A

DISSERTATION REPORT

on

Design and Analysis of Tunable Optical Filter Using Different Cavity Shapes

Submitted in
partial fulfilment for the degree of

Master of Technology in Electronics and Communication

By

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(2015PEC5118)

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CERTIFICATE

This is to certify that the dissertation report entitled **Design and Analysis of Tunable Optical Filter Using Different Cavity Shapes** composed by **Ms.Annu Meena (2015PEC5118)**, in the partial fulfilment of the Degree Master of Technology in **Electronics and Communication** of Malaviya National Institute of Technology,is the work completed by her under my supervision, hence approved for submission during academic session 2016-2017.The contents of this dissertation report, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Place: Jaipur
Date:

Ashish Kumar Ghunawat
Assistant Professor

DECLARATION

I, **Annu Meena**, declare that this Dissertation titled, "**Design and Analysis of Tunable Optical Filter Using Different Cavity Shapes** " and the work presented in it is my own. I confirm that:

- This work is done towards the partial fulfilment of the degree of "*Master of Technology*" at MNIT, Jaipur.
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- Where I have consulted the published work of others, this is always clearly attributed.
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- I have acknowledged all main sources of help.

Place: Jaipur
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PUBLICATIONS

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ABSTRACT

In this research ,a two dimensional photonic crystal based tunable optical filter having Si rods with different shape cavities, as H-shape ,X-shape , square and circular is designed and investigated. The shape of Si rods is also changed from circular to square and the shift in resonating frequency of filter is achieved. The area of each cavity has been kept constant for achieving the result.Photonic crystals have wide area of application in photonic integrated circuit. By removing some rods of dielectric materials in photonic crystal structure the light propagation in PBG region can be controlled . Therefore, the transmission and reflection spectra of PC can be adjusted. Photonic integrated circuits (PIC) in light of Photonic Crystals are winding up noticeably progressively supported in rising sign preparing and optical correspondence advances. In this proposal,numerical simulation of a photonic crystal based optical filter or demultiplexer is carried out by the cavity based resonator by introducing some defect in a perfectly periodic photonic crystal, whose parameters are chosen using the band gap map The measurements of the imperfections are solely custom fitted for the wavelength to be separated by means of that channel. Optical circulators, filters, de-multiplexer are some of the devices that are designed by using PC and available in the literature. Among all these devices, optical filter play an important role in the designing of optical Communication network. They can remove unwanted noise from the channels. By introducing resonators and reflectors in the PC waveguide structure, a filter can be realized. The filter is designed by creating point defect based resonator and two line defect based reflectors. These defects are formed by simple removing the Si (dielectric material) rods. The designs proposed in this paper are suitable in optical circuits as wavelength shifting circuits. Also, they can be used as noise filtering devices for communication purpose. Optimisation of the proposed design by changing the shape of cavity in the defects is also discussed based on the results of the calculations of the Finite Element Method(FEM).

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ABBREVIATIONS

Photonic crystal	(PC)
Photonic Band gap	(PBG)
Finite Element Method	(FEM)
Perfectly Matched Layer	(PML)
One Dimensional	(1D)
Two Dimensional	(2D)
Photonic Crystal Waveguide	(PCW)

Chapter 1

Introduction

1.1 Background

For quite a while it was inspected thought of having the ability to get substances with fancied properties by changing their mechanical and electrical property. Delineations would incorporate the wide creation and usage of alloys or the transistor in contraptions and the use of high temperature superconductors. In any case, today, the semiconductor equipment industry go up against the rising trial of upgrading the integrated device execution while endeavoring to restrain the extent of the device[1]. Critical change can be expert in such way in case one swings to other media, for example, the optical media [2,3] Studies show a creating enthusiasm for an extension in the breaking point of correspondence, for which many fields are thought about, one of which consolidates the optical medium.

In the course of the most recent couple of decades, another entryway is now open in the optical . IN this by optical properties of a material is controlled, and by astute utilization of the standards of reflection of light , refraction property and superposition of light, researchers have possessed the capacity to begin another upheaval in our universe of innovation called as Photonic Crystals,which are dielectric structures. They known as crystal on account of the periodicity and photonic on the grounds that they follow up on light. Photonic crystal are likewise present in nature. For example, the butterfly's wing and its rainbow game is due to the reflection of light on the wing. Photonic crystals, in which the electromagnetic waves cannot propagate for a particular region, give a promising instrument to control the stream of light in integrated optical device [2]. Growing interests have been appeared over the most recent couple of years in the plan and enhancement of photonic crystal based parts, for example, waveguides [4,5], lasers [6,7], splitters, strands [8], and so on. One such photonic crystal based optical device is the waveguide based optical filter.

During the last few decades,the improvement of semiconductor innovation has achieved gigantic changes to our general public and the life of individuals. The pattern for even higher thickness of reconciliation and speedier processors pushes the scaling down to the extraordinary for electronic device. The high resistance and in this manner long defer time related with the little element size, and the synchronization issue emerging from rapid transmission of information turns out to be more serious for electronic devices[1].

Optical devices are now in wide use, with optical fiber being a primary candidate because of the speed of information exchange and information rates it can deal with. However, with optical fiber, there dependably remains the requirement for electronic devices keeping in mind the end goal to encoding and decoding of light signals for handling. example, if signals of different wavelengths proliferating through a glass fiber need partition, they require to experience electronic processing for the demultiplexing, consequently presenting undesirable delay and complexity in plan. In any case, with photonic crystal filters the requirement for the electronic preparing is lessened to zero, and light waves can be demultiplexed or sifted as sought by the photonic crystal filter in their state. These photonic crystal, working alongside photonic crystal optical filters has an extent of accomplishing by methods for wavelength division multiplexing in communication.

Photonic crystal based filters have been a point of broad research for a long while now. A few techniques for light separating by photonic crystal have been proposed by analysts, including the cavity based, resonating approach, and so on. This work deals with the photonic crystal waveguide way to deal with the investigation of filters.

Photonic crystal waveguides have been a subject of broad research for a long while now. A few strategies for streamlining of photonic crystal structures have been proposed by specialists, including topology enhancement approach [**?**], geometry projection technique [13,14], recreated strengthening and the limited component strategy [15], various multipole technique [11,12], and so on. This theory talks about the enhancement and reenactment of different sorts of photonic crystal waveguides based filter by the changing the shape of resonator cavity. The work in this theory paper is significantly in view of the idea of photonic band gaps(PBG).

This thesis contains four more sections that take after, Chapter 2 gives a review on the foundation of photonic crystals and examines about its physical properties and the diverse sorts of photonic crystals structure, the physical causes of a band hole in a photonic crystals and their capacity to manage waves around tight twists. This has been done to give fundamental learning about photonic crystals which should see assist sections in the postulation.

Chapter 4 clarifies about the computational strategies utilized for photonic crystals and gives a short portrayal on the displaying instruments that has been utilized for the reproduction and investigation of the particular streamlined photonic crystals waveguides.

Chapter 5 is the most fundamental part of this theory which contains an explained concentrate on the work of this postulation. This section gives point by point portrayal on the plan and improvements of the pit based resonator and furthermore compress the change of state of depression how influence the which is the enhancement procedure that has been utilized to advance the essential resonator based PhC structures. An area in this part is devoted to the examination and improvement of transmission and better ouput.

Chapter 6 is the last part of this proposal, where conclusions are drawn and conceivable future prospect in this field is recommended.

Chapter 2

A BRIEF INTRODUCTION TO PHOTONIC CRYSTALS:

”Photonic Crystals” (PC) are dielectric structures varying the refractive index on the size of the wavelength of the signal. Because of this periodicity, a photonic band gap (PBG) is shaped and the engendering of electromagnetic waves is restricted for all wave lengths inside this band gap. In the course of recent years, different imperative logical and designing applications, for example, the control of light outflow and spread and the catching of photons have been understood the photonic band gap and unnaturally created defects. Photonic crystals are a type of photonic gadgets that use periodic structures to make photonic band gaps, practically equivalent to the In III-V compound semiconductors, photons with specific energies can’t be propagate through the structures. The periodicity of photonic crystal can be shaped by contrasts in dielectric steady, or by a mix of metal and dielectric, and subsequently the term metallodielectric photonic crystals.

2.1 History and Introduction to Photonic Crystals

This chapter is intended as a brief overview of the history, concepts and characteristics and application of photonic crystals. Although, a single chapter is insufficient to review a field that continues to grow almost exponentially, nevertheless much is focused on the most relevant aspects of the work presented in the remainder of this thesis.. Physical science of crystalline materials now is a standout amongst the most created parts of regular science. In 1887, Lord Rayleigh initially found the curious refractive properties of a crystalline mineral 13 with intermittent ”twinning” arrangements (crosswise over which the dielectric tensor experiences a mirror flip). From this perception he understood there is a restricted band of wavelengths for which light propagation was precluded through the planes [5]. In spite of the fact that, it was not until one hundred years after the fact when John and Yablonovitch consolidated the hypothetical apparatuses of current electromagnetism and strong state material science, in 1987, that examination in photonic band gap built up and flourished [6] . This speculation, which enlivened the name ”Photonic crystal” for structures showing photonic band gap, prompted numerous consequent advancements in principle, creation and application [7]. It has been demonstrated that the unconstrained discharge rate of the atoms in the media can be influenced by the changing of the optical properties of the media and the outflow rate can be upgraded because of coupling with the resonating states [8] or can be illegal if no light states are accessible for the given range of frequency [9]..

