INTERFERENCE BASED ALL-OPTICAL NAND NOR & XNOR LOGIC GATES FOR OPTICAL PROCESSING DEVICES

A PROJECT REPORT

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BACHELOR OF TECHNOLOGY

IN

ELECTRONICS & COMMUNICATION ENGINEERING

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GODAVARI INSTITUTE OF ENGINEERING & TECHNOLOGY (A)

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BONAFIED CERTIFICATE

This is to certify that the project work entitled **"INTERFERENCE BASED ALL-OPTICAL NAND NOR & XNOR LOGIC GATES FOR OPTICAL PROCESSING DEVICES"** submitted for partial fulfilment of bachelor of technology in Electronics and Communication Engineering Department to Godavari Institute of Engineering and Technology (A), Rajahmundry, A.P. affiliated to the JNTUK, Kakinada, is bonafide work done by, **V. KRISHNAVENI (16551A0474), B. V. V. VISALAKSHI (16551A0408), M. SAI RAM (16551A04A8) and N. V. SANDEEP (16551A0458),** under my guidance during the academic year 2019-2020 and it has been found suitable for acceptance according to the requirement of University.

This result embodied in the project report have not been submitted to any other university or institute for the award of degree.

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We solemnly declare that this project report "**INTERFERENCE BASED ALL-OPTICAL NAND NOR & XNOR LOGIC GATES FOR OPTICAL PROCESSING DEVICES"** is the bonafied work done purely by me/us. Carried out under the supervision of **Mr. D. GOWRI SANKAR RAO** towards partial fulfilment of the requirement of the Degree of BACHELOR OF TECNOLOGY in ELECTRONICS AND COMMUNATION Engineering as the administered under the Regulation of Godavari Institute of Engineering & Technology, Rajamahendravaram, AP, India and award of the Degree from Jawaharlal Nehru Technological University, Kakinada during the year 2019-2020.

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ABSTRACT

All-optical logic gates have great applications in high speed computing and data processing to overcome the problems of standard electrons. In this paper we report an all-optical NAND, NOR and XNOR logic gates based on two-dimensional (2-D) square lattice photonic crystal waveguides (PhCWs) composed of silicon rods in air. The proposed structure is designed with T-shaped waveguides without using nonlinear materials. The performance of the structure is examined and simulated by finite difference time domain (FDTD) method. The simulation results show that proposed all-optical logic gates could really function as NAND, NOR and XNOR logic gates without changing the design with proper variations of

input phase angle we can attain these logic gates. The design has an acceptable size of 5.4 μm × 8.4 μm and it provides a contrast ratio of 19.29db, 16db, 10.69db for the designed NAND, NOR and XNOR gates respectively.

CHAPTER 1 OPTICAL FIBER TECHNOLOGY INTRODUCTION

In general, optical or optical technology refers to anything that relates to light or vision, whether it be visible light or infrared light that performs a specific function. For example, optical fibre is a type of wire commonly made out of glass or plastic that carries light signals. These signals can be interpreted by a computer as data and is one example of how data can be transferred over a network. Optical technology can also used in some computers, where computations are done using photons in visible or infrared beams, instead of electric current. An optical fiber is a thin fiber of glass or plastic that can carry light from one end to the other. The study of optical fibers is called fiber optics, which is part of applied science and engineering. Optical fibers are used in telecommunications, but they are also used for lighting, sensors, toys, special camera for seeing inside small spaces. An optical fiber is a flexible, transparent fiber made by drawing glass (silica). Optical fibers typically include a core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by the phenomenon of total internal reflection which causes the fiber to act as a waveguide. Fibers that support many propagation paths or transverse modes are called multi-mode fibers, while those that support a single mode are called single-mode fibers (SMF). Multi-mode fibers generally have a wider core diameter and are used for short-distance communication links and for applications where high power must be transmitted. Single-mode fibers are used for most communication links. In the late 19th and early 20th centuries, light was guided through bent glass rods to illuminate body cavities. Optical fiber is used as a medium for telecommunication and computer networking, because it is flexible and can be bundled as cables. It is especially advantageous for long-distance communications, because infrared light propagates through the fiber with much lower attenuation compared to electrical cables. This allows long distances to be spanned with few repeaters. Fiber optics transmit data in the form of light particles or photons that pulse through a fiber optic cable. The glass fiber core and the cladding each have a different refractive index that bends incoming light at a certain angle. When light signals are sent through the fiber optic cable, they reflect off the core and cladding in a series of zig-zag bounces, adhering to a process called total internal reflection. The light signals do not travel at the speed of light because of the denser glass layers, instead traveling about 30% slower than the speed of light. To renew, or boost, the signal throughout its journey, fiber optics transmission sometimes requires repeaters at distant intervals to regenerate the optical signal by converting it to an electrical signal, processing that electrical signal and retransmitting the optical signal. Fiber optic cables are moving toward supporting up to 10-Gbps signals. Typically, as the bandwidth capacity of a fiber optic cable increases. Attenuation or loss in optical fibers basically refers to the loss of power. During transit, light pulse loses sum of their photons, thus reducing their amplitude. Attenuation measures the reduction in signal strength by comparing the output power with input power. Measurements are made in decibels (dB). The basic measurement for loss is done by taking the logarithmic ratio of input power () to the output power ().

Absorption loss is related to the material composition and fabrication process of fiber. Absorption loss results in dissipation of some optical power as hear in the fiber cable. Although glass fibers are extremely pure, some impurities still remain as residue after purification. The amount of absorption by these impurities depends on their concentration and light wavelength. The absorption of light may be intrinsic or extrinsic.

Linear Scattering Losses: Linear scattering occurs when optical energy is transferred from the dominant mode of operation to adjacent modes. It is proportional to the input optical power injected into the dominant mode. This process tends to result in attenuation of the transmitted light as the transfer may be to a leaky or radiation mode which does not continue to propagate within the fiber core, but is radiated from the fibre. To avoid the losses in optical fibre we are using photonic crystals.

