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Designing of Photonic Crystal Ring Resonator Based ADF at Perpendicular Drop Waveguide

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Abstract- In this paper the two dimensional photonic crystal ring resonator based an add/drop filter with perpendicular drop waveguide has been designed. This designed has been structured with the help of a basic optical based ring resonator. The simulation work has been performed with the help of Opti-FDTD software. The add and drop wavelength of the designed filter obtained was 1340nm and 1550nm respectively.

Keywords- Photonic crystal ring resonator, ring resonator, add/drop filter, FDTD method, photonic band gap.

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I. INTRODUCTION

The photonic crystal is a regular arrangement which consists of dielectric materials. These crystals are basically constructed so that that the transmission of light is influenced and in addition to this it does not allow the travelling of EM waves in every direction inside a defined range of spectrum is called band gap of photonic crystal [1, 2]. In photonic crystal when irregularities like point and line are introduced inside the arrangement then discontinuity occurs and the light is controlled inside the band gap. By implementing these types of characteristics various types of devices based on optics can be designed with photonic crystal as a main material [3].

In research society the photonic crystal based optical components have acquired a remarkable platform as they possess good speed, immense space, tremendous functionality, and long lasting life and along with these they have miniature size. With these properties the device becomes applicable for the construction of integrated circuits [4]. Today there are various types of devices which work on the principle of optics like, multi and de-multiplexers [5], beam splitters [6], add-drop filters [7], channel drop filters [8], sensors, and the list goes on. When the optical technology comes in the field of photonic crystal there has been a tremendous growth in the field of optical communication.

The optical communication is a communication in which luminous is used to exchange data from sender to recipient. The transmitter, channel and a receiver are the three important terms in the field of optical communication. The function of transmitter is to convert the data to an optical signal, a channel is a medium through which information passes, and finally the information is received at the receiver. In this communication network the filter that is used is termed as optical filter, the optical filters are basically those types of filters which have the capability to transmit the selected light in a particular spectrum and prohibiting the remaining ones [9]. The purpose to organize a filter is that it should allow certain signals to pass in specified wavelength while stopping the others. The filters are basically categorized according to property of frequency domain, such as LPF, HPF, BPF, BSF, APF etc.

One of the most important applications of optical filter is a channel drop filter, also the features of optics depend upon the frequency response which defines the modification of a coming signal in respect of magnitude and phase. These filters are also known as wavelength selective filters and also the add/drop filter.

The add/ drop filters which are designed with the help of ring resonator are small in size and the characteristics and the capability posses by these filters can be utilized in complex and adjustable configurations. Basically the ring resonator is an arrangement which is composed of a ring and two waveguides also known as straight waveguides which are coupled to few of the light which is injected and received as shown in figure 1.

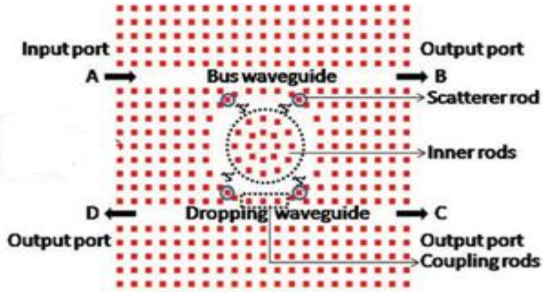

Figure1. Structure of a ring resonator [10]

The working principle of ring resonator states that whenever the light consisting of resonant wavelength moves through the loop from transmitting side of waveguide and because of positive interference it has the ability to make extreme various round trips and the output is received at output waveguide which is also regarded as detector waveguide [10].

In this paper the add/drop filter has been designed with the help of principle of ring resonator and the designed add/drop filter drop the wavelength at 90^0. The PWE and FDTD approaches has been used to compute the band gap and for wavelength computation respectively.

II. LITERATURE REVIEW

Over the last decade Photonic crystals has achieved a remarkable importance and are believed to be a favorable aspirant for their utilization in many propagation network based on optical technology. The research on different equipments based on optics has been undertaken by number of scientists and they have observed and analyzed their nature in various areas. The filters based on this technology have become a crucial subject in the area of research.

