Investigation of Optical Amplification Action in Dielectric Photonic Crystals Cavity Based Structure

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ABSTRACT

In this paper, optical amplification action is studied in a 2D Photonic Crystals (PhCs) cavity-based structure for the near-infrared (NIR) spectral range. The phenomenon is studied by coupling optical energy into the structure from two different optical sources, one acting as a data signal and another as a pump signal. The data signal is amplified in presence of a pump signal depending on the size of the optical cavity. The dielectric PhC structure consists of a slab waveguide sandwiched between a substrate and a cladding layer. The numerical design and simulations are performed in open-source software based on the Finite-difference Time-domain (FDTD) technique. The concluded results show optimum amplification results for a cavity size smaller than the standard size of PhC-elements. The proposed device can be efficiently used in applications requiring optical amplification such as optical switches, transistors, logical gates, and filters.

INTRODUCTION

Advances in technologies, the demand for runtime processing data is increasing exponentially and has made the semiconductor industry reach its breaking point.

Recently, optical technology has been the focus of research as an alternative to electronic technology.

Some crucial phenomena in optical data processing can be amplification and confinement of energy which are essential functions in programmable photonic circuits.

Periodic nanostructures such as photonic crystals (PhCs) are the best fitting candidates for above mentioned requirements with capability to manipulate and control light.

Moreover, PhC structures can work in both, in-plane index-guiding of light and out-of-the-plane coupling of the light exciting the so-called Fano-resonances or Guided-mode Resonances (GMR). This makes them versatile in terms of energy coupling and confinement.

OBJECTIVES

The optical amplification effect is investigated in a PhC cavity-based slab waveguide structure for a NIR spectral range of around 1.55µm.

The amplification effect is investigated using two optical sources acting as the data and the control (pump) signal.

An optical cavity is placed at the start of the PhC structure, and the optical amplification effect is studied by varying the radius of the cavity in an 11 PhC element-based structure.