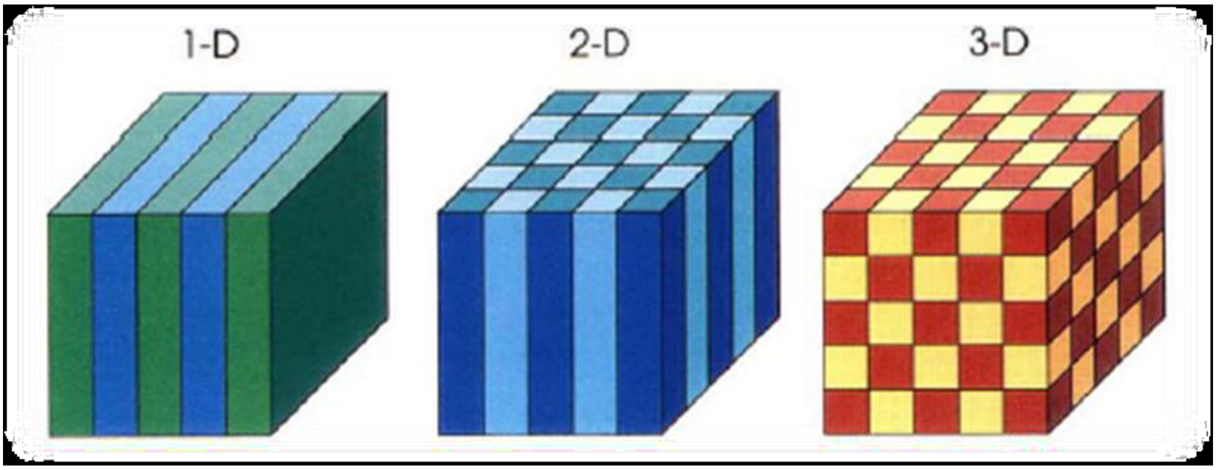
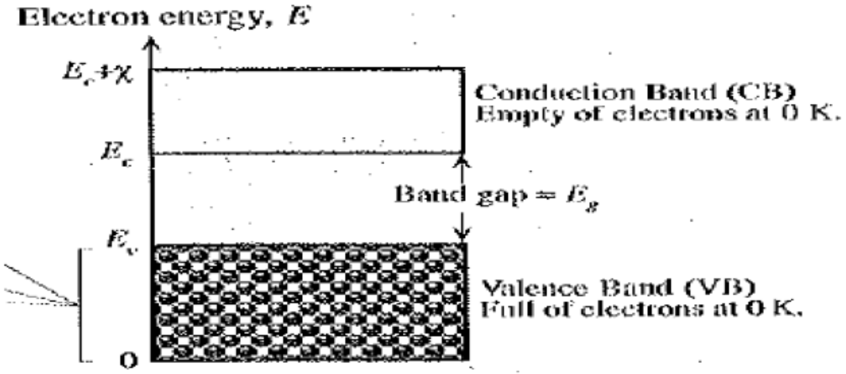


Figure 2.1: Periodically in 1-D, 2-D, 3-D



: The energy band diagram of electrons in a semiconductor (Source: Kasap, et.al 2001)

Figure 2.2: The Energy Band Diagram Of Electrons in Semiconductor

2.2 Photonic crystals and basic properties:-

A crystal can be defined as periodic arrangement of particles. The examples with which these particles are rehashed shape the crystal lattice. An electron going through a crystal cross section encounters an occasional potential. The conduction properties of crystal are demonstrated by the components of the crystal and the lattice arrangement. Electrons proliferate as waves and the energy of an electron in a particle is quantiged and can have just certain discrete esteems. A similar idea can be connected to the electron energy in a particle or a crystal with a few molecules. At the point when particles are mixed and form a crystal, their between nuclear collaborate and form electron energy bands, mostly two different bands (Kasap,). It is a result of this band gap, that waves that satisfy certain criteria can go through periodic potential without disseminating and furthermore propagate through while others confined. There are no permitted electron energies in the band gap it speaks to the forbidden electron energies in the crystal. The band can reach out to cover every conceivable heading of spread of an electron if the lattice capability of the crystal is solid. Henceforth, this would bring about a total bandgap. A decent case of such a material would be a semiconductor. In a semiconductor,there are two groups known as the valence band and the conduction band in which energy of electron lies that are seperated by the energy bandgap or the illegal bandgap, as appeared in the figure

So, in order to make the understanding of the properties of photonic crystals less complicated, its optical analogy to crystals is considered.If there should be an occurrence of photonic crystal, the particles-ions, atoms or particles are supplanted by materials having distinctive dielectric constants and the intermittent dielectric capacity would supplant the periodic capability of a crystal [1]. It is discovered that if the material being utilized has high proficiency (lossless medium), and if the dielectric constants of the distinctive medium being utilized, fluctuates significantly from each other, at that point the reflections and refractions of light by the interfaces of the photonic crystal enable photons to create diverse marvel, like the ones that can got because of the intermittent potential experienced by electrons inside a gem. The most vital property which decides noteworthiness of the photonic crystal is the photonic band gap.

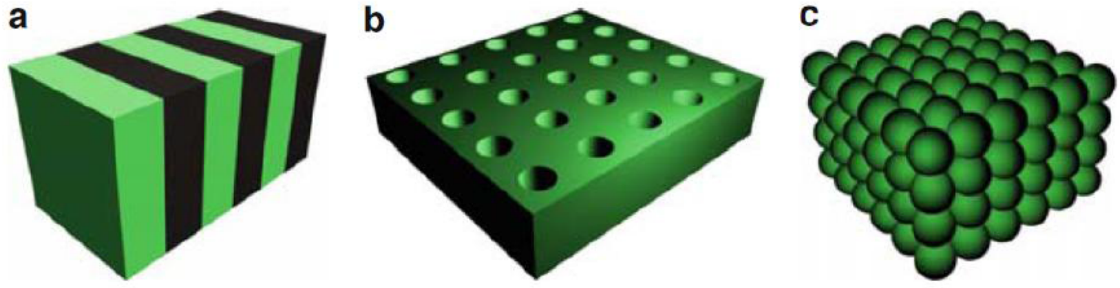


Fig2.2: Examples of a) 1D b) 2D c) 3D photonic crystal (Source: Sukhoivanov, et.al 2009)

Figure 2.3: Examples of a) 1D b) 2D c) 3D photonic crystal

The photonic band gap (PBG) relates to the energy or recurrence scope of light whose spread is precluded inside the photonic crystal, like the bandgap found in semiconductors. From the information of semiconductors it can be comprehended that, when photons with vitality, inside the PBG are incident on the structure, it is reflected back. In any case, if imperfections are brought into the intermittent structure, the impact would be same as the impact of acquaint-

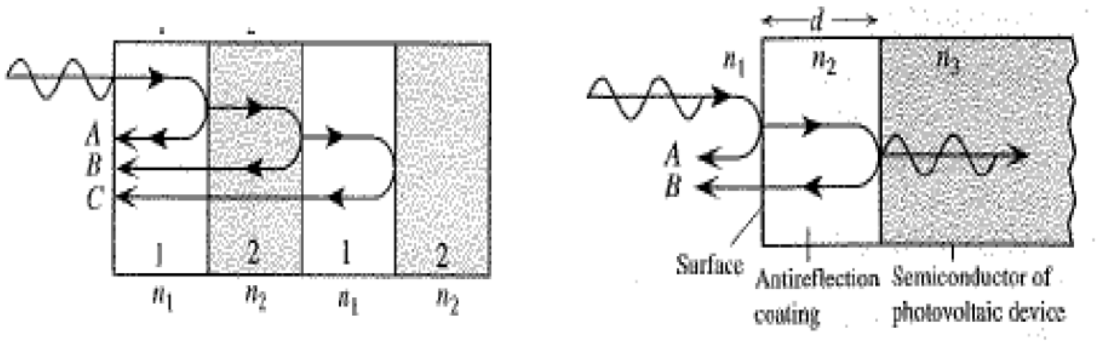


Fig2.3: The principle of dielectric mirror (Source: Kasap, et.al 2001)

Fig2.4: Illustration of how an anti reflecting coating works (Source: Kasap, et.al 2001)

Figure 2.4: The principle dielectric mirror

ing the deformity with the crystal structure of a semiconductor. Accordingly, the radiation inside the deformity recurrence will engender inside the structure and if there should be an occurrence of numerous imperfections, radiation will be guided like a waveguide (Joannopoulos, et.al 1998) Hence, one might say that the photonic precious stone is a low misfortune occasional dielectric material with nearness of photonic bandgap which enables light of specific frequencies to travel and averts proliferation of others. Based on the arrangement of the elements in the lattice, photonic crystals can be divided into three categories, namely one dimensional (1D), two dimensional (2D) and three dimensional(3D).

2.3 Types of photonic crystal

In 1D photonic crystal, the periodicity exists one way just, while in the other two ways it is uniform. The 1D photonic gem is included substituting layers of materials with various dielectric constants. Case of this can be given as the Bragg reflect, or the multilayer dielectric mirror, for example, the quarter wave stack. In these gadgets, light wave at every interface is halfway reflected and if the reflections from different interfaces meddle damagingly, it would wipe out the forward engendering wave. Then again, if the impedance is useful, at that point an expansive rate of the episode light will experience reflection (Kasap, et.al 2001). The 1D photonic precious stone is likewise utilized as hostile to reflecting coatings so as to enhance the nature of optical gadgets. A 1D photonic gem can have not very many varieties in its photonic structure, since it has a layered structure, consequently just the quantity of layers, refractive record of each layer and the thickness of layers could be shifted to achieve changes.

A 2D photonic crystal indicates periodicity in two ways while uniform in the third heading. Photonic band crevice shows up in the planes of periodicity. A further insight about the 2D photonic precious stone will be examined later in this part. Periodicity existing in each of the three planes frames the 3D photonic gems. The quantity of conceivable approaches to achieve changes in a 3D photonic precious stone is a great deal increasingly when contrasted with 1D or 2D photonic gem. By changing the game plan of components of 3D photonic precious stones, one can make new type of uses. The case of normally happening 3D photonic gem is the stone opal, which is well known for its exceptional optical properties, for example, flaunting distinctive hues when pivoted. This is because of its reflectance property which relies on upon the episode edge of light, which is then reflected at various wavelengths making the marvel. The geometry of 3D photonic precious stones can be changed in various ways with the goal that they can have different grid structures. The similitude between the material science of photonic precious stone and strong state physical science gives the likelihood to give the similarity between a few properties and calculation strategies connected to strong state and photonic gem physics.
Reciprocal lattice and First Brillouin zone Keeping in mind the end goal to comprehend the operation of optical gadgets, it is vital to know how the electromagnetic field would cooperate with the photonic crystal gadget. Thus, it is important to consider the conveyance of electromagnetic field inside the cross section. Subsequently, to have a thought regarding photonic crystal and fur-

thermore keeping in mind the end goal to plan photonic crystal based gadgets the utilization of reflectance range, transmittance range or the band structure of the precious crystal can be considered. It is most appropriate if band structures are utilized, since they give finish data about electromagnetic waves proliferating in the crystal.

