Light transmission in triangular lattice photonic crystal waveguides with 120-degree sharp bends

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Recently, valley photonic crystals (VPhCs) have been demonstrated in both honeycomb-lattice[1] and triangular-lattice[2][3] structures. When the inversion symmetry is broken, opposite chirality carried by the valley states become observable via various valleyphotonic effects and valley-dependent band topology can be defined in the momentum space. Hence, the broken inversion symmetry is the heart of valley photonic properties. In many of the previous works, one of the methods to verify the valleyphotonic effects is the observation of high transmission through 120-degree sharp bends in valley photonic crystal waveguides (VPhCWGs), which was claimed to result from the backscattering suppression effect of valley-polarized states. Here we investigate the effect of the inversion symmetry for the transmission via bends. We report the observation of high transmission of light through 120-degree sharp bends in trivial photonic crystal waveguides (TPhCWGs) possessing the inversion symmetry.

In this study, we investigate silicon-based slab-type PhCs with air holes arranged in a triangular lattice to construct TE waveguides. When the air holes are circular, the bulk lattice has inversion symmetry. When the air holes have a triangular shape, the inversion symmetry is broken. We conduct a comparison between the TPhCWGs (having the inversion symmetry) and VPhCWGs (without the inversion symmetry) for each of the following interface types: bearded interface, zigzag interface, triangular-lattice domain wall, and W1 waveguide. Firstly, we numerically calculated the transmittance spectra in a two-dimensional model in COMSOL. The Z-shaped bearded-interface VPhCWG shows high transmission (a red curve) within the single-mode region (colored yellow) as shown in Fig. 1(a). This high transmission is comparable to that in other VPhCWGs reported in the previous works. In fact, this waveguide is equivalent to a honeycomb-lattice VPhCWG with large breaking-symmetry perturbation in the hole sizes (one sublattice vanishes). The Z-shaped W1WG, in comparison, shows low transmission (Fig1 (b), a red curve). By changing the hole shape from triangle to circle, the waveguides in (a) are converted to the waveguides in (c), the bearded-interface TPhCWG with inversion symmetry. Surprisingly, the Z-shaped TPhCWG shows high transmission in the same mode in spite of the presence of the inversion symmetry. Figure 1 (d) shows the H_z field profile at a high-transmission frequency. We also investigated waveguides of other interface types in the same manner, and found that the presence of the inversion symmetry does not cause significant difference in terms of the Z-shaped bend transmission.

Furthermore, we fabricated straight and multi-bend PhCWGs with and without inversion symmetry and conducted transmittance measurements. We observed high transmission through the multi-bend inversion-symmetric PhCWGs of zigzag interface and triangular-lattice domain wall. The experimental results are consistent with the calculation results. The detail will be discussed at the meeting.

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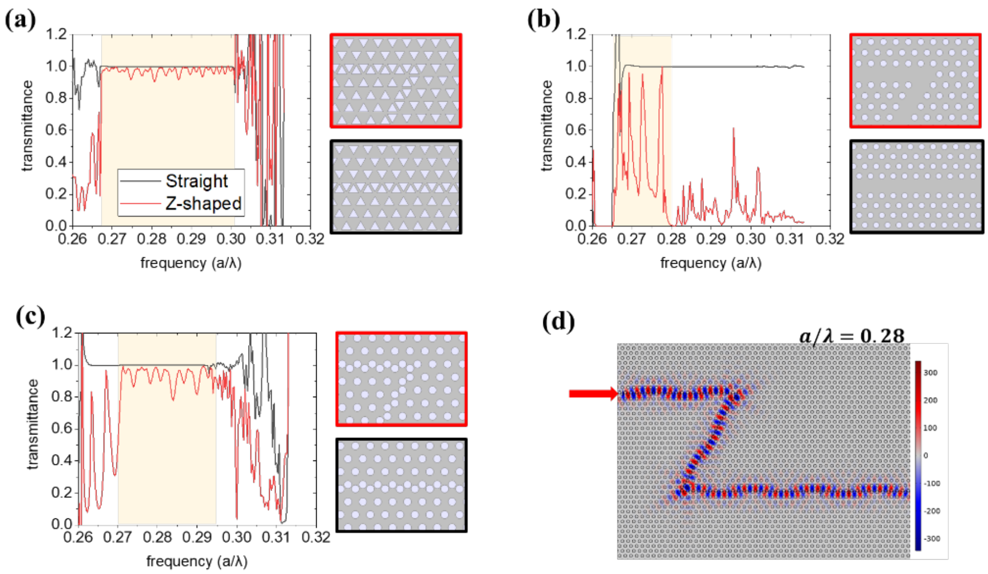

Fig.1 Calculated transmittance spectra of (a) bearded interface VPhCWGs, (b) W1WGs and (c) bearded interface TPhCWGs, red for Z-shaped waveguides and black for straight waveguides. (d) The out-of-plane magnetic field component of light traveling through the Z-shaped TPhCWG in (c), at the frequency $a/\lambda = 0.28$.