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STUDY OF 2D PHOTONIC BANDGAP JUNCTIONS FOR ITS APPLICATION IN ALL OPTICAL COMMUNICATION

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Abstract:- *All-optical signal processing is a promising technology for future optical transparent networks for its strong abilities to overcoming the electronics bottlenecks, supporting the ultra-fast optical signal processing without requiring costly optical-electrical-optical equipment. Photonic crystals are potentially very attractive for on chip all optical communication and highly advantageous in telecommunication due to smaller dimensions. In this paper, the PBG (Photonic band gap) junctions made by 2D (two dimensional) photonic crystal slab with junction formed due to two different types of lattices i.e. two different lattice constant of same material are studied and their utilization as optical buffer is analysed.*

Keywords: *photonic crystal; photonic band gap, optical signal processing*

I Introduction

The nonlinearity in SOA in Mach– Zehnder interferometer (SOA-MZI) configuration is used for realizing many logic operations for all optical signal processing.[1,2] The nonlinear Mach–Zehnder interferometer (NMZI) created with Photonic crystal waveguide[3],optical junction with very low crosstalk [4], the silicon photonic crystal heterojunctions proposed as on chip optical diode[5]offer useful features with extremely small dimensions.Thus the photonic crystal junctions and waveguides could be important for integrated photonic circuits, all optical signal processing and optical communication [6].In this paper, the attempt is made to study the photonic crystal junction and to find its application in all opticalprocessing. The photonic crystal junction is comprised of two-dimensional lattice of silicon rods in air. The Lumerical 2.5 Finite Different Time Domain (FDTD) simulation is used to analyze the behavior of the structure. The main objective is to study the properties of photonic bandgap based devices like Photonic bandgap (PBG) junctions and to find its utilization.

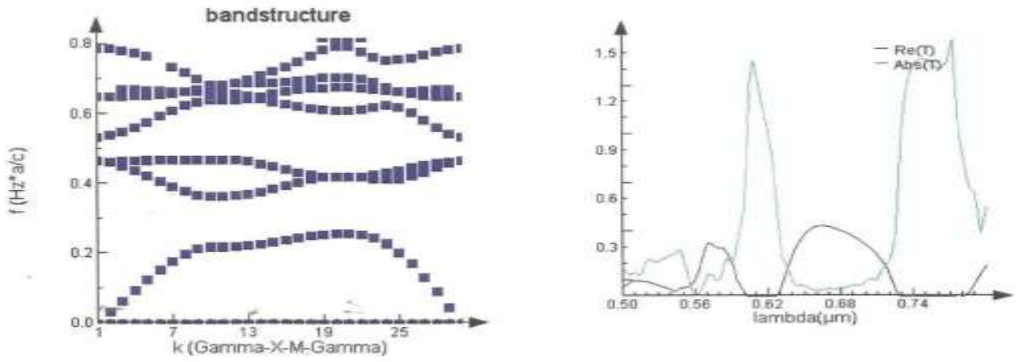
II. History

The Photonic crystals (PCs) are the optical materials with periodic dielectric structuresthat exihibits optical properties and are boom for photonics. The photonic are the periodic array of low- or high-dielectric material in a matrix. e.g. a slab of highdielectric material in periodic array of low dielectric air forming a two-dimensional (2D) photonic crystal. Yablonovitch[7] and John[8] discussed that as the periodic lattice of atoms causes electrons to have energy gap similarly in a photonic crystal, the periodic dielectriclattice causes photons to have frequency gaps, also known as photonic band gap(PBG). When light falls in this gap the photonic crystal reflects the light totally with no dependence on incident angleindifferent from conventional dielectric media. The light could be confined and guided in the better way than conventionally done using Photonic crystal.The photonic bandgap is the frequency gap comes due to a periodicity in the materials dielectric properties where the transmission of photons is prohibited through the material. A triangular arrangement of holes in the slab is used to obtain an omni-directional band gap. The introduction of defects into the photonic crystal slab on disturbing the periodicity leads to states that confined modes laterally and when these states have wave numbers outside of the light cone the mode is vertically confined and forms a photonic crystal cavity. The 2D photonic crystals are well designed and their applications as photonic band gap-based optical devices are reported.