Y. Akahane et al. [11], experimentally analyzed that irregularities like donor-type point and line irregularity waveguide are quite applicable in order to enhance the filtering action of a channel add/drop filter in the world of two dimensional photonic crystal. H. Takano et al. [12], introduced a very high Q nano-irregularity for designing the in-plane type CDF which mainly composed of a two port waveguide along with a point irregularity in a photonic crystal slab having a 2D nature. The CDF are a quite useful device for communication purpose in optics. V. D. Kumar et al. [13], demonstrated a ring in which coupling of waveguide exists based on photonic crystal. This type of resonators is quite applicable in filters, routers, switches, de-multiplexers which can be placed in integrated circuits of photonics. Although according to the proposed research paper, there are no such papers which deals with the performance of the ring resonator introduced in the paper. Besides this the authors have also determined the performance of resonance as the resonators are becoming an influencing component in the field of integrated circuits in the technology of photonics. A. Ghafari et al. [14], demonstrated an add/drop filter whose structure has been established with the help of a ring resonator with lattice of square in shape and the coupling has been provided to a duo of waveguide and also there is a coupling at central frequency of resonator wave in uppermost waveguide to one another and this method give rise to a proposed filter.

The proposed filter based on flower shape ring resonator which can be used in the application of wavelength division multiplexing. The below sections of paper includes designing of PCRR add/drop filter, simulation results and discussion.

III. LAYOUT DESIGN PROPOSED ADD/DROP FILTER

In the paper the two different designs has been made with the help of 2D photonic crystal which has been used as a prime material. The basic structure used for designing a filter is photonic crystal square lattice structure with 18*32 silicon rods suspended in air. The radius of a rod, r = 0.108µm whereas the lattice constant, a=540nm. The dielectric constant of the structure is 3.59 and the input optical source wavelength, λ= 1.554µm. The size and the thickness of the structure are 17.5*10 μm^2 and 2µm respectively. For the propagation of wave inside the structure or converting the inhibited band gap into the propagating band, line defect is introduced into the structure in order to break the periodicity of the PCs structure.

In the paper, with the help of the below basic structure we have demonstrated the design of single based ADF at 90^0 drop waveguide, which is an optical filter in a two dimensional (2D) Photonic Crystal and it mainly works on the principle of band gap.

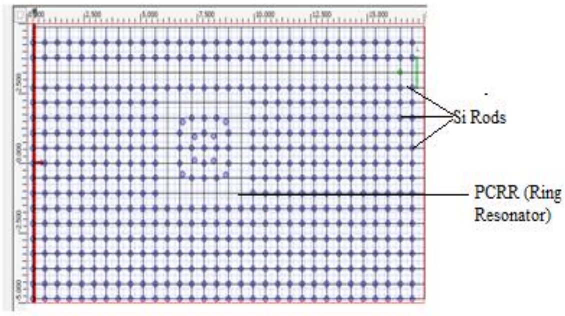

Figure2: Design layout of a basic optical ring resonator

The second demonstration of design of single add/drop filter, as discussed above has been made with the help of basic optical ring resonator structure. The proposed design consist of two waveguide i.e. bus and drop waveguide. The designed structure has three ports: Port A, port B and port C. The proposed design has the perpendicular drop waveguide.

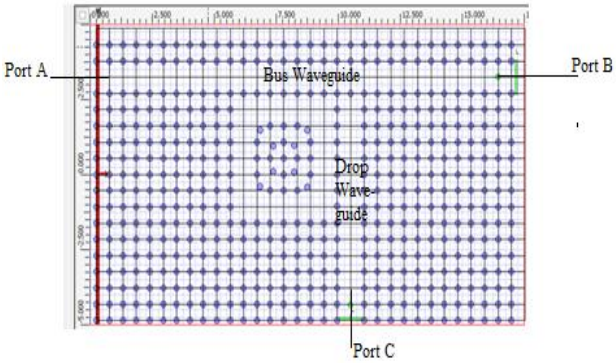

Figure3: Single Ring Resonator ADF at perpendicular drop waveguide.

IV. SIMULATION RESULTS

After designing of two structures, the simulation of the respective designs has been performed by using two methods i.e. Plane wave expansion method (for band gap calculation) and for field distribution, Finite Difference time domain method. Thus these two methods are significant in order to evaluate the response of filter and also in computation of band diagram of periodic and non periodic arrangement. The parameters which have been calculated are as follows:

A. Photonic Band Gap:

For the proposed structure the band structure diagram has been calculated and obtained at Figure 4. This PhC structure has two band-gap regions at $0.271 < a/\lambda < 0.363$ and $0.498 < a/\lambda < 0.567$ and both are in TM mode which are equal to 2,272 nm < λ < 3,044 nm and 1,455 nm < λ < 1,656 nm. The obtained ranges show that our structure is suitable for optical communication applications.