The initial phase in this procedure is discover the parameters which would depict the structure of a photonic precious stone. This incorporates terms, for example, unit cell, cross section vector, corresponding grid, complementary grid vectors and the principal Brillouin zone. The above terms will be clarified in this section utilizing the 1D or 2D structures for effortlessness.

Unit Cell:- Photonic crystal is involved a boundless occasional structure. So it takes after that, if the data of a solitary unit cell is comprehended than the data can be reproduced to comprehend the whole structure. At the end of the day, a unit cell is any area in space which, when deciphered, maps out the whole capacity of the crystal. In the locale for a unit cell, a base point is chosen and each point inside the unit cell is nearer to this base point instead of the neighboring base focuses. The photonic crystal grid is controlled by its unit cell, its shape and permittivity [17].

The accompanying technique is utilized to decide a unit cell of a photonic crystal [17] .

1. At first the base component of the photonic crystal has been chosen. On the off chance that the photonic crystal is included bars in air then a solitary pole can be picked as the base component.

2. Line portions are attracted to interface the base point with comparing purposes of neighboring components.

3. Straight lines are goes through the focal point of each of the already marked line sections and opposite to them.

4. The figure denoted by these lines created the unit cell of the photonic

crystals.

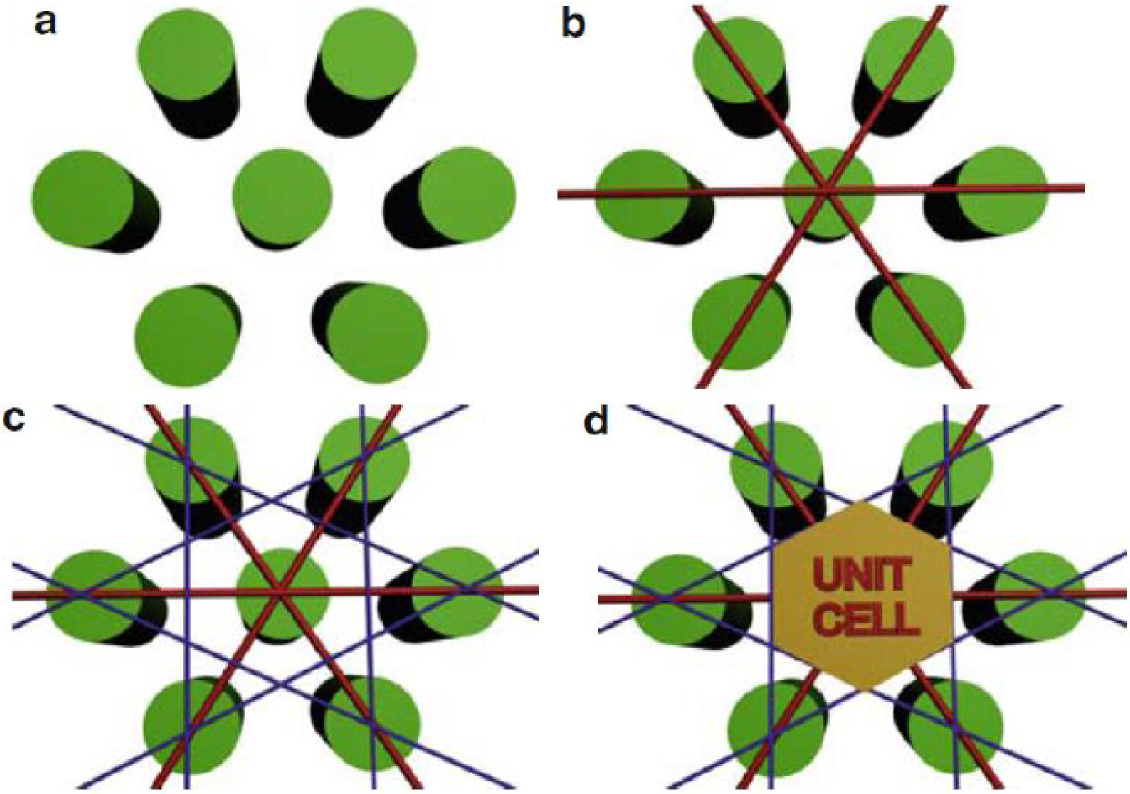


Figure 2.5: Process of unit cell arrangement

Lattice Vector: As specified some time recently, the unit cell is meant outline the whole capacity of the photonic crystal. The interpretation relies on upon the cross section vector. A cross section is an arrangement of discrete focuses in space that rehashes intermittently. It ought to be picked such that it fills the whole unit cell.The photonic crystal has a boundless intermittent structure, it is unrealistic to characterize an unlimited number of cross section vectors. So an arrangement of premise vectors, i.e. primitive cross section vector is characterized. Its is same as the quantity of measurement [17]. The grid vector can be composed in the general frame R = la1 + ma2 + na3, for a few whole numbers l, m and n. where R is known as grid vector, while the premise vector, a1,a2 and a3 are named primitive cross section vectors.

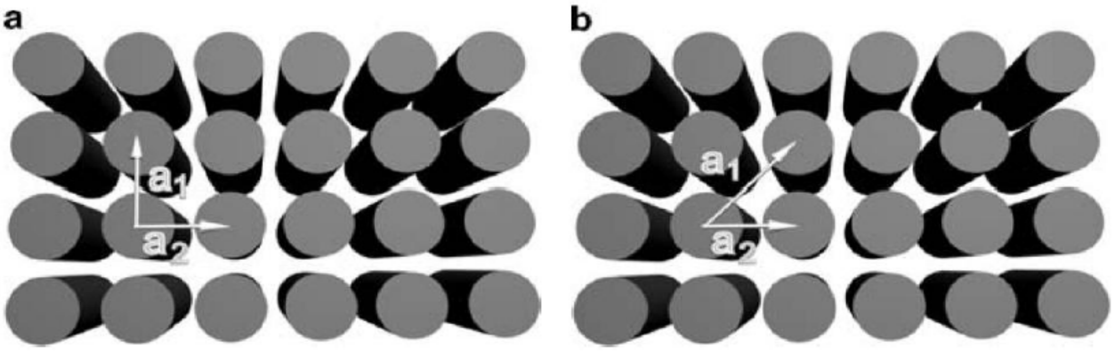


Fig2.6: Possible choices of primitive lattice vectors (Source: Sukhoivanov, et.al 2009)

Figure 2.6: Possible choices of primitive lattice vectors

2.4 Two Dimensional Photonic crystals:

In 2-D photonic crystal is intermittent along two of its axes and has periodical along the third axis, the band gap shows up in the plane of periodicity. Insights about the band gap of 2D photonic crystal will be examined in the following segment. In the event that light proliferates in this plane, at that point it is conceivable to partition the consonant modes into two free polarizations, each polarization have own band structure. It can likewise keep the spread of light toward any path inside the plane, not at all like the 1D crystal.

As per the figure 2.7, the segments are thought to be limitlessly long. For specific estimations of the grid consistent, ”a” (section dividing), the photonic crystal have a band gap along the x and y axis. Inside this crevice, no states are allowed and therefore light is reflected back.

Because of the variety of the shpae of the components and their situation, clearly there are an endless number of grid sorts accessible for a 2D photonic crystal. In any case, all in all, there are two regularly utilized cross section sorts

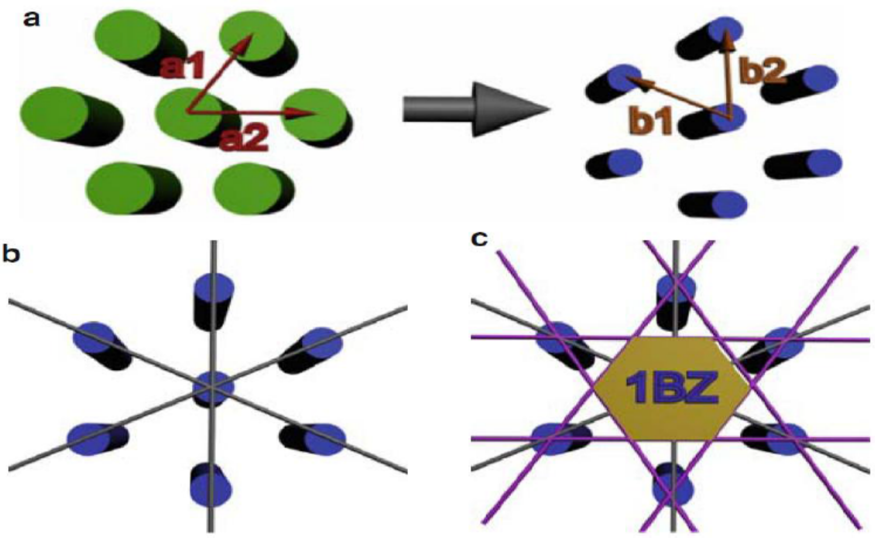


Figure 2.7: The Brillouin Zone for a 2D photonic crystal

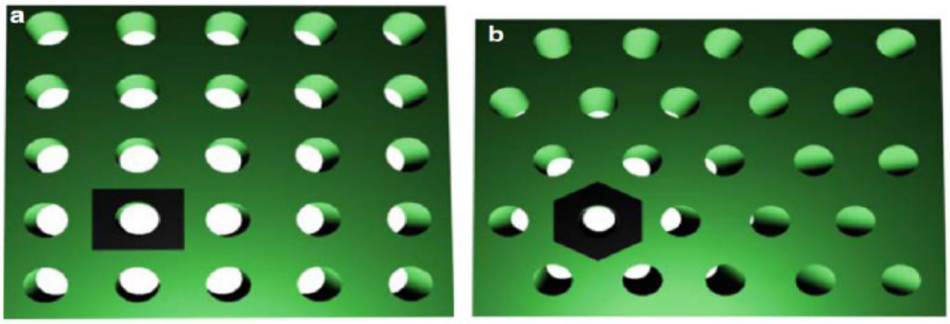


Fig2.10: Examples of 2D photonic crystal lattice types (Source: Sukhoivanov, et.al 2009)

Figure 2.8: Examples of 2D photonic crystal lattice types

of the two dimensional photonic crystal , the square and the hexagonal shape. The unit cell of a square cross section 2D photonic crystal has the state of a square and if there should arise an occurrence of hexagonal grid, the unit cell has the state of a normal hexagon.