The 2D photonic crystals consisting of arrays of circular holes/dielectric rods in dielectric rods/air in various lattice arrangements (square, triangular, etc.) are discussed by Wang.[9]. The photonic bandgap can be engineered for the position and size by proper design, the dielectric contrast between the host material and the constituent object material, lattice type and filling factor to be applied for specific applicationThe photonic crystals with elliptical air holes/dielectric columns and dielectric/ air holes respectively in a triangular lattice has been studied.[10,11]The photonic band gap with elliptical air holes in a dielectric medium in a rectangular lattice is studied [12].The complete photonic band gap is obtained in triangular, honeycomb or rectangular lattice arrangements.In this paper, the PBG (Photonic band gap) junctions made by 2D (two dimensional) photonic crystal slab with junction formed due to two different types of lattices i.e. two different lattice constant of same material are studied and their utilization as optical buffer is analysed.

III. Observations and Results

For 2D PhC operating in the telecommunication window (~1550 nm), the lattice constant is usually around a=400 nm while the radius of the holes can be varied between 0.25−0.4a. The photonic bandgap junction can be formed using two different materials, two different types of latticeswith same material and two different lattice constant.



(a) (b)

Fig 1 (a) Dispersion diagram of a perfect 2D photonic crystal calculated using the FDTD method. Silicon rods (=12.083) are defined in air in a square lattice where the radius of the holes is r=0.24a. (b) Transmission through the same photonic crystal in the Γ−k direction obtained by FDTD method

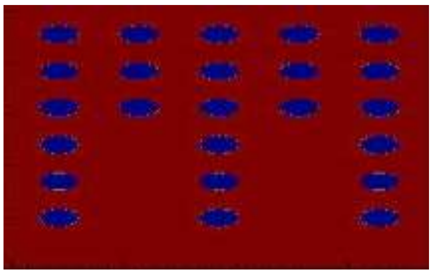


Fig 2 Photonic bandgap junction is formed using two different types of lattices and of same material.

The dispersion diagram of a perfect 2D photonic crystal calculated using FDTD method is given in Fig 1(a) and the transmission through the crystal is obtained by FDTD method is given in Fig 1(b).

The photonic bandgap junction formed using two different types of lattices with same material is shown in the fig 2To study this it is important to know the charactersticparameters i.ebandstructure, transmission and reflection curves of the component of junction separately.To find the optimal junction gap the Silicon rods in air with two different square lattices,with different junction gap (a) 0.3 µm, (b) 0.5 µm and (c) 0.7 µm are studied. It has found that the loss in **E** fields at output to input is maximum in 0.7 µm and minimum in 0.5 µm while the time delay per µm is maximum in 0.7 µm and minimum in 0.3 µm.

Considering the loss, time delay and minimum distance between two rods should be such that they do not coincide, the distance between two lattices is kept at 0.3 µm.The plane gaussian wave with centre wavelength 0.5 µm (at lower wavelength) is used.The time delay and loss is calculated by time domain direct observation of short optical pulse transmission.

The different lattices (1)a_x=a_y=0.5µm ,a_x=a_y=1µm;(2) a_x=a_y=0.5µm , a_x=a_y=1.5µmand square and rectangular lattices(3) a_x=a_y=0.5µmand a_x= 1µm and a_y=0.5 µm;(4) a_x=a_y=0.5µmanda$_x$= 1.5µm and a_y=0.5 µm formed the junctions which are studied.

The transmission-reflectance curves and dispersion vs wavelength of silicon rod of radius r=0.24a in air square lattice a_x=a_y=1 µm, square lattice a_x=a_y=1.5 µm, rectangular lattice a_x= 1µm and a_y=0.5 µm, rectangular lattice a_x= 1.5µm and a_y=0.5 µm is shown in fig 3 (a)-(d).and fig 4 (a)-(d). The frequency bandgap decided for the device is 0.1-0.5 Hz. These junctions are stimulated for dispersion in fig 4 (a),(b),(c),(d)) using mode solution software using 2.5 FDTD method.