- ## PHOTONI CRYSTALS

The optical properties of periodic structures can be observed throughout the natural world, from the changing colours of an opal held up to the light to the patterns on a butterfly's wings. Nature has been exploiting photonic crystals for millions of years, but humans have only recently started to realize their potential. One-dimensional periodic structures in the form of thin film stacks have been studied for many years, but three-dimensional photonic crystal were first proposed by Yablonovitch and John in 1987. Yablonovitch proposed that three-dimensional periodic dielectric structures could exhibit an electromagnetic bandgap arrange of frequencies at which light cannot propagate through the structure in any direction. He also predicted that unwanted spontaneous emission within a semiconductor can be prevented by structuring the material so that the frequencies of these emissions fall within a photonic bandgap; since no propagating states exist at that frequency, emission is effectively forbidden. John showed that many of the properties of PhCs survive even when the periodic lattice becomes disordered. In such structures, if the index contrast is sufficiently large, strong light localization can still occur, in analogy to the electronic bandgaps of amorphous semiconductors. Perhaps more relevant to much of the PhC research that has followed, and to the topic of this thesis, was Yablonovitch's interpretation of the cavity modes that can be introduced into a periodic structure by creating a defect or "phase slip”. While resonant cavities in distributed feedback lasers had had already been demonstrated using this approach, Yablonovitch showed that modes could be localized in three-dimensions and explained the effect in terms of defect states in the photonic bandgap. From this observation, and the initial proposals for limiting spontaneous emission, the concept of controlling light with periodic structures has developed rapidly into a topic of worldwide research. Bandgaps in periodic materials were already well understood from solid-state physics, where the presence of electronic bandgaps in semiconductors has revolutionized electronics. Many of the concepts from solid-state research have been carried over to photonic crystals including the notation and nomenclature, and perhaps this is what has allowed the field to make such rapid progress in less than twenty years.

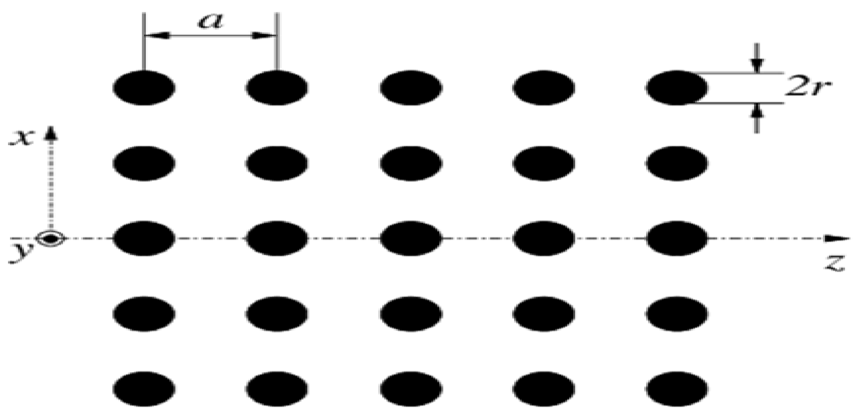


Figure 1.1: Photonic crystal lattice

1.2 HISTORICAL PERSPECTIVE OF PHOTONIC CRYSTALS

In 1887, Lord Rayleigh studied the 1-D photonic crystals consist of multi-layer dielectric stacks. This study showed the photonic band gap which also known as stop band. Vladimir P. Bykov investigated the effect of band gap on the spontaneous emission within the structure. He also gave theoretical concept for 2-D and 3-D PhC structures. In 1979, Ohtaka developed a formal for the calculation of band gap of 3-D PhC structures.

In 1987, the two milestone papers were published by Yablonovitch and John. The main idea of Yablonovitch's paper was to control the spontaneous emission by engineering the density of states. The idea of John's paper was to control the flow of light by using photonic crystal. It is difficult to design the structure in optical scale. It results most of work that were theoretically studied. In 1991, Yablonovitch presented the first 3-D bandgap in the microwave regime. Thomas Krauss demonstrated the 2-D photonic crystal at the optical wavelength in 1996. There are number of research work occurred around the world to improve the optical processing as well as to use the PhC slab. In 1998, Philip Russell developed first commercial used photonic crystal fiber. The study of 2-D photonic crystal is fast as compared to 3-D, due to difficulty level of construction. There is study of naturally occurring PhC based structure for better understanding.

Table 1.1 Historical progress of photonic crystal.

1887	Study of 1-D PhC which show the stop band
1987	Two milestone paper was published based on 2-D photonic crystal
1991	Yablonovitch verified the existence for 3-D PhC in the micrometre range
1996	Present the 2-D PhC at the optical wavelength
1998	Development of first commercial optical fiber based on photonic Crystal

1.3 TYPES OF PHOTONIC CRYSTALS

1.3.1. ONE DIMENSSIONALPHOTONIC CRYSTALS:

Although the term photonic crystal (PhC) is relatively recent, simple one-dimensional (1-D) PhCs, as shown in Fig.1.2, in the form of periodic dielectric stacks have been used for considerably longer. Their wavelength-selective reflection properties see them used in a wide range of applications including high-efficiency mirrors, optical filters and distributed feedback lasers. The simplest PhC is an alternating stack of two different dielectric materials. When light is incident on such a stack, each interface reflects some of the field. If the thickness of each layer is chosen appropriately, the reflected fields can combine in phase, resulting in constructive interference and strong reflectance, also known as Bragg reflection. In contrast to two- and three-dimensional PhCs, 1-D Bragg reflection occurs regardless of the index contrast, although a large number of periods is required to achieve a high reflectance if the contrast is small. Since the absorption in dielectric optical materials is very low, mirrors made from dielectric stacks are extremely efficient, and can be designed to reflect almost 100% of the incident light within a small range of frequencies. The main limitation of these dielectric mirrors is that they only operate for a limited range of angles close to normal incidence. Another, more recent application of 1-D PhCs is the fiber Bragg grating (FBG), in the refractive index of the fiber core is varied periodically along its axis, typically approximating a sinusoidal profile. This case is somewhat more complex because the refractive index varies continuously, rather than discretely, as in the previous example, but the properties are essentially the same. The main difference is that the refractive index contrast in the FBG is so small ($\Delta n \leq 0.5\%$) that the operational bandwidth is very narrow and thousands of periods are typically required to obtain the desired reflectance properties. FBGs are now an integral part of fiber optic systems.