2.5 Application of Photonic Crystals

The investigation of material properties has prompt numerous achievements in Science. Ancient progenitors have wisely gained the ability of separating materials from nature, considering its physical properties to design devices for their survival. In the long run, mankind needed something beyond the crude type of materials. Researchers and architects started treating with existing ones to make new materials with significantly more unrivaled properties, for example, stainless steel, earthenware production, and so forth. Today, a wide assortment of counterfeit materials with astounding physical and compound properties is under lock and key. In this century, control over materials has reached out to incorporate their electrical and attractive properties. Advances in semiconductor material science have allowed to alter conductivity, porousness of materials, in this way spearheading the uncommon time of transistors and coordinated circuits. Considerably more as of late, graphene has ended up being a novel material with marvelous electrical conductivities and transport administrations. In the most recent decade, another outskirts has risen with a comparative objective: to control the optical properties of materials. Researchers and specialists craving to manufacture materials with the capacity to specifically disallow light, coordinate light or even confine light in coveted locales.

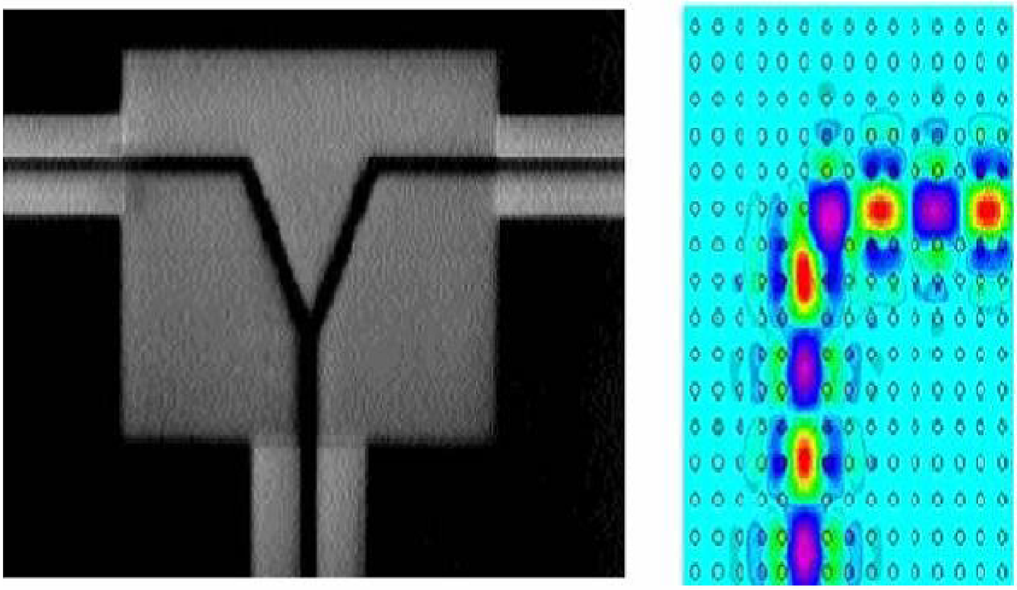


Figure 2.9: Line defect in a photonic crystal Left: A beam splitter photonic crystal Right: electric field of light propagating down a waveguide with a sharp bend carved out of a square lattice of dielectric rods

2.3.1 Waveguides One extremely encouraging use of PhCs is gone for enhancing the execution of waveguides [19] albeit optical fiberss direct light finished long separations, small scale circuits of light in view of waveguides don't exist. PBG materials evacuate this issue by expelling all the foundation electromagnetic modes over the pertinent band of frequencies. Presently, when a light is shone on the crystal it has no place else to go thus it follows the way of the deformity. The PBG confines the light and keeps it from getting away from the optical small scale circuit. Indeed, even through a 90o twist, 98% of the power in the light that goes in one end leaves the other.

Controlling and catching light utilizing waveguides and resounding holes are two essential optical capacities that empower a scope of every single optical gadget to be made. Waveguides not just play out the assignments of their electrical analogs, wires, by exchanging light starting with one a player in a circuit then onto the next, however are utilized as a part of numerous different gadgets, for example, couplers, intersections and interferometers. Thunderous holes have numerous potential applications that make utilization of the sharp unearthly reaction and extremely solid field forces that happen at resonance.

2.3.2 Integrated Circuits One of the objectives of photonic crystal is to make ultra little optical and optoelectronic incorporated circuits as conceptualized in Fig.1.5.4. Such gadgets coordinate nano-ampere laser exhibits with various swaying frequencies, waveguides that fuse sharp curves, optical modulators, wavelength selectors, et cetera, all in a territory under 100 100 μ2. The optical gadgets are made by presenting suitable simulated imperfections and light producers in the crystal.

Chapter 3

Literature Survey

3.1 Literature Review

(1987)Eli Yablonovitch**"Inhibited Spontaneous Emission in Solid-State Physics and Electronics"**Phys. Rev., 2059[20] It has been perceived for quite a while that the unconstrained emanation by molecules is not really a settled and changeless property of the coupling amongst issue and space, yet that it can be controlled by adjustment of the properties of the radiation field. This is similarly valid in the strong state, where unconstrained emanation assumes a central part in restricting the execution of semiconductor lasers, hetero junction bipolar transistors, and sunlight based cells.

(1998) J. C. Knight, J. Broeng, **"Photonic band gap guidance in optical fibers"** [21], Science 282, 14761479. An on a very basic level diverse kind of optical waveguide structure is illustrated, in which light is restricted to the region of a low-record district by a two-dimensional photonic crystal. The waveguide comprises of an additional air gap in a generally standard honeycomb example of gaps running down the length of fiber.

(1999) O. Painter, R. K. Lee, **"Two dimensional photonic band-gap defect mode laser"** [22], Science 284, 18191821 A laser cavity from a solitary deformity in a two-dimensional photonic crystal is illustrated. The optical micro cavity comprises of a half wavelength-thick waveguide for vertical constrainment and a two-dimensional photonic crystal mirror for horizontal restriction. A deformity in the photonic crystal is acquainted with trap photons inside a volume of 2.5 cubic half-wavelengths, roughly 0.03 cubic micrometers. The laser is manufactured in the indium gallium arsenic phosphide material framework, and optical pick up is given by stressed quantum wells intended for a pinnacle emanation wavelength of 1.55 micrometers at room temperature.

In 2002 S. F. Mingaleev, **"Sharp bends in photonic crystal waveguides as nonlinear Fano resonators"** [23]. We show that high transmission through sharp twists in photonic crystal waveguides can be depicted by a basic model of the Fano reverberation where the waveguide twist assumes a part of a particular limited imperfection. We infer viable discrete conditions for two sorts of the waveguide twists in two-dimensional photonic crystal and get correct investigative answers for the resounding transmission and reflection. This approach enables us to get a more profound knowledge into the material science of resounding transmission, and it is additionally helpful for the investigation and outline of energy subordinate transmission through the waveguide with implanted nonlinear deformities.

(2002)S. Noda, M. Imada, **"Semiconductor three-dimensional and two-dimensional photonic crystals and devices"** [24], IEEE Journal of Quantum Electronics 38(7), 915 One of the essential building-blocks of miniature photonic crystal (PC)-based photonic integrated circuits (PICs) is the sharp bend. Our group has focused on the 2-D photonic crystal based on a triangular lattice of holes perforating a standard heterostructure. The latter, GaAlAs-based or InP-based, is vertically a monomode waveguide. We consider essentially one or two 60/spl deg/ bends defined by one to five missing rows, spanning both cases of monomode and multimode channel waveguides.

2006, T. Frandsen, L. H., Hede, K. K., Harpth, A., Borel, P. I. and Kristensen, M. **Wavelength-division demultiplexing using photonic crystal waveguides** [25], IEEE Photon. Technol. Lett. 18(1), 226-228).A ultracompact triplexer in light of a move of the cutoff recurrence of the basic mode in a planar photonic gem waveguide with a triangular grid of air openings is introduced and streamlined. Some deformity gaps are acquainted with control the pillar proliferation.

The radii of the openings are changed to acknowledge it. The numerical outcomes acquired by the limited distinction time-area technique demonstrate that the proposed triplexer with an aggregate size 12 μm 6.5 μm can isolate three particular wavelengths i.e. 1310, 1490 and 1550 nm with the eradication proportions higher than -18dB.

(2012)S. Robinson, R.Nakkeeran,**"Investigation on two dimensional photonic crystal resonant cavity based bandpass filter"** [26], Optik123(5)451457.In this paper, another plan of include drop channel based two-dimensional photonic precious stone ring resonator is proposed. The structure is made of a triangular grid of silicon poles with the refractive list n1=3.4641 which are punctured in air with refractive record n2=1. Full methods of the all ring resonator and their comparing deteriorated shafts are figured utilizing the Plane Wave Expansion (PWE) strategy and the channel's transmission range is computed utilizing two-dimensional Finite Contrast Time Domain (2D-FDTD) numerical strategy. Full Width Half Maximum (FWHM) data transfer capacity of the channel at the yield transmission range - from 1.507 1.511m - is 4nm.The dropping effectiveness and quality variable of channel drop channel are 100 % and 502.66, individually.The proposed structure is little what's more, the general measurement is 10m18.5m which is appropriate for photonic integrated circuits.

(2013) S.Pu, H.Wang, N.Wang, X.Zeng,**"Tunable flat band slow light in reconfigurable photonic crystal waveguides based on magnetic fluids"** [27], Opt. Commun. 311 1619. A sort of two-dimensional photonic crystal line-imperfection waveguide with 45-turned square cross section is proposed to exhibit moderate light wonders. Penetrating the photonic gem waveguide with suitable attractive liquids can produce wide level groups of guided modes, which offer ascent to the fantastic moderate light properties. The transfer speed focused at λ_0=1550 nm of the composed W1 waveguide is impressively vast (around 54 nm). The got bunch speed scattering 2 inside the transmission capacity is ultralow (shifting from - 2118a/2πc to 1845a/2πc, where an and c are the time of the cross section and the light speed in vacuum, separately). At the same time, the standardized postponement transmission capacity item is generally expansive contrasted and different works. Reconfiguring the photonic precious stone waveguide with attractive liquids of various fixations can amazingly tune the moderate light parameters and the exchange off between them, while the kind of attractive nanoparticles constituting the attractive liquids irrelevantly influence the moderate light properties. The unequivocal straight variety of the moderate light parameters with the attractive liquid fixation is advantageous for the commonsense tuning.