Optical buffer is strongly demanded in IP packet photonic routers. The group velocity dispersion describes the speed of light at which pulse envelope propagates. Initially, slow light was generated using photonic crystal waveguide. The application of PBG junction device is analysed using time domain direct observation of short optical pulse transmission for optical buffer for on chip communications. Time delay per µm for the four different junction is shown in Table 1.

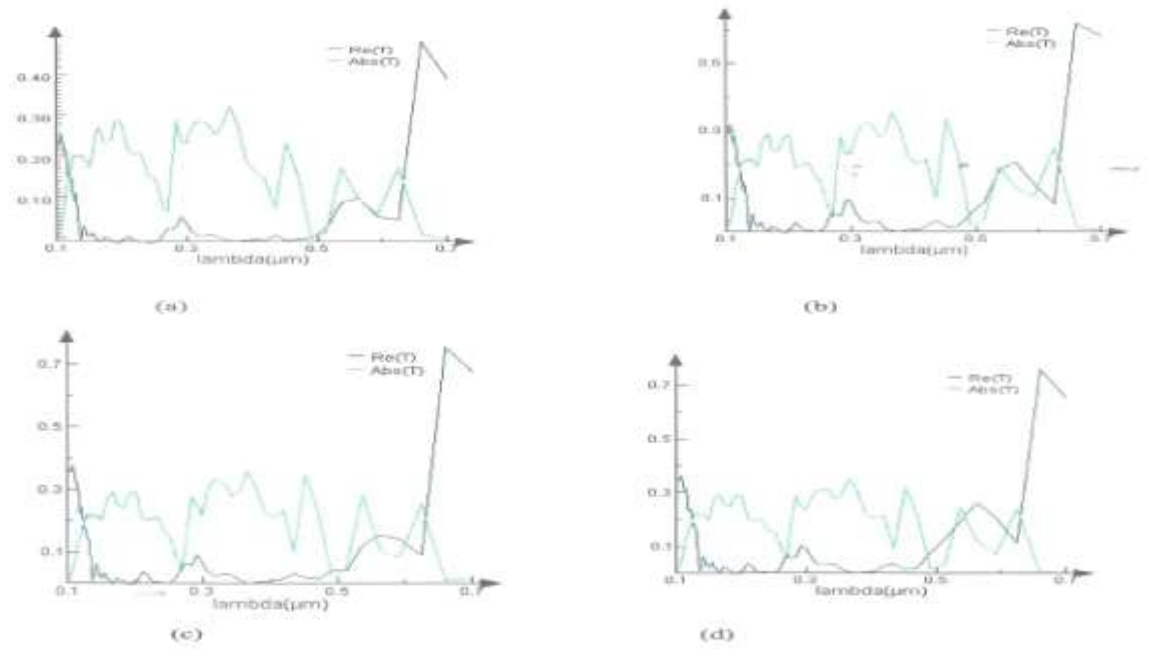


Fig 3Transmission and reflectance curve of silicon rod of radius r=0.24a in air (a). square lattice $a_x=a_y=1$ µm (b).square lattice $a_x=a_y=1.5$ µm (c).rectangular lattice $a_x=1$µm and $a_y=0.5$ µm (d). rectangular lattice $a_x= 1.5$µm and $a_y=0.5$ µm.

