

CHALCOGENIDE PHOTONIC CRYSTALS AS CHANNEL DROP FILTER FOR OPTICAL COMMUNICATION

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A channel drop filter of chalcogenide photonic crystal is studied. This drop filter consist a point defect cavity near an air waveguide in chalcogenide photonic crystal. The drop filter mode is descried with the point defect cavity along with the position of the cavity from air waveguide in chalcogenide photonic crystal.

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1. Introduction

Photonic crystals (PCs) [1] are novel class of optical media represented by natural or artificial structures with periodic modulation of the refractive index. Such optical media have some peculiar properties which gives an opportunity for a number of applications to be implemented on their basis. Photonic structures can be found in nature *i.e.* the beautiful coloration of the Morpho butterfly's wings is caused by a periodic submicron structure within the scale [2, 3]. Of similar origin is the spectacular iridescence of a spine from the sea mouse that produces bright colors with changing the angle of observation [4]. Another famous example of a natural photonic crystal is natural opal [5] with the shining optical properties that are described below.

PCs have attracted much attention for both fundamental and practical point of view in the past two decades. 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 [6-8] based on two-dimensional photonic crystal waveguide (2-D PCW). Among them, the filter is very important for the applications in optical circuits and optical communication.

Chalcogenides have generated a great deal of interest because of their attractive properties: glasses can be formed over a wide range of compositions which allows their optical and mechanical properties to be adjusted for a suitable application; the refractive index is high, typically between 2.4 and 3 (allowing a 2-D photonic bandgap) [9]; linear absorption losses are low over a wide wavelength range (near- to mid-infrared). Two photon absorption and free charge carriers are higher in Si material compared to chalcogenide glasses material [10], which are the advantage of chalcogenide glasses for all optical signal processing applications. The researchers presented that Chalcogenide glass a PC platform [11, 12] appears to be a promising architecture for confining and guiding light at the wavelength scale.

In the present paper, the optical filter is described as a point defect cavity near an air waveguide in chalcogenide photonic crystal of square lattice. This channel drop filter can be used to drop particular frequency signal from input wave, which signal frequency value depends on geometry of defect.

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2. Theory

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 selective coupling is achieved by introducing one resonant point defect cavity nearby the waveguide, obtained by removing a chalcogenide rod as shown in Figure 1. 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 [13].

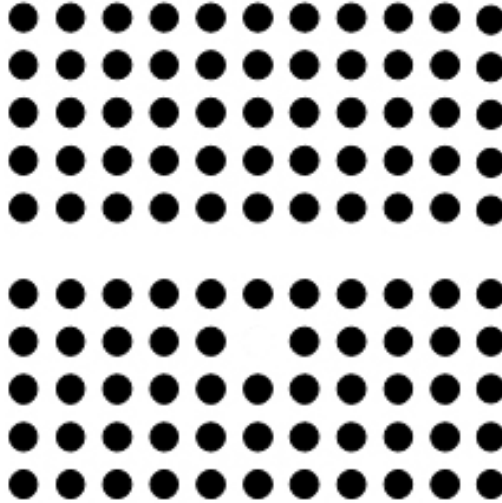


Fig. 1. The schematic diagram of 2-D chalcogenide photonic crystal as optical filter.

Waveguides in the 2D photonic crystal are studied in the present paper by a "finite-difference time-domain (FDTD) method [14] with perfectly matched layer (PML). In the present paper, we use the FDTD method with a computational domain of 30×25 lattice constants (total 750 unit cells). The waveguides are along the direction of the longer side of the computational domain. Each unit cell contains 441 (21×21) discretization grid points for the FDTD time-stepping formulas. The computation domain is surrounded by PML (with 12 layers of the discretization grid). 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 centre 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.

3. Results and discussion

The Normalized transmission spectra are plotted for 2-D chalcogenide PC of square lattice for above model of filter system in Figure 2 with different distances between point defect cavity and air waveguide d . From the figure, it is clearly shown that as the point defect moves far from the air waveguide the quality factor ($Q \sim \Delta\omega/\omega_0$) in drop signal will be increases. When the distance between the point defect and the air waveguide is $d = a$, the wide dip range in transmission just because of huge interaction between the point defect and waveguide. While for $d = 3a$, the transmission rises for drop signal along with the quality factor. Therefore, the distance $d = 2a$ between point defect cavity and air waveguide is more suitable for optical filter applications.