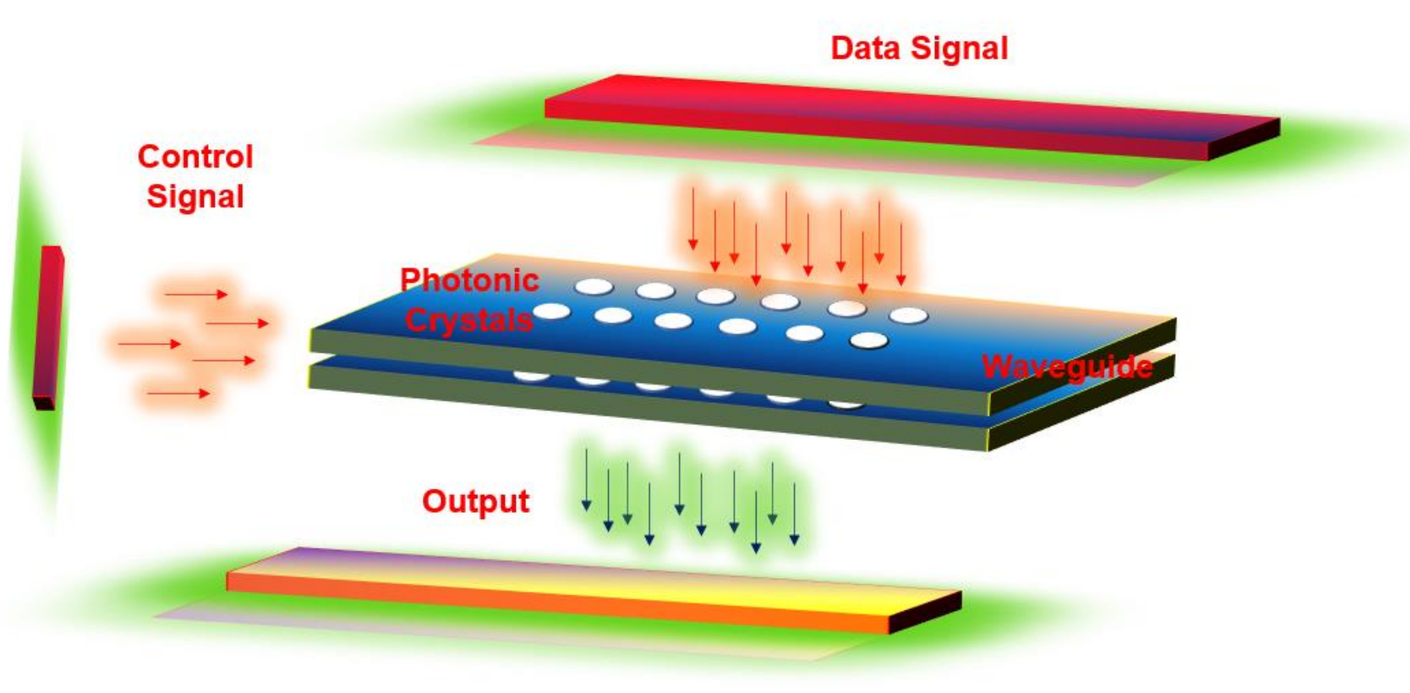
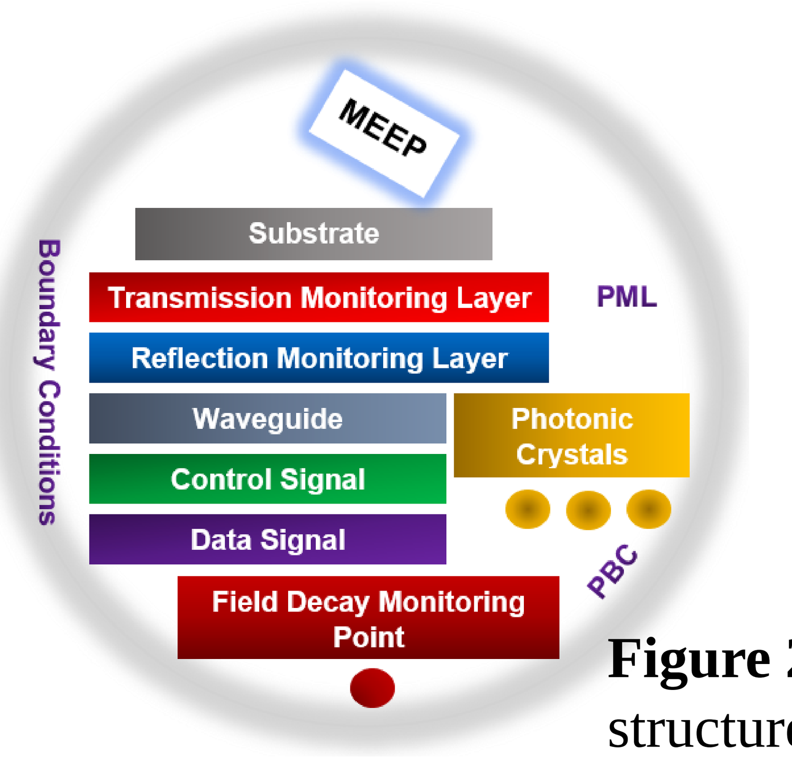


Figure 1. The designed structure of the optical switch

METHODOLOGY

The design of the proposed structures is investigated using the Finite-difference Time-domain (FDTD) approach which works on the solution of Maxwell equations in the time domain to compute the propagation of the EM field using open-source MIT Electromagnetic Equation Propagation (MEEP) software



