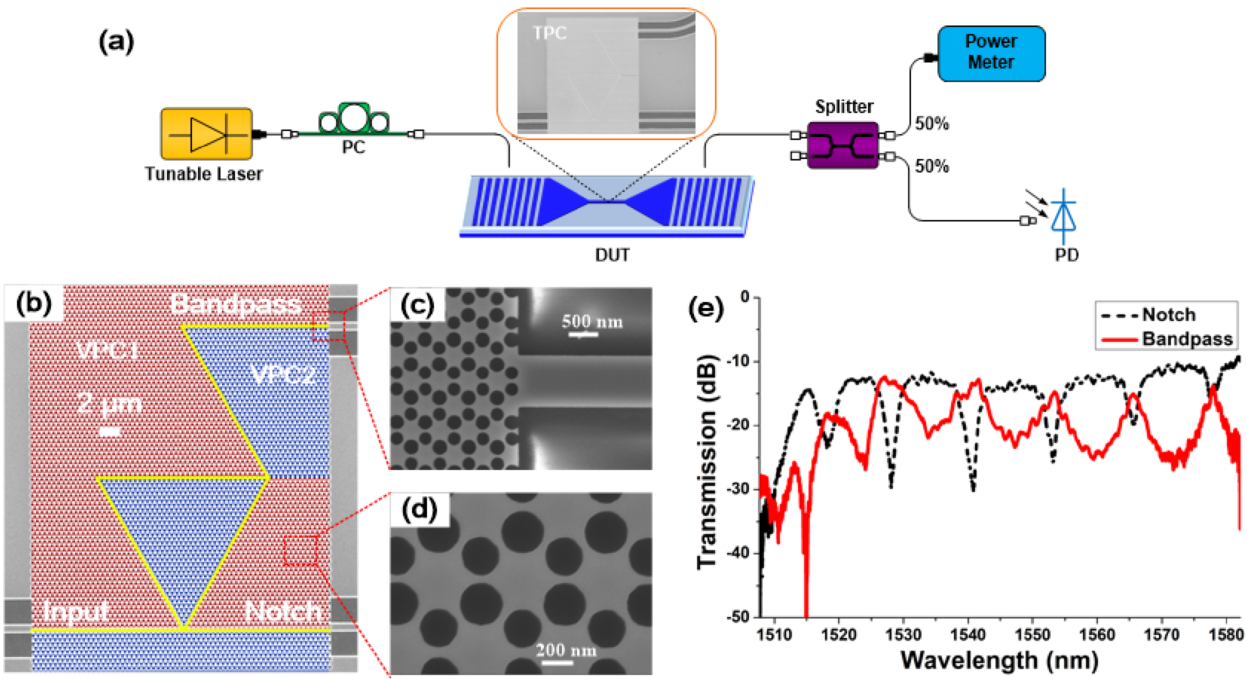

Fig. 2. (a) Schematic of the experimental setup used for the transmission spectrum measurement of the TPC chip. PC: polarization controller, DUT: device under test, PD: photodetector. (b) SEM image of the TPC bandpass/notch filter. The VPC1 and VPC2 areas are shaded in red and blue, respectively. The waveguiding edges are highlighted in yellow. A branching edge waveguide (connected to the bandpass port) is introduced in addition to the resonator structure shown in Fig. 1(d). The other parameters are kept the same. The input, notch and bandpass ports are indicated in the figure. (c, d) Zoom-in SEM images of (c) the interface between the silicon strip waveguide and the topological straight waveguide and (d) the nanoholes composing the TPC devices (circled by two red dashed boxes in Fig. 2(b)). (e) Measured transmission spectra at the notch (black dashed line) and bandpass ports (red solid line) of the fabricated TPC bandpass/notch filter.

3. Conclusion

In conclusion, we have proposed and experimentally demonstrated a silicon topological photonic bandpass/notch filter. Thanks to the robust transport of light in TPCs, highly efficient guiding and trapping of light can be achieved at the nanoscale. Optical bandpass/notch filtering characteristics are observed in a wavelength range of 1520 nm – 1580 nm, with overall insertion losses lower than 15 dB. Our results show potential for implementing complex functional devices enabled by topological photonics.

4. References

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