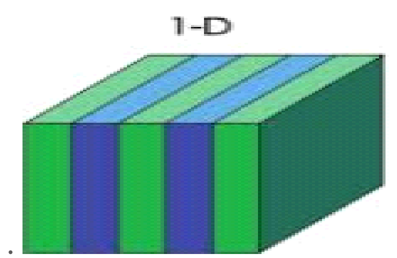


Figure 1.2: Structure of one-dimensional photonic crystal

1.3.2. TWO DIMENSIONAL PHOTONIC CRYSTALS

Both two-dimensional (2D) can be thought of as generalizations to the 1D case where a full 2D bandgap appears only if the 1D Bragg reflection condition is satisfied simultaneously for all propagation directions in which the structure is periodic. For most 2D periodic lattices this occurs providing the index contrast is sufficiently large, and typically consist of an array of dielectric cylinders in a homogeneous dielectric background material, although there are many other possible geometries. If the refractive index contrast between the cylinders and the background is sufficiently large, 2D bandgaps can occur for propagation in the plane of periodicity —perpendicular to the rods. Light at a frequency within the bandgap experiences Bragg reflection in all directions due to the periodic array of cylinders. However, as in the 1D case where light could still propagate in two-dimensions, in a 2D PhC propagation can still occur in the non-periodic direction, parallel to the cylinders. Thus, an alternative means of confinement is required in the third dimension to avoid excessive losses due to diffraction and scattering. As in semiconductor devices, much of the interest in photonic crystals arises not from the presence of a bandgap alone, but rather from the ability to create localized defect states within the bandgap by introducing a structural defect into an otherwise regular lattice. For example, the removal of a single cylinder from a 2D PhC creates a point-like defect or resonant cavity, and the removal of a line of cylinders can create a waveguide that supports propagating modes. Many potential applications based on this concept have been proposed and demonstrated. A second class of 2D PhC applications exploits the unique properties of the propagating modes that exist outside the bandgaps in defect-free PhCs.

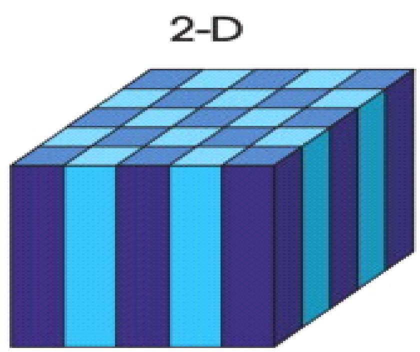


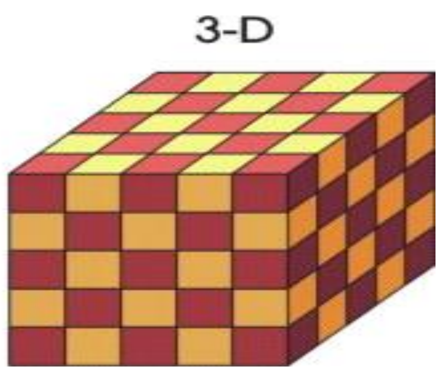
Figure 1.3: Structure of to-dimensional photonic crystals

1.3.3 THREE DIMENSIONAL PHOTONIC CRYSTALS

Initially, the three-dimensional photonic crystal was introduced in 1987. Their works has motivated the control of the wavelength distribution of light continuously emitted through the matter in order to improve the efficiency of the semiconductor laser diodes. The three-dimensional photonic crystal has permittivity modulation alongside three directions. This structural configuration is larger as compared to other dimensions like 1D and 2D photonic crystals. Many researchers have been working towards the 3DPC design of novel geometrical configuration with new applications in both science and engineering fields. For example, the most known 3DPC structure is the stone opal and it has unique optical properties like different colors appearing when rotating stone.

It consists of number of microspheres positioned at nodes of face centered cubic lattice. Here, the reflectance through such structures is strongly dependent on the incident angle. So, when it turns to a certain direction it reflects the radiation at different wavelength range. The optical properties of the photonic crystal depends upon the periodic modulation of the permittivity (or refractive index) of the media. we can observe the effects which has strong analogy of solid states i.e., the periodic arrangement of atoms in a crystal structures.

The different types of photonic crystal having most similarities like, the periodic modulation of the refractive index of the material, lattice formation is same like atomic lattice of solid states and the characteristics of photons in a photonic crystal is similar characteristic of electron and hole pairs in that due to the lattice periodicity the photonic crystal and the solid state providing complete band gap. Such kind of similarities can make to draw the analogies between photonic crystal and solid state physics. Accordingly it gives some of the possible analogies between the properties and the computation methods which can be applied to the solid state and the photonic crystal physics.



1.4: Structure of three dimensional photonic crystal

1.4 DEFECTS IN PHOTONIC CRYSTALS

A crystal is never perfect; a variety of imperfections can mar the ordering. A defect is a small imperfection affecting a few atoms. The simplest type of defect is a missing atom and is called a vacancy. Since all atoms occupy space, extra atoms cannot be located at the lattice sites of other atoms, but they can be found between them; such atoms are called interstitials. Thermal vibrations may cause an atom to leave its original crystal site and move into a nearby interstitial site, creating a vacancy-interstitial pair. Vacancies and interstitials are the types of defects found in a pure crystal. In another defect, called an impurity, an atom is present that is different from the host crystal atoms. Impurities may either occupy interstitial spaces or substitute for a host atom in its lattice site. Dislocations are formed when a crystal is grown, and great care must be taken to produce a crystal free of them. Dislocations are stable and will exist for years. They relieve mechanical stress. If one presses on a crystal, it will accommodate the induced stress by growing dislocations at the surface, which gradually move inward. Dislocations make a crystal mechanically harder. When a metal bar is cold-worked by rolling or hammering, dislocations and grain boundaries are introduced; this causes the hardening. There is no sharp distinction between an alloy and a crystal with many impurities. An alloy results when a sufficient number of impurities are added that are soluble in the host metal. However, most elements are not soluble in most crystals. Crystals generally can tolerate a few impurities per million host atoms. If too many impurities of the insoluble variety are added, they coalesce to form their own small crystallite. These inclusions are called precipitates and constitute a large defect. The most interesting applications and devices arise when defects are introduced into the crystal lattice. Defects can be either a line defect or a point defect.