(2013) M.R.Rakhshani, M.A.Mansouri Birjandi, **"Realization of tunable optical filter by photonic crystal ring resonators"**[27],Optik124(22)53775380.We have outlined a tunable two dimensional (2D) channel drop channel (CDF) in light of photonic crystal ring resonators (PCRR). Dropping productivity and Q element of single enhanced ring are 100 % and 842, individually. In this channel the quality element is essentially enhanced as for other distributed reports. We research parameters which affect full wavelength in this CDF, for example, dielectric steady of internal, coupling, adjoining and entire poles of the structure and span of inward bars. The transmission range for our proposed design has been explored utilizing the 2D limited contrast time area (FDTD) technique. The range of the proposed structure is around 117 μm2.

(2014) S.Pu, S.Dong, J.Huang, **"Tunable slow light based on magnetic-fluid-infiltrated photonic crystal waveguides"** [28], J.Opt.16(4) 045102 Tunable moderate light is proposed with photonic crystal structures invaded with attractive liquids as well as applying remotely attractive field to the penetrated gadgets. The W0.9 line-imperfection waveguide is shaped inside the hetero structure-chunk with triangular grid. Two distinct criteria deciding the data transfer capacity are embraced to measure the moderate light execution. Under the low scattering (steady gathering record) standard, the wavelength transfer speed focused at a wavelength of λ0 = 1560 nm can be tuned in the scope of 18.4528.32 nm (4.739.28 nm) when the penetrated attractive liquid fixation increments from 0.29 % to 1.95 %. The relating normal gathering record diminishes from 21.39 (22.66) to 18.34 (18.04). Correspondingly, the neighborhood attractive field figure (i.e. the quality of remotely connected attractive field) can tune the wavelength transfer speed around 1550 nm (under the consistent gathering file) and the normal gathering file in the scope of 6.80 nm10.42 nm and 16.9114.69, separately. The aftereffects of this work might be useful for tentatively planning and understanding the attractive liquid based tunable moderate light.

(2014) Y.Zhao, Y.Zhang, **"Research on temperature and magnetic field sensing characteristics of photonic crystal fiber filled with magnetic fluid"** [30], Microw. Opt. Technol Lett.56(4))831834. A straightforward, financially savvy and touchy fiber optic attractive sensor created with ferrofluid and monetarily accessible fiber optic parts is portrayed in this paper. The framework utilizes a ferrofluid penetrated outward Fabry-Perot interferometer (EFPI) grilled with an infrared wavelength spectrometer to gauge attractive flux thickness. The whole detecting framework was created with financially accessible segments so it can be effectively and monetarily recreated in expansive amounts. The gadget was tried with two diverse ferrofluid sorts over a scope of attractive flux densities to check execution. The sensors promptly distinguished attractive flux densities in the scope of 0.5 mT to 12.0 mT with estimation sensitivities in the scope of 0.3 to 2.3 nm/mT relying upon ferrofluid sort. Accepting a traditionalist wavelength determination of 0.1 nm for cutting edge EFPI discovery capacities, the assessed achievable estimation determination is on the request 0.04 mT. The natural little size and fundamental structure complimented without hardly lifting a finger make it appropriate for a wide exhibit of research, modern, instructive and military applications.

2015 O.Guillan-Lorenzo, F.Diaz-Otero, **"Design and optimization of a low loss tapered photonic crystal waveguide structure"** [32], Opt.QuantumElectron, 1 9.We survey the distinctive sorts of scattering built photonic crystal waveguides that have been produced for moderate light applications. We present the gathering record transfer speed item (GBP) and the misfortune per delay regarding dB ns 1 as two key figures of legitimacy to depict such structures and analyze the diverse trial acknowledge in view of these figures. A key result of the correlation is that moderate light in view of photonic precious stones executes also or superior to anything moderate light in light of coupled ring resonators.

Chapter 4

Computation Method

The modes of the photonic crystal must of course be solutions of Maxwells equations. However, symmetry considerations place restrictions on the possible form of the solutions. In particular, the modes must satisfy the appropriate translation symmetry.

4.1 Software Used: Comsol Multiphysics 5.2.1.166

Comsol Multiphysics depends on the finite element method. The (FEM) is procedure for finding estimated answers for limit esteem issues for incomplete differential conditions. It is in like manner suggested as (FEA). It subdivides a colossal issue into more diminutive, more clear parts that are called constrained segments. The fundamental conditions that model these restricted parts are then accumulated into a greater course of action of conditions that models the entire problem.FEM by then uses variational techniques from the investigation of assortments to unpleasant an answer by constraining a related goof function.

COMSOL Multiphysics is a restricted segment examination, solver and reenactment programming/FEA programming group for various material science and building applications, especially coupled marvels, or multiphysics. The package is cross-arrange (Windows, Mac, Linux). Despite standard material science based UIs, COMSOL Multiphysics in like manner licenses entering coupled structures of mostly differential conditions (PDEs). The PDEs can be entered clearly or using the implied delicate shape. Since variation 5.0 (2014), COMSOL Multiphysics is in like manner used for making material science based applications. These applications can be continue running with a standard COMSOL Multiphysics allow also with a COMSOL Server allow. An early frame (before 2005) of COMSOL Multiphysics was called FEMLAB.

4.2 THE FINITE ELEMENT METHOD

Now a days the finite element method (FEM) is considered as one of the settled in and accommodating methodology for the PC course of action of complex issues in different fields of planning: basic building, mechanical building, nuclear outlining, biomedical planning, hydrodynamics, warm conduction, geomechanics, et cetera. From inverse side, FEM can be investigated as a competent instrument for the induced course of action of differential conditions depicting various physical systems.

The achievement of FEM is build, as it were, in light of the crucial limited component technique approach used: the meaning of the issue fit as a fiddle, the restricted segment dicretization of this arrangement and the convincing plan of the resulting constrained part conditions. These principal strides are a comparative whichever issue is considered and together with the use of the electronic PC demonstrate an exceptionally regular approach to manage outlining investigation.

In 1909 Ritz developed an effective method [5] for the harsh game plan of issues in the mechanics of deformable solids. It fuses a gauge of imperativeness utilitarian by the known limits with darken coefficients. Minimisation of helpful in association with each dark prompts the plan of conditions from which the dark coefficients may be settled. One from the rule restrictions in the Ritz procedure is that limits used should satisfy as far as possible conditions of the issue.

4.2.1 Comparison of FEM with other methods

The regular strategies accessible for the arrangement of general field issues, similar to flexibility, liquid stream, warm exchange issues, and so on., can be delegated introduced in Fig. 4.1. Beneath FEM will be contrasted and systematic arrangement of differential condition and Ritz technique considering the pole under pliable load

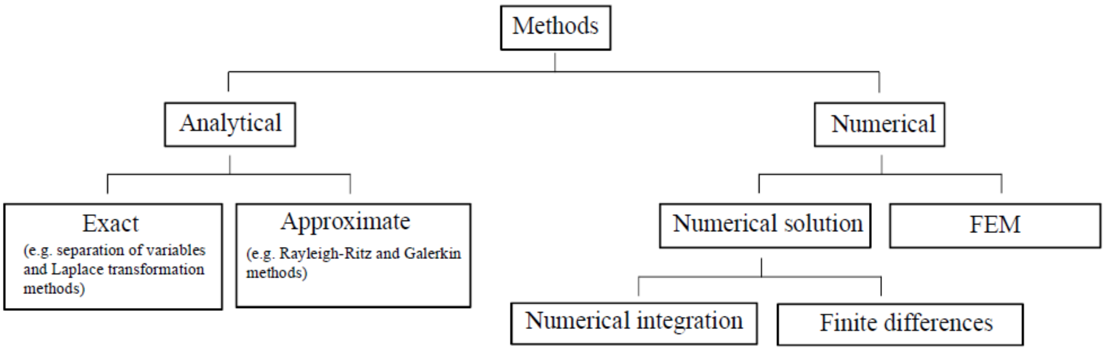


Figure 4.1: Classification of common methods

4.3 The Wave Optics Module

The Wave Optics Module takes care of issues in the field of electromagnetic waves at optical frequencies (relating to wavelengths in the nano-to micrometer range).The fundamental conditions for electromagnetics are naturally accessible in the majority of the material science interfacesan element novel to COMSOL Multiphysics. This additionally makes nonstandard demonstrating effectively accessible.The module is valuable for reproductions and outline of optical applications in essentially all territories where you find electromagnetic waves, for example,

1. Optical strands
2. Photon
3. Photonic crystal
4 Nonlinear optics
5.Laser resonator design
6. Active gadgets in photonics

The material science interfaces cover the accompanying sorts of electromagnetics field reenactments and handle time-consonant, time-ward, and eigenfrequency/eigenmode issues:In-plane, axisymmetric, and full 3D electromagnetic wave spread , Full vector mode examination in 2D and 3D

Material properties incorporate inhomogeneous and completely anisotropic materials, media with additions or misfortunes, and complex-esteemed material properties. Notwithstanding the standard postprocessing highlights, the module underpins coordinate calculation of S-parameters and far-field designs. You can include ports with a wave excitation with indicated control level and mode sort, and include PMLs (perfectly matched layers) to reproduce electromagnetic waves that spread into an unbounded domain waveguides.

