WAVEGUIDE BEND FILTER APPLICATION OF 2-D PHOTONIC CRYSTAL

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Chalcogenide photonic crystals of square lattice with defect is described as a waveguide bend filter application. This filter bend has been developed to insert a point defect in a perfect waveguide bend and it has high transmission of a resonance frequency of defect mode. The resonant point defect has properties to allow or stop narrow frequency mode with high quality factor. It also has been analyzed that chalcogenide As_2S_3 is more useful over Si materials.

(Received October 7, 2010; accepted December 21, 2010)

Keywords: Chalcogenide, Photonic crystal, Waveguide, Filter etc.

1. Introduction

Photonic crystals (PCs) [1] are flexible and competent tools that control the propagation of light in optical media by allowing light to propagate over a desired range of frequencies. Novel concepts have been proposed, and various new applications of PC have been predicted, *e.g.* optical cavity, waveguide, optical filters, beam splitters, channel demultiplexers, and optical switches [2-4] based on two-dimensional photonic crystal waveguide (PCW). Among them, the optical filter is an important for the applications in optical circuits and optical communication.

Mostly, Photonic Crystals have been made from Si or III–V semiconductors. While their active functions have typically exploited thermal or free-carrier nonlinear effects, both of which are relatively slow [5]. Chalcogenides have generated great deal of interest due to their attractive properties: can be formed over a large range of compositions; refractive index is high, linear absorption losses are low over a wide wavelength range and a large $\chi^{(3)}$ nonlinearity. Chalcogenide glasses have attracted significant attention in recent years as a promising nonlinear material for all-optical devices [6]. Now, Chalcogenide glasses offer an important alternative to silicon as a nonlinear material with which to realize all-optical photonic devices.

In the present paper, the waveguide bend filter is described as line defect waveguides along with point defect in chalcogenide photonic crystal of square lattice. The field distribution patterns for that are studied.

2. Theoretical method

As photonic band-gap (PBG) system, we consider a square lattice of As_2S_3 chalcogenide rods in air, as shown in figure 1. The refractive index of As_2S_3 chalcogenide is 2.405 and the radius of rod is $r = 0.2a$, where a is the lattice constant. One waveguide has been created by removing one row of chalcogenide rods. The band gap for chalcogenide As_2S_3/air PBG system in the frequency range is from 0.38456 to 0.4641 (in unit: $\omega a/2\pi c$) for TM-mode [7, 8].

Waveguides in the 2D photonic crystal are studied in the present paper by a "finite-difference time-domain (FDTD) method [9] with perfectly matched layer (PML). In the present paper, we use the FDTD method with a computational domain of 25x25 lattice constants (total 625 unit cells). The waveguides are along the direction of the longer side of the computational domain. Each unit cell contains 441 (21x21) discretization grid points for the FDTD time-stepping formulas. The computation domain is surrounded by PML. The total number of time steps is 10,000 with each time step $\Delta t=0.99/c\sqrt{\Delta x^2+\Delta y^2}$, where c is the speed of light, Δx and Δy are space intervals.

A pulse source is located at the input access waveguide. The source is the product of the Gaussian function and the exact solution (at the center frequency) of the guided mode in the access waveguide. Moreover, one can easily normalize the transmission spectra, by comparing the energy flow (Poynting vector) through the output port with that without PC waveguides in between.

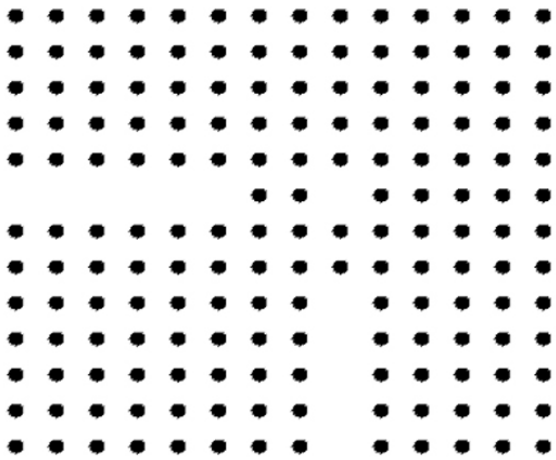


Fig. 1 . The schematic diagram of 2-D chalcogenide photonic crystal as waveguide bend filter.

3. Results and discussion

The waveguide bend filter device is form to create a point defect by absence a single rod, in adjacent to two waveguide perpendicular to each other, also each of which is formed by the absence of a row of rods. The Normalized transmission power is plotted for 2D PC of square lattice for above model of waveguide bend filter system in figure 2. This spectrum exhibits several important features, most notable a sharp peak precisely centered at the resonance cavity mode frequency 0.43 (in unit $\omega a/2\pi c$). This sharp peak can be used as waveguide bend filter applications.