1.4.1 LINE DEFECT

Line defects, or dislocations, are lines along which whole rows of atoms in a solid are arranged anomalously. The resulting irregularity in spacing is most severe along a line called the line of dislocation. Line defects can weaken or strengthen solids. Introducing line defects in photonic crystals provides a way of creating waveguides for light. The waveguide properties can be tailored by controlling the lattice structure of the surrounding photonic crystal as well as the exact defect region. Photonic crystal waveguides can be highly dispersive, leading to the possibility of slowing down light. After years of research it has started to become clear, however, that light propagation in photonic crystal waveguides is fundamentally limited by unavoidable fabrication imperfections, in particular in the slow-light regime, thus making photonic crystal waveguides uncompetitive with traditional ridge waveguides for most standard waveguiding applications. However, photonic crystals are very efficient for enhancing light-matter interaction and the required modification of the LDOS appears to be rather robust to disorder. Photonic crystal waveguides have been proposed as a way of creating an efficient and broadband single-photon source by coupling a single photon from a quantum emitter directly to the propagating mode of a photonic crystal waveguide. Two main types of dislocations are identified: edge dislocations and screw dislocation, although most real dislocation are intermediate between these types. They are characterised by two direction vectors: the dislocation direction — the direction of the linear structure in question, and the Burgers vector — the principal direction of the strain (displacement) field near the dislocation.

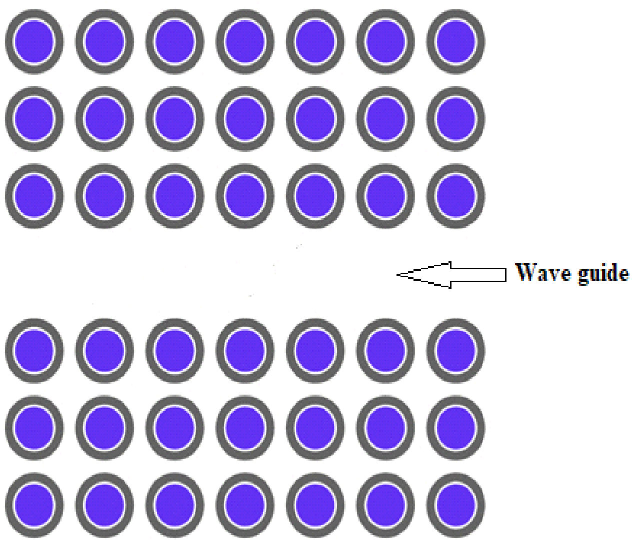


Figure 1.5: Line defect introduced in crystal structure

1.4.2 POINT DEFECTS

A point defect occurs when the crystal periodicity is primarily broken at one lattice site or at a few adjacent sites, although its influence can propagate far away into the crystal (see below). The simplest examples of a point defect are substitutions vacancies and interstitials, in which, respectively, atoms on a given site are replaced by a different species, are absent altogether or occupy a position that is usually unoccupied. Substitutional disorder in alloys can be thought as an extreme example of a high density of point defects. Point defects often occurs in pairs up to maintain stoichiometry or charge neutrality, as in the case of Frenkel defects (a vacancy and an interstitial) or Schottky defects (vacancy of ions with opposite charge). In the case of extended defects, the coordination environment around the defect site is modified to approximate the preferred environment of the new species. For example, if a cation with a preference for tetrahedral coordination is substituted on an octahedral site, the six surrounding anions can be distorted and one or two can be missing altogether, forming an extended defect. If present in sufficient concentration, point defects can give rise to diffuse scattering, in complete analogy to substitutional disorder. Another form of diffuse scattering associated with point defects is Huang scattering: this arises from the static displacement field due to the elastic deformation of the lattice around the defect, and its treatment is analogous to that of first-order TDS. Point defects are defects that occur only at or around a single lattice point. They are not extended in space in any dimension. Strict limits for how small a point defect is are generally not defined explicitly. However, these defects typically involve at most a few extra or missing atoms. Larger defects in an ordered structure are usually considered dislocation loops. For historical reasons, many point defects, especially in ionic crystals, are called centres. For, example a vacancy in many ionic solids is called a luminescence centre, a colour canter, or F-centre. These dislocations permit ionic transport through crystals leading to electrochemical reactions.

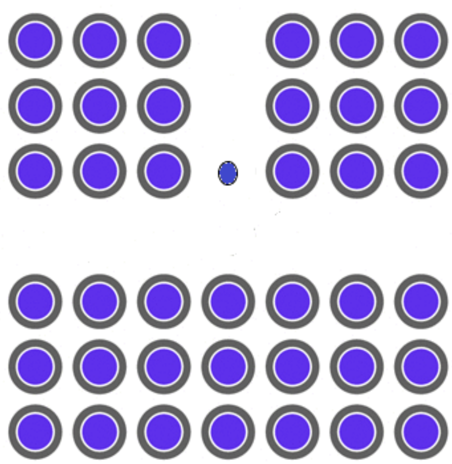


Figure 1.6: Point defects introduced in crystal structure

1.5 PHOTONIC BAND GAP

Photonic bandgap fibers are optical fibers where a photonic bandgap effect rather than a core region with increased refractive index is utilized for guiding light. Essentially, a kind of two-dimensional Bragg mirror is employed. Such a guiding mechanism normally works only in a limited wavelength region. The earliest realization of such fibers, called Bragg fibers, was based on concentric rings with different refractive index. Later, a special type of photonic crystal fiber has been developed, which also implements guidance with a photonic bandgap, but in this case based on tiny air holes.