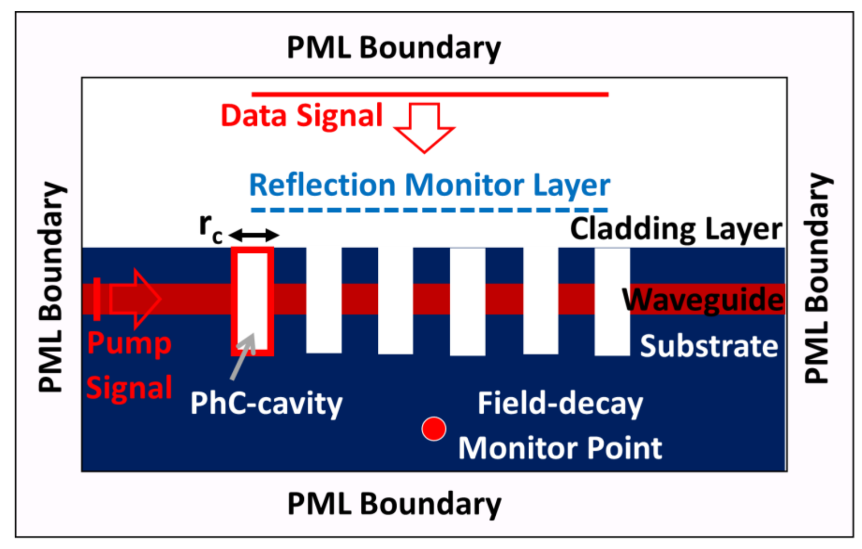


Figure 2. (a) Properties of MEEP (b) Simulated structure of the optical switch

RESULTS AND DISCUSSION

(A) Optimum value of PhC-cavity radius for the data signal

The data signal generated by the excitation source vertically above the substrate is filtered by the PhC structure resulting in a Fano-resonance peak in the reflection spectrum. In order to choose the optimum size of the PhC cavity placed at the start of the PhC membrane to tune the amplification effect. Moreover, is varied from r_c=0.06a to 0.35a as shown in figure (a). Congruently, the change in the reflection peak is reflected in figure (b) w.r.t to increase in the radius of cavity presenting a downward progression.