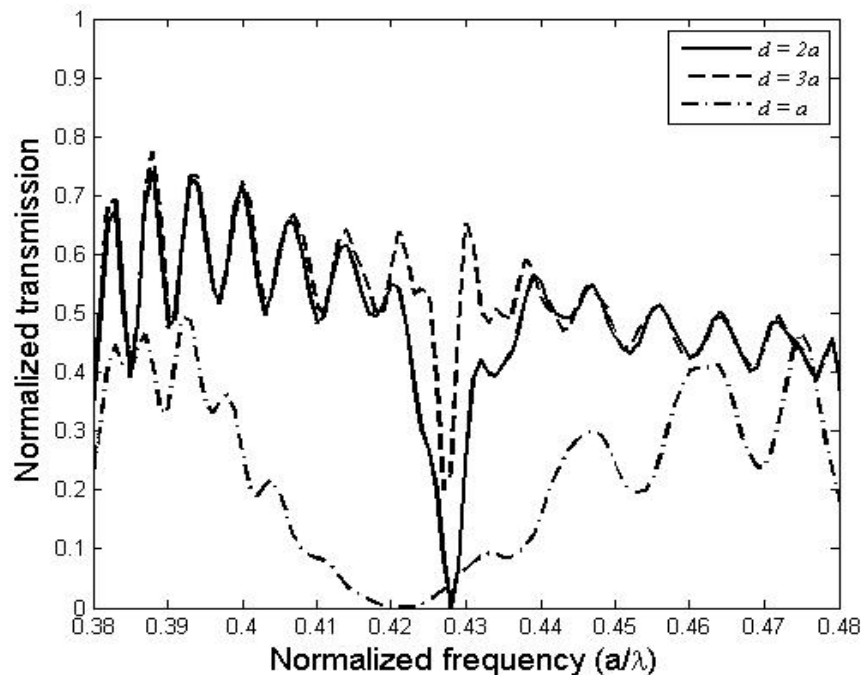


Fig. 2. The transmission at output port of air waveguide of 2-D Chalcogenide PC of As_2S_3 rods in air when a point defect is at distance d from waveguide.

The Band structure diagram for point defect chalcogenide photonic crystal is described in previous study [8]. The point defect introduces a localized mode in PBG region, which is almost flat. So, this doesn't cause direct transmission of light through crystal. It is used to trap light signal in the defect and works as cavities. The frequency of that light signal depends upon the size/dimension of the defect rod/cavity. In this case, when a point defect cavity is associated with an air waveguide then the input signal propagate through air waveguide and coupled with point defect cavity. If the frequency of the input signal is same as the resonant frequency of the point defect cavity, the input light wave couples to the cavity and there in no output power at the output port of waveguide. The effect of the size of point defect cavity on the transmission is plotted in Figure 3.

As the drop filter mode has a frequency in the PBG, it must exponentially decay once it enters the crystal. The frequency of drop filter mode can be controlled by changing size of the defect rod/defect cavity [1, 8]. Photonic crystal waveguide filters exhibiting wavelength selectivity can be realized by coupling a defect cavity to a linear waveguide [15, 16]. An optical filter is very important for the applications in optical circuits and optical communication, and plenty of works have been done on the filter based on one-dimensional and two-dimensional photonic crystal structures.

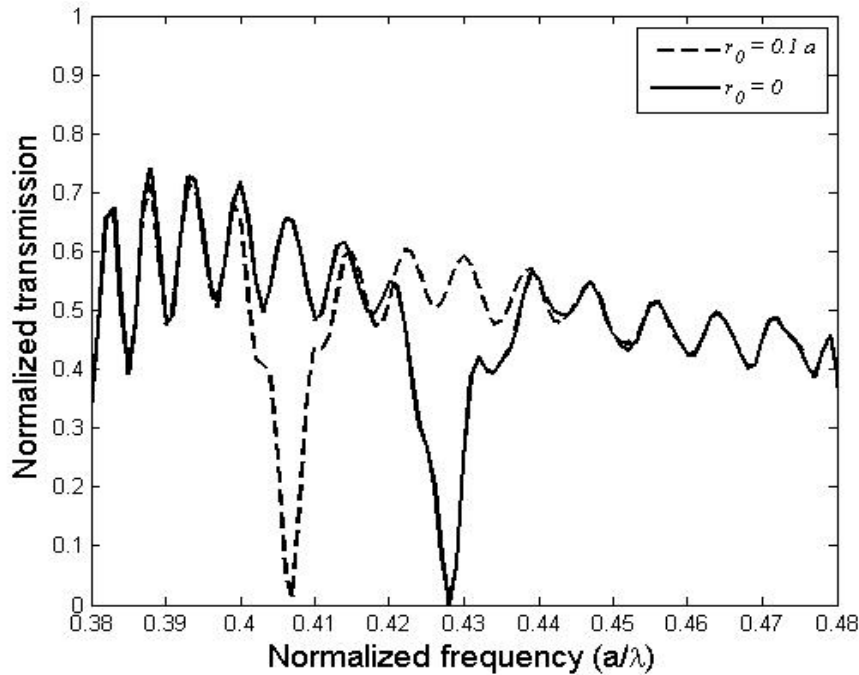


Fig. 3. The transmission at output port of air waveguide of 2-D Chalcogenide PC of As_2S_3 rods in when a point defect associated with waveguide (solid line for $r_0 = 0$ and dashed line for $r_0 = 0.1a$).

4. Conclusions

In the present work, it is found that if the input light wave signal frequency is the same as the resonant frequency of the point defect cavity associated with waveguide, there is no transmission at output port of that waveguide. The position of point defect affects the filter mode in form of quality factor of the drop filter mode, which increases as point defect go away from waveguide. On the other hand, the size of the point defect can be used as frequency of filter mode, which decreases with size of point defect cavity.

Acknowledgments

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