4.4 S-Parameter Calculations

S-Parameter Calculations For high-repeat issues, voltage is not an especially portrayed component, and it is imperative to describe the scattering parameters (S-parameter) to the extent the electric field. To change over an electric field outline on a port to a scalar complex number identifying with the voltage in transmission line speculation an eigenmode advancement of the electromagnetic fields on the ports ought to be performed. Acknowledge that an eigenmode examination has been performed on the ports 1, 2, 3, and that the electric field plans E1, E2, E3, of the basic modes on these ports are known. Further, acknowledge that the fields are institutionalized concerning the fundamental of the power stream over each port cross range, separately. This institutionalization is repeat subordinate unless TEM modes are being overseen. The port excitation is associated using the fundamental eigenmode. The figured electric field Ec on the port includes the excitation notwithstanding the reflected field. The S-parameters are given by

$$S_{11} = \frac{\int_{port1}((E_c - E_1).E_1^*)dA_1}{\int_{port1}(E_1.E_1^*)dA_1} \tag{4.1}$$

$$S_{21} = \frac{\int_{port2}(E_c.E_2^*)dA_2}{\int_{port2}(E_2.E_2^*)dA_2} \tag{4.2}$$

$$S_{31} = \frac{\int_{port3}(E_c.E_3^*)dA_3}{\int_{port3}(E_3.E_3^*)dA_3} \tag{4.3}$$

S-PARAMETERS IN TERMS OF POWER FLOW For a managing structure in single mode operation, it is likewise conceivable to decipher the S-parameters regarding the power move through the ports. Such a definition is just the supreme estimation of the S-parameters characterized in the past segment and does not have any stage data. The meaning of the S-parameters as far as the power stream is

$$S_{11} = \sqrt{\frac{\text{Power reflected from Port 1}}{\text{Power incident on port 1}}} \tag{4.4}$$

$$S_{21} = \sqrt{\frac{\text{Power delivered to Port 2}}{\text{Power incident on port 1}}} \tag{4.5}$$

$$S_{31} = \sqrt{\frac{\text{Power delivered to Port 3}}{\text{Power incident on port 1}}} \tag{4.6}$$

4.4.1 S-Parameters and Ports

S-Parameters in Terms of Electric Field Scattering parameters (or S-parameters) are intricate esteemed, recurrence subordinate lattices portraying the transmission and impression of electromagnetic waves at various ports of gadgets like channels, recieving wires, waveguide moves, and transmission lines. S-parameters start from transmission-line hypothesis and are characterized regarding transmitted and reflected voltage waves. All ports are thought to be associated with coordinated burdens, that is, there is no reflection straightforwardly at a port. For a gadget with n ports, the S-parameters are the place S11 is the voltage reflection coefficient at port 1, S21 is the voltage transmission coefficient from port 1 to port 2, et cetera. The time normal power reflection/transmission coefficients are acquired as — Sij —2. Presently, for high-recurrence issues, voltage is not a very much characterized substance, and it is important to characterize the scrambling parameters as far as the electric field.

POWER FLOW NORMALIZATION The fields E1, E2, E3, and so on, should be normalized such that they represent the same power flow through the respective ports. The power flow is given by the time-average Poynting vector,

$$S_{av} = \frac{1}{2}\mathrm{Re}(E \times H^{*}) \tag{4.7}$$

The measure of power flow out of a port is given by the ordinary part of the Poynting vector,Beneath the cutoff frequency the power flow is zero, which suggests that it is unrealistic to standardize the field as for the power flow beneath the cutoff frequency. In any case in this locale the S-parameters are insignificant and don't should be computed. In the accompanying subsections the power stream is communicated specifically as far as the electric field for TE, TM, and TEM waves.

4.4.2 S-Parameter Calculations Ports

The Optics interfaces have a worked in help for S-parameter counts. To set up a S-parameter examine utilize a Port limit include for each port in the model. S-Parameter Variables This module naturally creates factors for the S-parameters. The port names (utilize numbers for scopes to work effectively) decide the variable names. On the off chance that, for instance, there are two ports with the numbers 1 and 2 and Port 1 is the inport, the product creates the factors S11 and S21. S11 is the S-parameter for the reflected wave and S21 is the S-parameter for the transmitted wave. For accommodation, two factors for the S-parameters on a dB scale, S11dB and S21dB, are additionally characterized utilizing the accompanying connection: The model and material science interface names likewise show up before the variable names so they may differ.

S-Parameters in Terms of Electric Field Scattering parameters (or S-parameters) are unpredictable esteemed regarded, recurrence subordinate networks the transmission and impression of electromagnetic waves at particular ports of devices like channels, radio wire, waveguide moves, and transmission lines. S-parameters begin from transmission-line speculation and are described with respect to transmitted and reflected voltage waves. All ports are believed to be related with coordinated burdens, that is, there is no reflection clearly at a port. For a gadget with n ports, the S-parameters are

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} & \dots & S_{1n} \\ S_{21} & S_{22} & S_{23} & \dots & S_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ S_{d1} & S_{d2} & S_{d3} & \dots & S_{dn} \end{bmatrix}$$

4.5 Maxwells Equations

Prologue to Maxwell's Equations Electromagnetic examination on a plainly visible level includes comprehending Maxwell's conditions subject to certain limit conditions. Maxwell's conditions are an arrangement of conditions, written in differential or basic shape, expressing the connections between the major electromagnetic amounts.

These amounts are the: 1. Electric field force E
2. Electric relocation or electric flux thickness D
3. Magnetic field power H
4. Magnetic flux thickness B
5. Current thickness J
6. Electric charge thickness

The conditions can be planned in differential or indispensable frame. The differential frame are displayed here, in light of the fact that it prompts differential conditions that the limited component strategy can deal with. For general time-fluctuating fields, Maxwell's conditions can be composed as

$$\Delta \times H = J + \frac{\partial D}{\partial t} \tag{4.8}$$

$$\Delta \times E = -\frac{\partial B}{\partial t} \tag{4.9}$$

$$\Delta . D = \rho \tag{4.10}$$

$$\Delta . B = 0 \tag{4.11}$$

MAXWELL EQUATION The initial two conditions are likewise alluded to as Maxwell-Ampre's law and Faraday's law, individually. Condition three and four are two types of Gauss' law, the electric and attractive shape, separately. Another crucial condition is the condition of continuity,which can be composed as Out of the five conditions specified, just three are free. The initial two consolidated with either the electric type of Gauss' law or the condition of congruity frame such an autonomous system.Out of the five conditions specified, just three are free. The initial two joined with either the electric type of Gauss' law or the condition of coherence shape such a free system.

4.5.1 Constitutive Relations

$$D = \epsilon_0 E + P \tag{4.12}$$

$$B = \mu_0(H + M) \tag{4.13}$$

$$J = \sigma E \tag{4.14}$$

Here ϵ_0 is the permittivity of vacuum, μ_0 is the penetrability of vacuum, and σ the electrical conductivity. In the SI framework, the penetrability of a vacuum is been $4\pi \times 10^7 H/m$. The speed of an electromagnetic wave in a vacuum is given as c0 and the permittivity of a vacuum is gotten from the connection

$$\epsilon_0 = \frac{1}{c_0^2 \mu_0} = 8.854 \times 10^{-12} F/m \tag{4.15}$$

To get a nearby framework , the constitutive relations delineating the clearly obvious properties of the medium, are joined. They are given as The electric polarization vector P delineates how the material is enchanted when an electric field E is accessible. It can be deciphered as the volume thickness of electric dipole minutes. P is generally a component of E. A couple of materials can have a nonzero P in like manner when there is no electric field appear.

Chapter 5

Result and Disscussion

5.1 Introduction

Photonic crystals [PC] are receiving extra attention by researchers due to their Photonic bandgap (PBG) property, which can control the propagation of EM (electromagnetic waves) in particular range of frequency [1, 2, 3, 4]. Photonic crystals have wide area of application for photonic integrated circuit. By removing some rods of dielectric materials in photonic crystal structure we can control the light propagation in PBG region [5].therefor, we can adjust the transmission and reflection spectra of PC. Optical circulators, filters, de-multiplexer are the devices, designed by PC [6, 7, 8]. Among all these devices, optical filter play an important role in designing of optical Communication network. They can remove unwanted noise from the channels. By introducing resonators and reflectors in the PC waveguide structure, a filter can be realized.

5.2 Structural Design

The wave guide dimensions are, 19a × 21a (where a is the lattice constant or pitch) with dielectric rods in air background. The filter shown in Fig.[5.1] has X-shape cavity acting as resonator and two-line defect based reflectors. These defects are created by removing rods of dielectric material (Si). The material of reflector rods and all other rods, is Silicon with refractive index η=3.48 (dielectric constant ϵ_r=11.4). Perfectly Matched Layer (PML) are used around the whole structure as boundary condition. PMLs may have hypothetical material properties which provide zero reflection theoretically. The main aim of PMLs is to avoid reflections of outgoing waves from the boundaries [11]. The radius of rods in PC is $r = 0.1159 \times a$, where a is lattice constant and the radii of reflectors are selected as $1.5 \times r$. The material of reflector rods kept same as other rods in PC with ϵ_r =11.4. The lattice constant of PC is a=0.6384 μm.

In Fig. 5.1 port 1 and port 2 are input and output ports respectively. The plane wave is given as input at port 1 with 1W power in positive +z-direction. The electric field direction is parallel to axis of Si rods. When the cavity resonates at certain frequency the X-shape resonator couples the input wave from port 1 to the output port 2 [12]. This can be seen from Fig 5.2 which depicts the transmission and reflection spectra of the design. The black curve and red curve shows the forward propagation and backward reflection respectively.

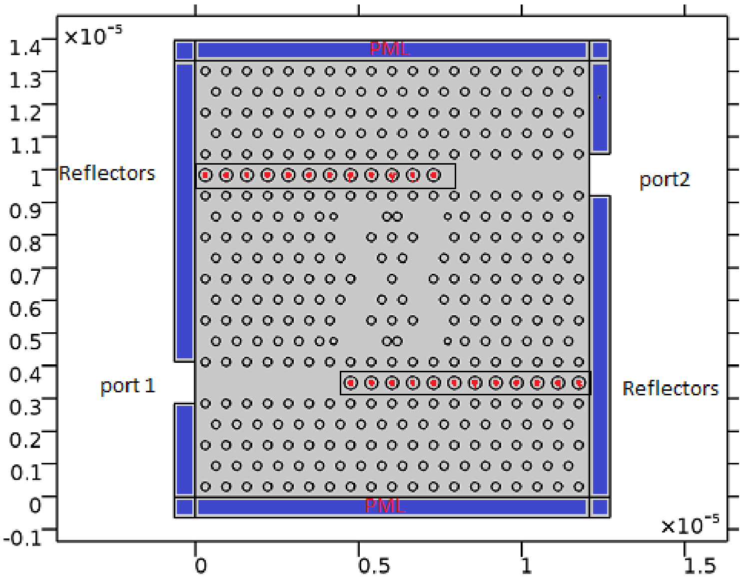


Figure 5.1: Schematic design of filter with X-shape cavity acting as resonator and two-line defect based reflectors. Blue strips shown are the perfectly matched layers (PML)