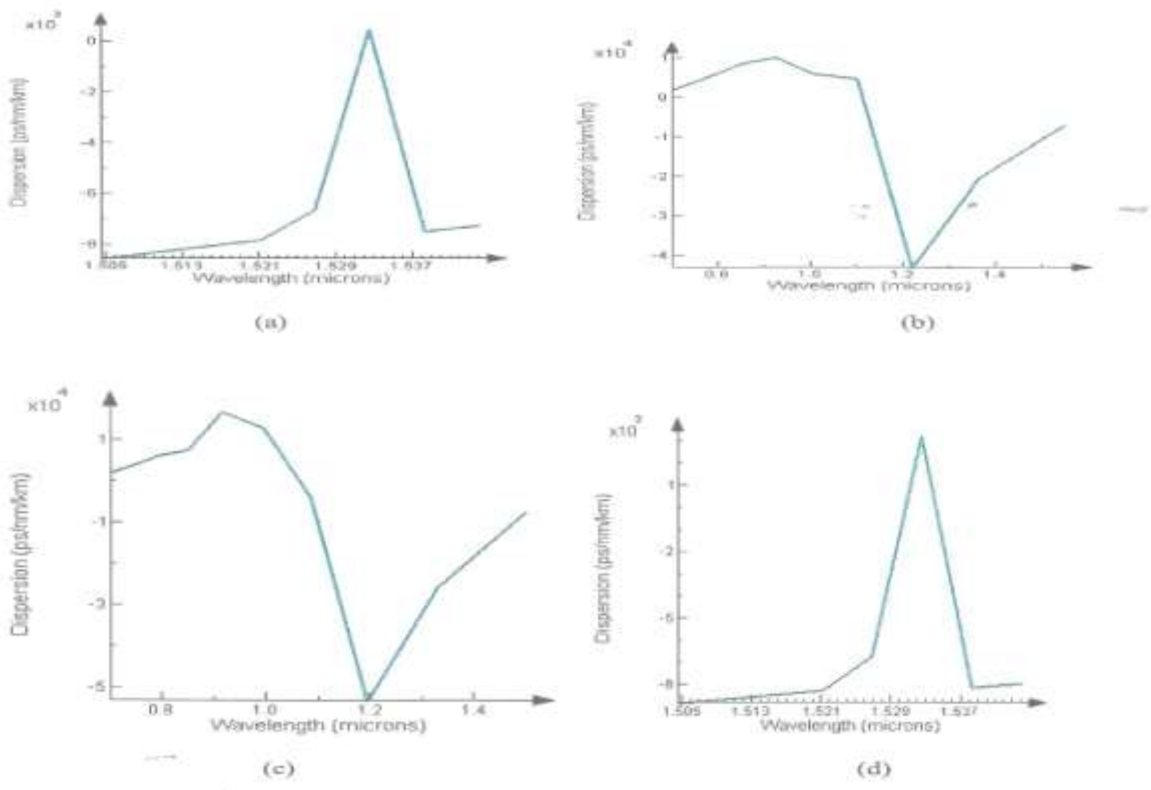


Fig 4 Dispersion vs wavelength for (a) Junction between two square lattices with lattice constants 0.5 µm and 1 µm. (b). Junction between two square lattices with lattice constants 0.5 µm and 1.5 µm. (c). Junction between a square lattices ($a_x=a_y= 0.5$µm) and a rectangular lattice ($a_x=0.5$µm and $a_y=1$µm). (d). Junction between a square lattices ($a_x=a_y= 0.5$µm) and a rectangular lattice ($a_x=0.5$µm and $a_y=1.5$µm).

Table 1 Time delay per µm for the four different junction

S.N	Junctions	Length(µm)	Time Delay per µm in fs	Loss(dB/µm)	Loss(dB)
1	Junction between two square lattices with lattice constants 0.5 µm and 1 µm	3.75	5.06	0.0856	0.321
2	Junction between two square lattices with lattice constants 0.5 µm and 1.5 µm	4.75	4	0.0150	0.0715
3	Junction between square lattices (a_x=a_y= 0.5µm) and a rectangular lattice (a_x=0.5µm and a_y=1µm	2.75	4	0.1545	0.425
4	Junction between a square lattices (a_x=a_y= 0.5µm) and a rectangular lattice (a_x=0.5µm and a_y=1.5µm	2.75	4.36	0.0315	0.08671

IV. Conclusion

Thephotonic band gap junctions will serve better for on chip communication and can be improved for higher time delays. The improvement can be done by changing the material on both sides of junction, taking the combination with triangular lattice the time delay can be increased. This may give better result than PCW as optical buffer as these junctions are showing lesser dispersion while in PCW the higher order dispersion is a big problem. The most prominent feature is that at particular and in specified range of wavelengths,they are showing zero and negative dispersion which can be proved to be very useful for future on chip communications.

Conflict of Interest

The authors declare that there is no conflict of interests regardingthepublicationofthispaper.

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