The refractive index of the core itself can be lower than that of the cladding structure. The core can even be hollow, so that its refractive index is that of air. As most of the light is then propagating in air rather than in glass, such kinds of hollow-core photonic bandgap fibers may be used for guiding light in spectral regions where the absorption in the glass is relatively high. For example, light from a CO_2 laser may be guided. Also, hollow-core fibers have a very weak nonlinearity, which makes them promising e.g. for the dispersive compression of ultrashort pulses with high peak power, or for the delivery of high-power laser beams. However, photonic bandgap fibers are generally more difficult to produce due to their tight fabrication tolerances, have a limited bandwidth for low-loss transmission, and often exhibit relatively high propagation losses. It is also substantially more difficult to understand and model their propagation characteristics, compared to index-guiding fibers.

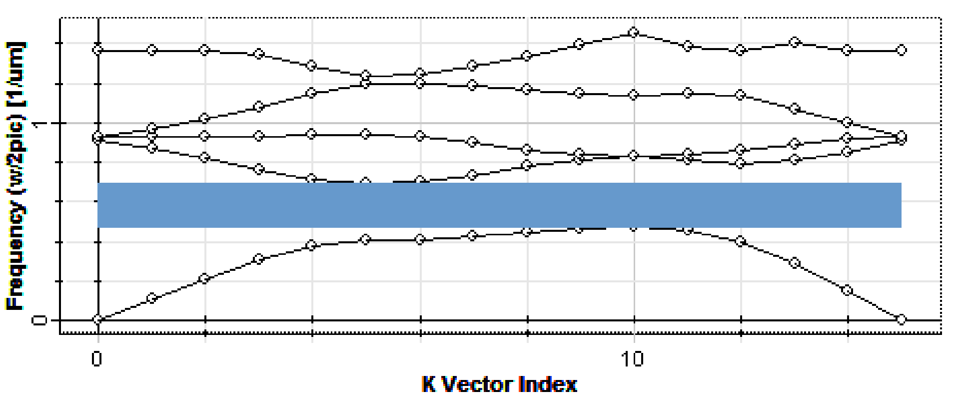


Figure 1.7: Photonic band gap diagram using PWE band solver in FDTD

1.6 ADVANTAGES OF PHOTONIC CRYSTALS

There are many advantages over the conventional optical devices. Its main advantage is to control optical properties and confinement of light by engineering the design of structure. Some of advantages are shown below:

1.Photonic crystals reflect light of particular wavelength range which results in one mode of cavities unlike the metal cavities. The metal reflects all wavelength which results in infinite mode.

2. It can withstand with high electric fields

3. The size of photonic crystal devices are in the order of wavelength of light. Therefore, the devices are compact in size.

4. It processes the data at high speed as the travelling speed in structure is speed of light.

5. These devices are immune to short circuits as well as noise as the information carriers are photons unlike electrons in metallic wires.

6. Power consumption is low due to linear property of photonic crystal.

7. It confines the light highly in the structure due to large difference present for effective index.

8. It controls the spontaneous emission in the lattice.

1.7 DISADVANTAGES OF PHOTONIC CRYSTALS

On the other hand, photonic crystal offers few disadvantages. The main disadvantage is complexity to design on the 3-D scale [14]. There are several experiment occurred to yield efficient results. The other disadvantage of photonic crystal is the designing cost. It is more expensive than the conventional devices.

Due to various advantages, photonic crystal based devices are developed rapidly to meet the growing demand of high speed and capacity.

1.8 INTRODUCTION TO THE SOFTWARE

R-Soft (2011) is commercially available software that includes many modules. Namely, Band Solve module allows one to compute the band structures of the PhC as well as its modes field distribution by means of PWE method while Full wave implements FDTD method applying it to the field distribution computation inside the arbitary structures nd, in special case, the band structure.

1.8.1 PLANE WAVE EXPANSION

Plane wave expansion method (PWE) refers to a computational technique in electromagnetics to solve the Maxwell's equations by formulating an eigenvalue problem out of the equation. This method is popular among the photonic crystal community as a method of solving for the band structure (dispersion relation) of specific photonic crystal geometries. PWE is traceable to the analytical formulations, and is useful in calculating modal solutions of Maxwell's equations over an inhomogeneous or periodic geometry. It is specifically tuned to solve problems in a time-harmonic forms, with non-dispersive media. The plane wave expansion method allows the calculation of dispersion curves (i.e. the relation linking the frequency to the wave number for any propagating mode) of periodic structures made of, for example, elastic materials such as photonic crystals. This chapter presents the method with many details in the case of bulk photonic crystals (i.e. structures of infinite extent) and discusses its advantages and drawbacks. It is also shown that it can be used for analysing the evanescence of waves inside the photonic band gaps and for drawing the equifrequency contours of any periodic structure. Considering very simple periodic structures such as one-dimensional infinite atomic when chains, the chapter briefly explains the concepts that are necessary for studying when more complex periodic structures such as the photonic crystals – namely the unit cell, the direct lattice, the reciprocal lattice, the Brillouin zones, the dispersion curves and the band gaps. The PWEM is highly efficient for calculating modes in periodic dielectric structure. It is the method of choice for calculating the band structure of photonic crystals. It is not easy to understand at first, but it is easy to implement.

1.8.2 FINITE-DIFFERENCE TIME-DOMAIN

Finite-difference time-domain or Yee's method (named after the Chinese American applied mathematician Kane S. Yee, born 1934) is a numerical analysis technique used for modelling computational electrodynamics (finding approximate solutions to the associated system of differential equations). Since it is a time-domain method, FDTD solutions can cover a wide frequency range with a single simulation run, and treat nonlinear material properties in a natural way.

The FDTD method belongs in the general class of grid-based differential numerical modeling methods (finite difference methods). The time-dependent Maxwell's equations (in partial differential form) are discretized using central-difference approximations to the space and time partial derivatives. The resulting finite-difference equations are solved in either software or hardware in a leapfrog manner: the electric field vector components in a volume of space are solved at a given instant in time; then the magnetic field vector components in the same spatial volume are solved at the next instant in time; and the process is repeated over and over again until the desired transient or steady-state electromagnetic field behavior is fully evolved.