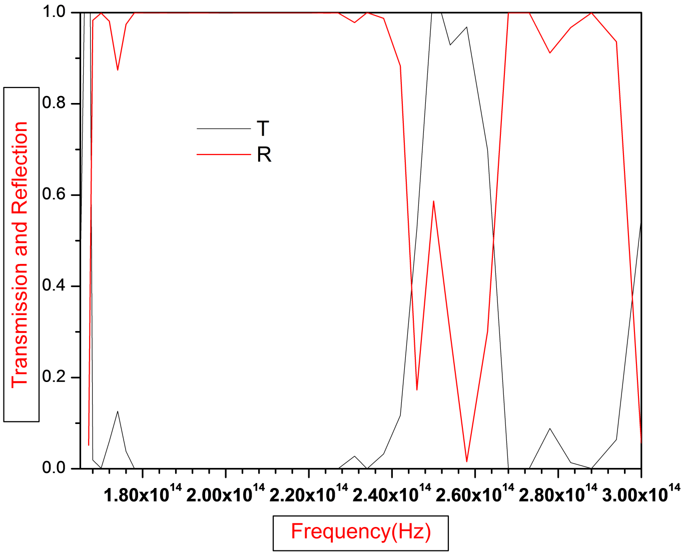


Figure 5.2: The transmittance spectra of Fig The black curve shows forward propagation at port 2 and red curve shows the backward propagation at port1

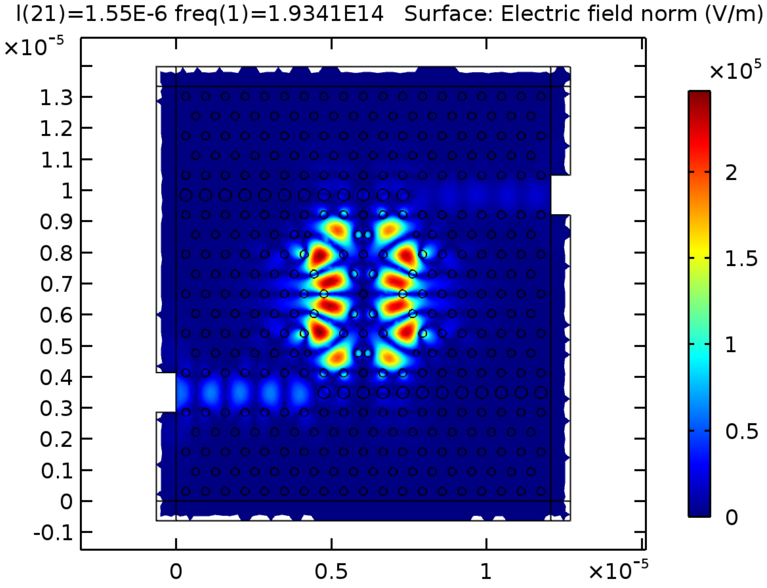


Figure 5.3: Electric field distribution at 1550nm

5.3 Simulation Results

In X-shape cavity structure, the photonic band gap (PBG) range of photonic crystal for TM polarization lies between 1.80×10^{14} -2.312×10^{14} Hz. The perfect photonic crystal prohibits the EM (electromagnetic) waves in the PBG and reflected in this region. By introducing some point and line defects in PC structure, EM waves can be made to propagate in the PBG region. S-parameter shows the performance of electrical networks, which works at microwave and radio frequency ranges. The S-parameter used to calculate the transmission and reflection spectra are calculated as[]

$$S_{11} = \left(\frac{\int \partial\Omega (E - E_1).E_1^*}{\int \partial\Omega E_1.E_1^*} \right) \tag{5.1}$$

$$S_{21} = \left(\frac{\int \partial\Omega E.E_2^*}{\int \partial\Omega E_2.E_2^*} \right) \tag{5.2}$$

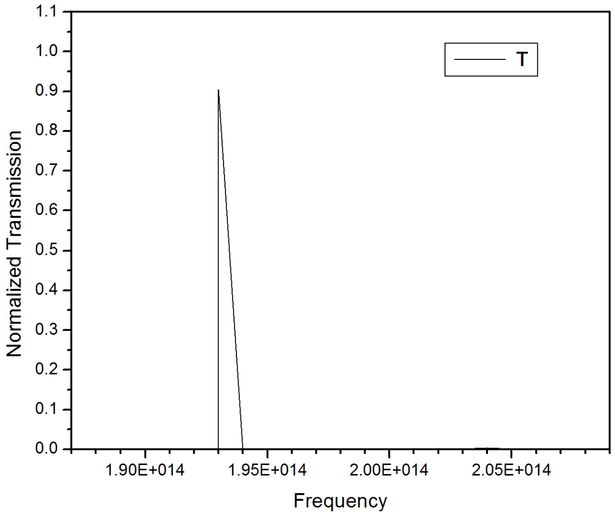


Figure 5.4: Transmission spectra of filter. The resonance condition is at frequency 1.93×10^{14} Hz.

Where S_{21} and S_{11} parameters are the transmission and reflection coefficient at port 2 and port 1, respectively. E denotes the reflection and excitation field at port 1, the E_1 and E_2 fields can be calculated by Eigen mode analysis at port 1 and port 2, respectively. $\partial\Omega$ is the surface normal of port 1 and 2.The point defect based X-shape resonator can be treated as a filter component, which used to confine the light at particular frequency. Electric field distribution of proposed structure in Fig 5.3 depicted that the resonating frequency of filter is at 1.93 $\times 10^{14}$ Hz. There is only one resonating peak in frequency range 1.80$\times 10^{14}$ - 2.20 $\times 10^{14}$, that means at 1.93 $\times 10^{14}$ Hz frequency filter confines the EM wave effectively with transmission coefficient value 0.91.

5.3.1 Varying the shape of resonator

To better investigation of filter performance, we choose different kind of structures by keeping the area of the different shape based resonator is same. In fig. H-shape, circular and square shape filter design is shown with square and circular shape Si rods are used for resonator structure.

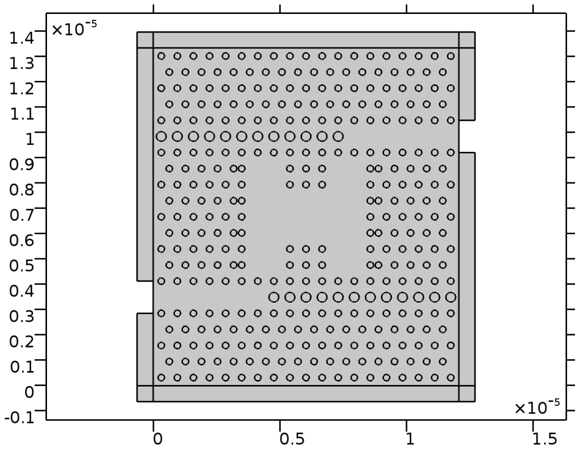


Figure 5.5: Schematic Design of hshape cavity with circular rods

Fig. depicts six kind of geometries having h-shape,circular and square shape cavities with circular and square shape rods. In these deigns the cavity area is same as H-shape cavity area. The filling fraction of circular and square rods are same as in X-shape cavity.

The electric field distribution of Fig 5 is shown in Fig 6 and Fig 7. The resonating frequency achieved is different by using different shape resonating cav-

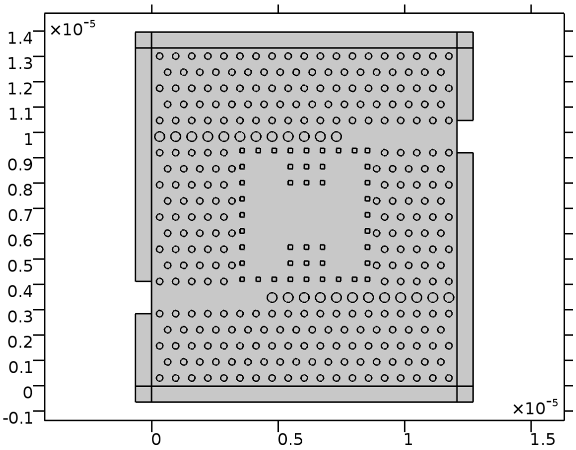


Figure 5.6: Schematic Design of hshape cavity with square rods

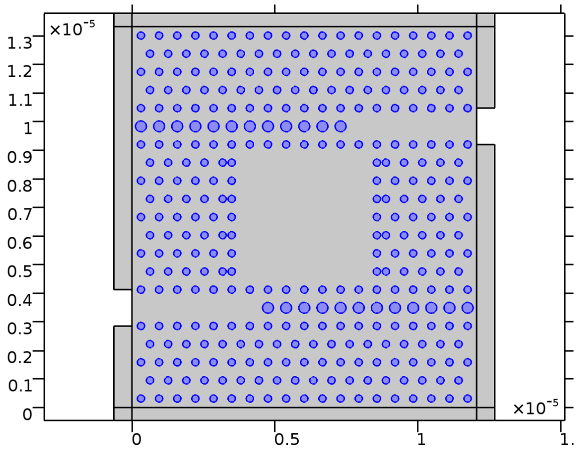


Figure 5.7: Schematic Design of square shape cavity with circular rods

ities. From Fig.6 and Fig 7 resonance conditions achieved for square and circular cavity is at frequency 2.08×10^{14} and 1.9217×10^{14} Hz. Fig 8 shows a comparative curve for all the above designed cavities which clearly shows different resonating conditions using different shape cavities. It depicts that different designed cavities such as H-shape, square and circular shows a different resonating frequency which can acts as a tunable wavelength selective filter.