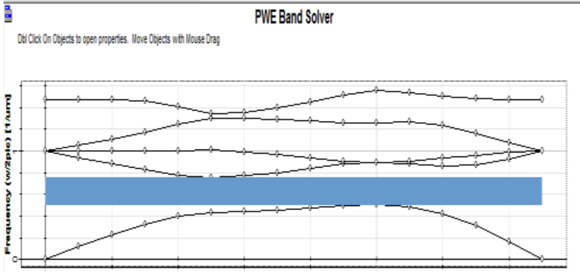

Figure4: Photonic Band Gap of designed ADF.

B. Field Distribution

i) Field Distribution of Basic Optical Ring Resonator.

The field distribution of basic optical ring resonator consist of the resonating wavelength or in other words the on wavelength, λ_{ON} = 1550nm with efficiency of 100%. Thus the designed structure can be used in order to design other add/drop filter.

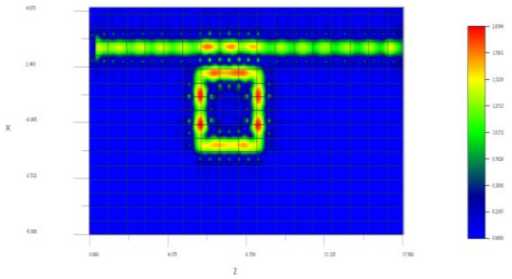

Figure5: Field distribution of basic optical ring resonator at 1550 nm

ii) Field Distribution of Single resonator ADF

The second field distribution has been done of ADF at perpendicular drop waveguide. The simulation has been performed at two wavelengths i.e. on resonance and off resonance. The figure 6 and 7 shows the field distribution of 1340nm and 1550nm for add wavelength (λ_{OFF}) and drop wavelength (λ_{ON}) respectively. The efficiency of add wavelength is 100% whereas the drop wavelength efficiency is 70%.

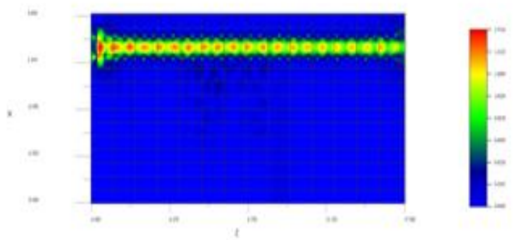

Figure 6: Field distribution of single resonator ADF (at 90^0) at 1340 nm

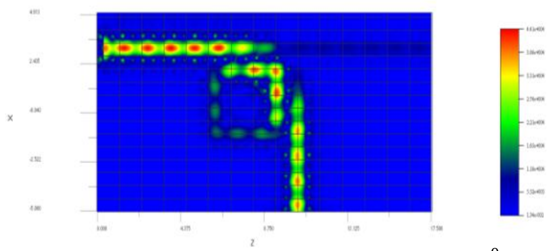

Figure7: Field distribution of single resonator ADF (at 90^0) at 1550 nm.

Figure 8 signifies the transmission spectrum of the proposed filter. At 1340nm wavelength there is zero coupling and the efficiency came out to be around more than 99% as shown below.

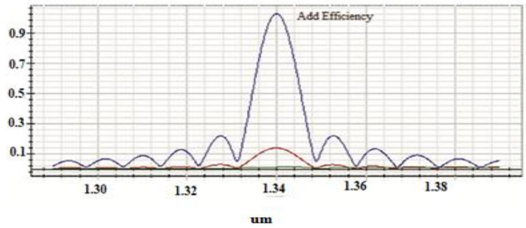

Figure 8: Transmission spectrum at 1340nm

Figure 9 signifies the transmission spectrum at the guided wavelength. At this situation a coupling exists between the waveguide and the ring resonator. The drop wavelength gives the efficiency of around 70%.

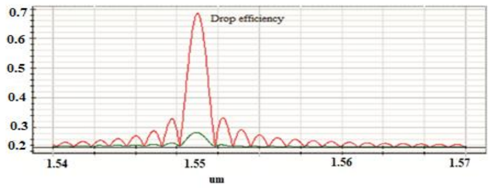

Figure 9: Transmission spectrum at 1550nm

V. CONCLUSION AND FUTURE WORK

The proposed filter is designed with the help of flower shape ring resonator with18*32 silicon rods suspended in air. The radius of a rod, r = 0.108μm and lattice constant of 540nm.The layout design of ADF has been made with the help of a basic optical ring resonator. The dielectric constant of the structure is 3.59 and the input optical source wavelength, λ= 1.554μm. The size and the thickness of the structure are 17.5*10 μm^2 and 2μm respectively. The drop efficiency computed is 70%. The efficiency of the filter can be improved and also the tuning can be enhanced by the use of double ring resonator filter which will be the future aspect of the proposed paper as there is less effect of external sources on this type of structure.

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