The Finite-Difference Time-Domain (FDTD) method provides a direct integration of Maxwell's time-dependent equations. During the past decade, the FDTD method has gained prominence amongst numerical techniques used in electromagnetic analysis. Its primary appeal is its remarkable simplicity. Furthermore, since the FDTD is a volume-based method, it is exceptionally effective in modelling complex structures and media. However, the distinct feature of the FDTD method, in comparison to the Method of Moments (MoM) and the Finite Elements Method (FEM) is that it is a time-domain technique. This implies that one single simulation results in a solution that gives the response of the system to a wide range of frequencies. The time-domain solution, represented as a temporal waveform, can then be decomposed into its spectral components using Fourier Transform techniques. This advantage makes the FDTD especially wellsuited for most EMI/EMC problems in which a wide frequency range is intrinsic to the simulation.

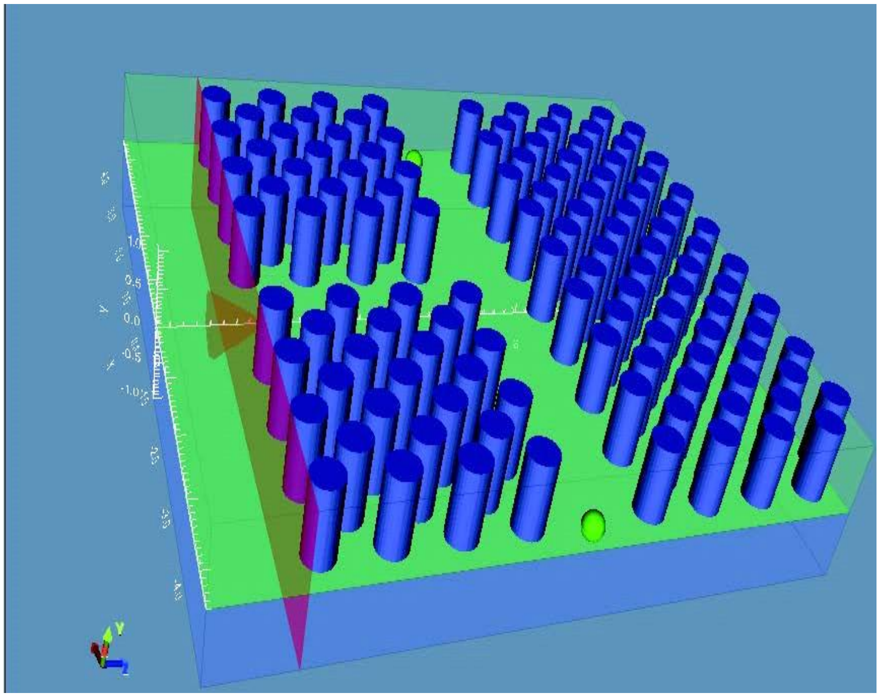


Figure 1.8: Finite-difference-time-domain

CHAPTER 2

LITERATURE REVIEW

Saif H. Abdulnabi et al., (2019) "All-optical logic gates based on nanoring insulator–metal–insulator plasmonic waveguides at optical communications band".

We propose, analyze, and simulate a configuration to realize all-optical logic gates based on nanoring insulator–metal–insulator (IMI) plasmonic waveguides. The proposed plasmonic logic gates are numerically analyzed by finite element method. The analyzed gates are NOT, OR, AND, NOR, NAND, XOR, and XNOR. The operation principle of these gates is based on the constructive and destructive interferences between the input signal(s) and the control signal. The suggested value of transmission threshold between logic 0 and logic 1 states is 0.25. The suggested value of the transmission threshold achieves all seven plasmonic logic gates inonestructure.Weusethesamestructurewiththesamedimensionsat1550-nmwavelengthfor all proposed plasmonic logic gates. Although we realize seven gates, in some cases, the transmission of the proposed plasmonic logic gates exceeds 100%, for example, in OR gate (175%), in NAND gate (112.3%), and in XNOR gate (175%). As a result, the transmission threshold value measures the performance of the proposed plasmonic logic gates. Furthermore, the proposed structure is designed with a very small area (400 nm × 400 nm). The proposed all-optical logic gates structure significantly contributes to the photonic integrated circuits construction and all-optical signal processing nanocircuits.

A. R. M. Zaghloul et al., (2018) "Complete all-optical processing polarization based binary logic gates".

In this paper they present a complete all-optical-processing polarization-based binary-logic system, by which any logic gate or processor can be implemented. Following the new polarization-based logic presented in [Opt. Express 14, 7253 (2006)], we develop a new parallel processing technique that allows for the creation of all-optical-processing gates that produce a unique output either logic 1 or 0 only once in a truth table, and those that do not. This representation allows for the implementation of simple unforced OR, AND, XOR, XNOR, inverter, and more importantly NAND and NOR gates that can be used independently to represent any Boolean expression or function. In addition, the concept of a generalized gate is presented which opens the door for reconfigurable optical processors and programmable optical logic gates. Furthermore, the new design is completely compatible with the old one presented in [Opt. Express 14, 7253 (2006)], and with current semiconductor based devices. The gates can be cascaded, where the information is always on the laser beam. The polarization of the beam, and not its intensity, carries the information. The new methodology allows for the creation of multiple-input-multiple-output processors that implement, by itself, any Boolean function, such as specialized or non-specialized microprocessors. Three all-optical architectures are presented: orthoparallel optical logic architecture for all known and unknown binary gates, single branch architecture for only XOR and XNOR gates, and the railroad (RR) architecture for polarization optical processors (POP). All the control inputs are applied simultaneously leading to a single time lag which leads to a very-fast and glitch-immune POP. A simple assnd easy-to-follow step-by-step algorithm is provided for the POP, and design reduction methodologies are briefly discussed. The railroad (RR) architecture of polarization optical processors (POPs) is introduced to design any complex Boolean expression, which lead to the concept of electro-elimination to continuously process the information optically without the need to convert the laser beam into an electronic signal. The POP is very easily understood by the simulation of a bullet train traveling at the speed of light on a railroad system preconditioned by the crossovers determined by the control signals. All control signals are applied to the POP simultaneously eliminating the need for a timing diagram and any problems associated with the inherent time delays of electronic microprocessors. Therefore, the POP is not vulnerable to glitches and is inherently stable. The RR-architecture POP can be used to design any binary gate with any truth table. Therefore, it is equally applicable to all types of binary gates, including for example Fredkin gates, Toffoli gate, threshold gates, testable reversible-logic gates, and all future gates.