Where S_{21} and S_{11} parameters are the transmission and reflection coefficient at port 2 and port 1, respectively. E denotes the reflection and excitation field at port 1, the E_1 and E_2 fields can be calculated by eigen mode analysis at port and port 2, respectively. $\partial\Omega$ is the surface normal of port 1 and 2. The point defect based H-shape resonator can be treated as a filter component, which used to

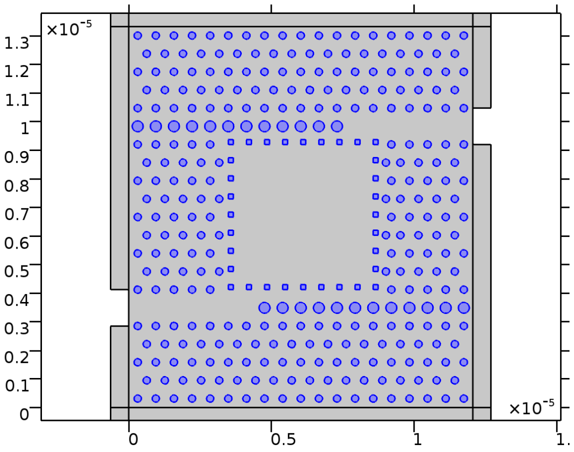


Figure 5.8: Schematic Design of square shape cavity with square rods

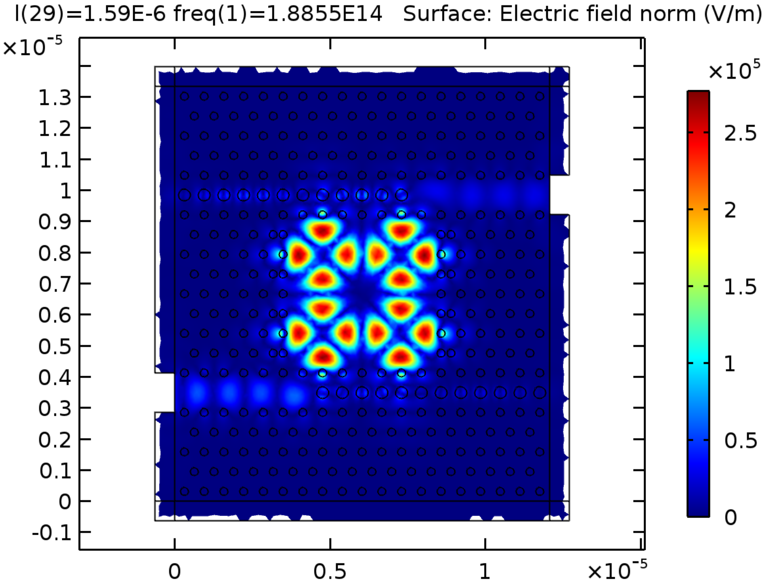


Figure 5.9: Electric field distribution at wavelength 1590nm

confine the light at particular frequency.

Electric field distribution of proposed structure in fig. [5.4] depicted that the resonating frequency of filter is at 2.05 $\times 10^{14}$ Hz. There is only one resonating peak in frequency range 1.80×10^{14} - 2.20 $\times10^{14}$, that means at 1550 $\times10^{14}$ Hz frequency filter confines the EM wave effectively with transmission coefficient value 0.91.

The electric field distribution of fig.5.4 and 5.6 are shown in fig. 5.9 and 5.10 respectively. The resonating frequency achieved is different by using different shape resonating cavities. From fig.[5.5] and fig.[5.9] resonance conditions

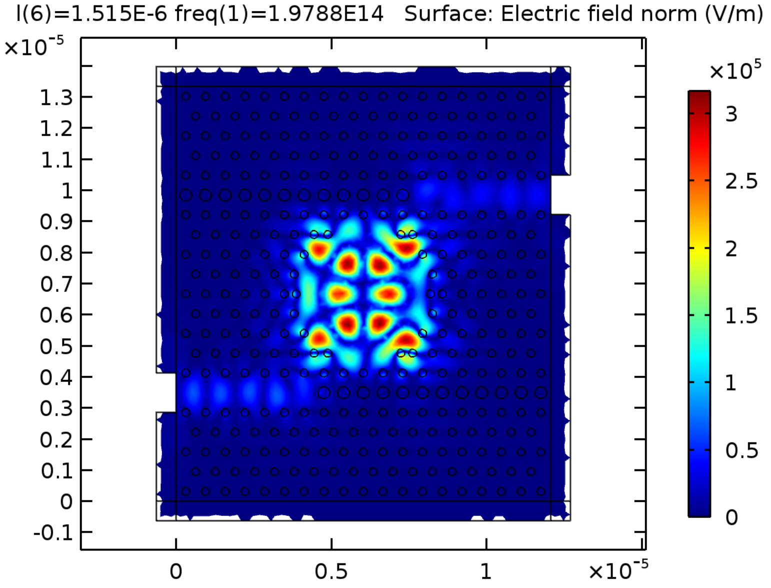


Figure 5.10: Electric field distribution at wavelength 1515nm

achieved for square and circular cavity is at frequency $2.08{\times}10^{14}$ and $1.9217{\times}10^{14}$ Hz.

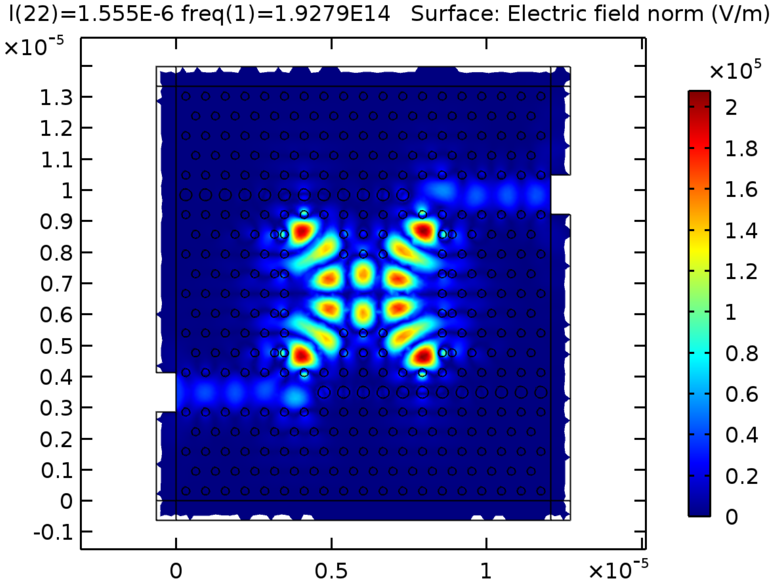


Figure 5.11: Electric field distribution at wavelength 1555nm

Fig. 5.12 shows a comparative curve for all the above designed cavities which clearly shows different resonating conditions using different shape cavities. It depicts that different designed cavities such as H-shape, square and circular shows a different resonating frequency which can acts as a tunable wave-

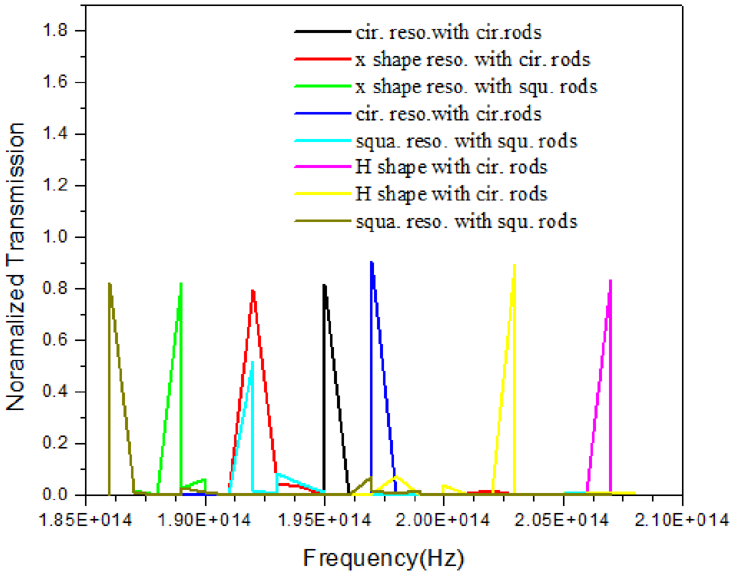


Figure 5.12: Comparison of Transmission spectra versus Frequency for different shape resonator cavities

length selective filter.There is no major change in the band width,therefore no variation in the quality factor.

The major problem in device fabrication is once it is fabricated it's become very difficult to adjust the structural parameters.In our work, with the help of six designed cavities having same area and other structural parameters, we can achieve reduction in the difficulties of device fabrication. One of the main advantage of this filter is, the possibility of tuning of wavelength by changing the shape of cavity. Fig. 5.12 shows a tunable wavelength selective filter by varying the shape of resonating cavities.

5.3.2 Comparison of Quality Factor of Different Shapes

From below table we can analise the quality factor improvement of different cavity shapes based resonator based.

Table 5.1: Quality Factor of different cavity shapes

S.No.	Shape of Cavity	Quality Factor
1	X-shape cavity(circular rods)	1630
2	X-shape cavity(square rods)	1435
3	Square Shape Cavity(square)	531
4	Circular Shape Cavity(square)	679
5	H-shape cavity	1146

Chapter 6

Conclusion

In this theory, an eight sorts of filter of photonic crystal waveguide based resonator structures and gadgets have been outlined and examined and recognized the essential physical impacts that decide . The fundamental target of this work was to plan X shape, H shape, Circular and Square shape photonic crystal waveguides and to streamline the outline by differing the shapes. Enhancement is defended with the transmission loss. This work has been contrasted and the already distributed work by different scientists on photonic crystal particularly on the diverse curve waveguide. The plan and examination for the transmission misfortune has been performed utilizing the product COMSOL Multiphysics. In this work, the optical properties of two-dimensional photonic crystal have been hypothetically researched utilizing the techniques created in the system of the postulation. Reproductions that include presenting X, H, circular and square resonator into a generally cross section have yielded fascinating outcomes.

In this thesis, filter with different shapes H-shape, square, and circular shape cavity acting as resonators is investigated. The transmission and reflection spectra of filters are computed using S-parameter. It can be observed that by changing the shape of resonating filter, the frequency shift can be achieved realizing them as tunable frequency selective optical filters. The proposed design is also suitable for noise filtering as a very narrow band pass filtering is achieved.

With X-shape resonator the resonating wavelength at 1.55 μm is achieved and then by varying the shapes of si rods different resonating wavelength is also achieved.While introducing different shapes of resonator different differnt resonating wavelength is achieved.Therefore,tunable frquency shifted optical filter is designed.

6.0.1 Future Scope

In different late works, distinctive sorts of photonic crystal has been utilized and proposed. The future point is to consolidate those photonic crystal courses of action in the outline and investigation. For more exact examination of a plan, it is important to incorporate more precise parameter checking to outline future devices with tremendously progressed and perfect improvements. Presently a-days in various structures, PhC is added to smother the multimode yield flag. In this way, a definitive objective to outline such PhC for the distinctive gadget structure like Semiconductor Laser, numerous quantum well (MQW) LED and so on.

In this proposition, the improvement work has been performed by experimentation technique utilizing the COMSOL programming. The current pattern for the improvement is to utilize some propel techniques like topology advancement strategy utilizing MATLAB, geometry projection enhancement technique utilizing COMSOL, reproduced toughening creation innovation, and so on.

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