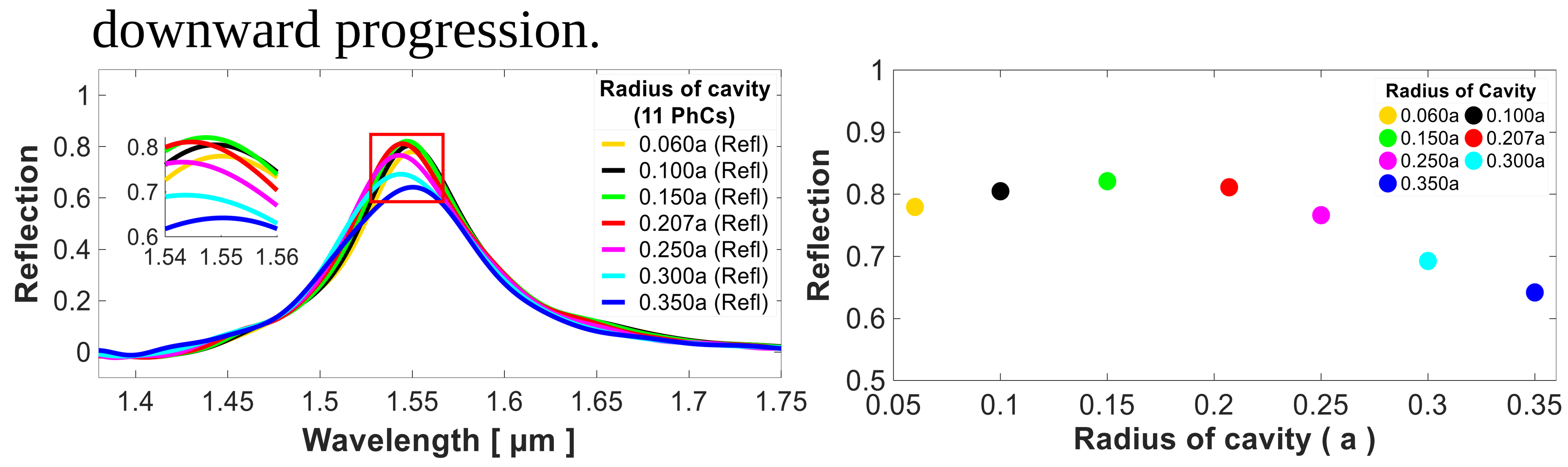


Figure 3. (a) Change in radius of cavity (b) Reflection vs change in radius

(B) Optical amplification effect using the pump source

In this step, the amplification effect is investigated by turning on the data and the pump source simultaneously in order to find out the optimum size of the PhC cavity to get the best results for an optical amplification when the pump source is on. Moreover, three different cavity radius values were chosen i.e. r_c=0.10a, 0.207a, and 0.35a as shown in figure (a) and shows good results for r_c=0.100a and 0.207a. Correspondingly, the figure (b) represents the change in reflection peak when the pump signal is on w.r.t to change in the radius of the cavity.

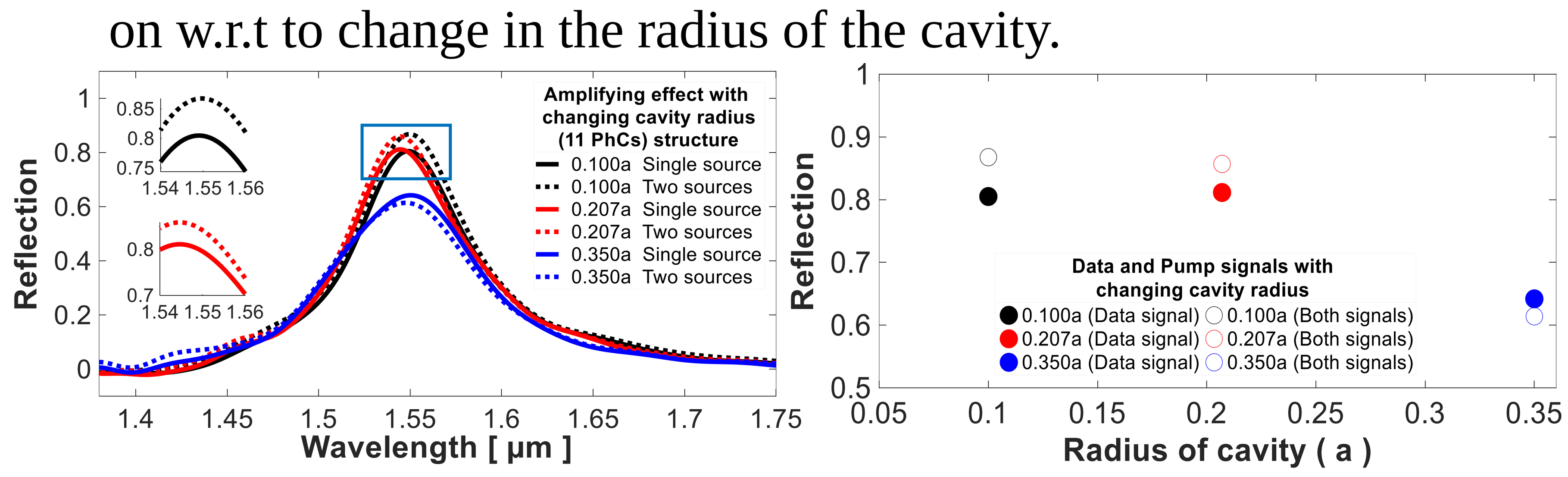


Figure 4. (a) Change in radius of cavity (b) Reflection vs change in radius

CONCLUSION

The PhC-cavity radius is investigated for the data source without implementation of the pump source. In the second step, the optical amplification action is investigated by turning on both of the sources simultaneously.