Ke Ji et al., (2018) "A hybrid multiplexer/de-multiplexer for wavelength-mode-division based on photonic crystals".

A hybrid multiplexer/de-multiplexer (HMUX/HDEMUX) for wavelength-mode-division based on photonic crystals (PCs) is presented. The proposed device consists of a point-defect cavity, a wavelength-selective cavity and asymmetrical parallel waveguides. Coupled-mode theory (CMT) is applied to the analysis, and the finite-difference time-domain (FDTD) method is used for the simulations. The simulation results show that the device can multiplex the fundamental and first order modes of 1550 and 1310 nm. It exhibits not only a low insertion loss (<0.37 dB) but also low mode crosstalk (<−13 dB). Thus, the PC-based HMUX/HDEMUX has considerable potential for application in large-capacity optical communication systems.

A novel HMUX/HDEMUX for WDM-MDM based on PCs is proposed. According to the time-dependent coupled-mode theory, a point-defect cavity and a wavelength-selective cavity are introduced into the PC to filter the optical wave. Moreover, according to lateral coupled-mode theory, mode conversion is achieved by the APW. The WDM and MDM are integrated into a single chip, reducing the loss produced by the coupling of different devices, and the overall device dimensions are 51 μm × 9 μm. The simulation results show that the device offers the advantages of high transmittance, low insertion loss and low crosstalk. The ultra-compact PC-based HMUX/HDEMUX exhibits performance superior to that of conventional devices. The device can be extended to achieve multiplexing/de-multiplexing of more modes and wavelengths. Therefore, it has considerable potential for future applications in ultrahigh-speed and large-capacity communication systems.

S.Divya et al., (2017) "Designing of All Optical Nand Gate Based On 2d Photonic Crystal".

Thus paper explains the design of all-optical 2-input NAND gate based on 2-D photonic crystal. In order to analyze the operation of NAND gate, two resonant rings have been used. Based on the Kerr effect, high intensity optical power is injected into the device. The indium phosphide and gold rod based rectangular lattice photonic crystal structure with refractive index 3.1 and 3.6 is considered. The band analysis and the transmittance characteristics are analyzed using plan wave expansion (PWE) and finite different time domain method (FDTD) are used to analyze the behaviour of the structure. Moreover, the operational wavelength of the input ports is 1.55μm. The consistency of simulation results with the logical table of NAND gate confirms the suitable functionality of the device. An optical two input logic NAND gate and the photonic crystal are comprised of 2D-square lattice of dielectric rods are made of indium phosphide and gold rod in air substrate. The high Kerr coefficient is presented in the resonant rings by launching high intensity optical power in to the resonant ring. Moreover the structure is operated at 1.55 μm wavelength. In this proposed structure, when both logic condition is ON the bias light is not dropped to the output waveguide and is not passed towards the output port and the output condition will be 0, logic ports turned OFF when either one of the port is in OFF condition or either one of the port is in ON condition, the bias light will drop to the output waveguide and gate will become 1.

Orrathai Watcharakitchakorn et al., (2017) "Design and Modeling of the Photonic Crystal Waveguide Structure for Heat-Assisted Magnetic Recording".

The application of the photonic crystal (PC) waveguide (WG) as the light delivery system in the heat-assisted magnetic recording (HAMR) system is demonstrated. The structure consists of a 90° bending PC waveguide and a ridge dielectric waveguide taper coupler. Three-dimensional (3D) models of structures are built and simulated in order to determine light coupling and transmission efficiencies. Geometric parameters including the taper length (LTP), coupler inlet width (WFW), and PC waveguide width (WWG) are investigated.)e initial simulation shows that the transmission efficiency of over 90% can be achieved with the coupler integrated with the straight PC waveguide. This paper investigates a PC waveguide-based light delivery system for HAMR. We examined taper coupling and bending structures. PC waveguide model is created by removing a single row of photonic crystals in a triangular lattice array of air holes in the silicon substrate. The PC waveguide operates at 1,550 nm and can accommodate both TM- and TE-polarized sources. The lattice space (a) and air hole radius (r) are 612 and 263 nm, respectively di-electric coupler model is designed by varying the inlet waveguide width (WFW) and the taper length (LTP) from 5 to 30 μm. The PC waveguide width of interest are 0.8a√3 or 0.848 μm and 1.0a√3 or 1.060 μm.) dielectric taper coupler integrated with the straight PC waveguide structure shows the highest coupling efficiency of 95.3% with the WFW 10 μm, LTP 5 μm, and WWG 0.8a√3 μm structure. For WWG 1.0a√3 μm, there are 3 structures with LTP 5 μm that achieve over 90% coupling efficiency, that is, 94.6% for WFW 15 μm, 97.4% for WFW 25 μm, and 90.8% for WFW 30 μm. The 1.0a√3 μm width is chosen for integration with the 90° bending structure to form the proposed light delivery structure since it provides larger guiding area at the bending section.

Enaul haq Shaik et al., (2016) "Multi-mode interference-based photonic crystal logic gates with simple structure and improved contrast ratio".