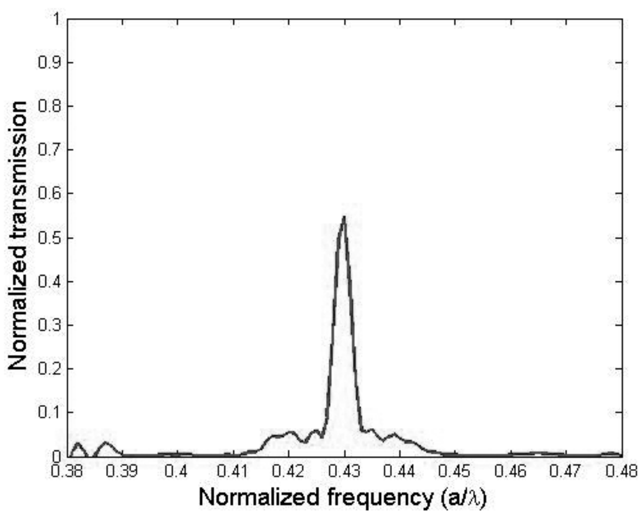
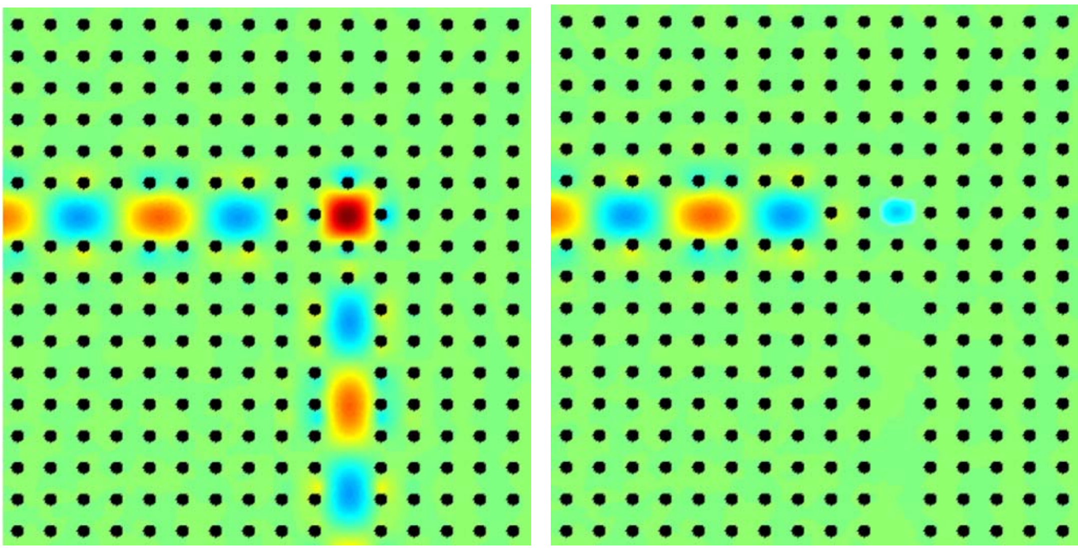


Fig. 2. The transmission at output port of 2-D chalcogenide As_2S_3 photonic crystal as waveguide bend filter.

The existence of the resonance peak conforms to intuition: near the resonance frequency, the light form the input waveguide can couple into the cavity, and the cavity in turn can couple into the output waveguide. At the high and low frequencies correspond to outside the bandgap, the energy propagates through the photonic crystal instead of being confined to the waveguide and cavity. The field distribution pattern for transmission at resonance is shown in the below figure 3(a). If the frequency is shifted by only 1% the transmission drops almost 2%, corresponding to the field at the center of peak. The fractional width $\Delta\omega/\omega_0$ at half maximum is precisely equal to $1/Q$, where Q is the quality factor of the cavity mode. The quality factor Q for this case is equal to 115. When the input light frequency is not similar to the resonance frequency of cavity mode frequency, is not allow propagating further. The field distribution pattern for transmission different from the resonance frequency is shown in below figure 3(b).



(a) (b)

Fig. 3. The field distribution diagram for 2-D chalcogenide As_2S_3 photonic crystal as waveguide bend filter at (a) Normalized frequency 0.43 and (b) Normalized frequency 0.40.

In low contrast optical fiber, a bend radius of less than a few centimeters will result in nearly complete radiation loss. The same thing will happen in case of ordinary dielectric waveguide bend or branch. Whereas the situation is changed in case of photonic crystal waveguide because of the photonic bandgap prohibits radiation losses [1]. As it is known that two-photon absorption has been long recognized as a serious problem for all-optical signal processing [10]. The suitability of a material for all-optical processing is characterized by a nonlinear figure of merit, $T = n_2/\beta\lambda$ where β is the two-photon absorption coefficient and λ the wavelength. Chalcogenide glasses exhibit a T greater than 2 and more often greater than 10. Furthermore, in some materials, two-photon absorption results in the production of free carriers with long lifetimes [11], which slows the response time of the nonlinear interaction and limits its usefulness. Silicon is an example of a material with high two-photon absorption ($T \approx 0.4$). The free carriers generated in silicon cause a large rise in the linear absorption, which is an additional problem. Therefore, chalcogenide glasses have an attractive material for recent interest in photonic crystal devices applications.

4. Conclusions

In the present paper, it is found that the waveguide bend filter device has high transmission power at output signal at resonance frequency mode and rest of the bandgap region not allowed signal. It can be used as narrow band region filter application along with the bend on light at sharp 90^0 angle with the input light wave. The chalcogenide As_2S_3 has the advantage over Si for all optical propagation application devices.

Acknowledgement

One of us (B. Suthar) is thankful to CSIR, New Delhi for financial support in form of a fellowship.

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