We present a MMI-based photonic crystal all optical logic gate. Structure for logic functions such as XNOR, XOR, OR and NAND with square-type lattice of Si rods in air host. Phase-based logic inputs produce intensity-based logic outputs with high contrast ratio. The calculated ON to OFF contrast ratio for the logic functions XNOR/XOR and OR/NAND is 40.41 and 37.40 dB, respectively. Further, it is improved by 11.53 and 12.46% for XNOR/XOR and OR/NAND logic functions, respectively, by reducing the back reflection with the introduction

of absorbing waveguides. The structure in both the forms has a fast response period that is less than or equal to 0.131 ps. The size of the structure is quite compact with dimension6.4 m×8.8 m. Phase-based inputs provide intensity-based output with high contrast ratio for XNOR, XOR, OR and NAND logic functions. In order to avoid the back reflection into the input ports, the proposed structure is modified by creating the absorbing waveguides. The basic logic gate structure provides a contrast ratio of 40.41 and 37.40 dB for XNOR/XOR and OR/NAND logic functions,respectively,at1550nm,which has been improved further by11.53and12.46%,with the introduction of absorbing waveguides in the structure. The response period of both the structures is less than or equal to 0.131 ps.

Lokendra Singh et al., (2016) "Design of All-Optical Universal Gates using Plasmonics Mach-Zehnder Interferometer for WDM Applications".

All optical integrated circuits have great application in high-speed computing and information processing to overcome the limitation of conventional electronics. In this work, a novel design of all optical universal gates using optical Kerr effect and optical bistability of a plasmonics based Mach-Zehnder interferometer (MZI) has been proposed. A MZI is capable for switching of light which depends on the intensities of optical input signal. The study of device is carried out using finite-difference-time-domain (FDTD) method and verified using MATLAB simulation. In this work, all optical universal gates using plasmonics Mach-Zehnder interferometer are designed and verified. The proposed designs are ultra-compact in nature and useful for optical computing technologies. The nonlinear Kerr-material provides ultrafast switching which can be used to develop switching components for WDM applications.

Enaul haq Shaik et al., (2016) "Design of photonic crystal based all-optical AND gate using T-shaped waveguide".

In this paper a new configuration of all-optical AND gate based on two-dimensional photonic crystal composed of Si rods in air. Two AND gate structures with and without reference input are proposed. The proposed structures are designed with T-shaped waveguide without using nonlinear materials and optical amplifiers. The performance of the proposed AND gate structures is analyzed and simulated by plane-wave expansion and finite difference time domain methods. The AND gate without reference input needs only one T-shaped waveguide, whereas the AND gate with reference input needs two T-shaped waveguides. The former AND gate offers a bit rate of 6.26 Tbps with a contrast ratio of 5.74 dB, whereas the latter AND gate offers a bit rate of 3.58 Tbps whose contrast ratio is 9.66 dB. It can be expected that these small size T-shaped structures are suitable for large-scale integration and can potentially be used in on-chip photonic integrated circuits The significance of the reference input in improving the functional performance of the AND gate and the method of optimizing parameter for determining the high contrast ratio are explored. The AND logic gate without the reference input provides a bit rate of 6.26 Tbps with a minimum contrast ratio of 5.74 dB. The AND gate with probe input provides a bit rate of 3.58Tbps with a minimum contrast ratio of 9.66 dB.

Tamer et al., (2015) "All-optical S-R flip flop using 2-D photonic crystal".

The photonic crystals (PhC) draw significant attention to build all optical logic devices and considered one of the solutions for the opto-electronic bottleneck via speed and size. The paper presents a novel all optical SR flip flop memory based on two optical NOR gates using 2D PhC. The design of optical Flip Flop is based on four nonlinear photonic crystal ring resonator and T-type waveguide. The total size of the proposed optical memory flip flop is equal to 30 μm × 30 μm. The structure has lattice constant ‘a’ is equal to 630 nm and bandgap range from 0.32 to 044. The flip flop design has a switching time in few Picoseconds and low power input of 50 mW. The PhC structure has a square lattice of silicon rod with refractive index of 3.39 in air. The overall design and the results are discussed through the experimental implementation and the numerically simulation to confirm its operation and feasibility. The structure is experimentally simulated by the finite different time domain (FDTD) and Plane Wave Expansion (PWE) methods. The proposed optical flip flop has two inputs (S-R), two extra optical supply (Ports A and B), and two outputs Q and Q0 with normal status for set and reset states. The proposed flip flop will be useful in the future for using the structure in all-optical computing and optical information processing to increase the speed and the performance of the optical network.

Ashkan pashamehr et al., (2015) “All-optical AND/OR/NOT logic gates based on photonic crystal ring resonators”.

Photonic crystal based ring resonators are best choice for designing all-optical devices. In this paper, we used a basic structure of photonic crystal ring resonators and designed all optical logic gates which are working using the Kerr effect. The proposed gates consisted of upper and lower waveguides coupled through a resonator which was designed for dropping of special wavelength. The resonance wavelength was designed for 1550 nm telecom operation wavelength. We used numerical methods such as plane wave expansion and finite difference time domain (FDTD) for performing our simulations and studied the optical properties of the proposed structures. Our results showed that the critical input power for triggering the gate output was lower compared to previously reported gates. This effect occurs when two input beams are simultaneously enter the resonant cavity, and because of increase in optical field, the refractive index changes and consequently the resonant wavelength shifts. To do so, a bias input was introduced and defined with a wavelength identical to resonance wavelength of ring. When another input set to high and simultaneously enter the ring, it can change the transmission spectra and the propagation of light is controlled. Using this property and setting the bias to higher power, the all optical gates are designed and the results show that the proposed structures require lower input power for operation.

Nakkeeran Rangaswamy et al., (2015) "Design of photonic crystal-based all-optical AND gate using T-shaped waveguide".

In this paper a new configuration of all-optical AND gate based on two-dimensional photonic crystal composed of Si rods in air. Two AND gate structures with and without reference input are proposed. The proposed structures are designed with T-shaped waveguide without using nonlinear materials and optical amplifiers. The performance of the proposed AND gate structures is analyzed and simulated by plane-wave expansion and finite difference time domain methods. The AND gate without reference input needs only one T-shaped waveguide, whereas the AND gate with reference input needs two T-shaped waveguides. The former AND gate offers a bit rate of 6.26 Tbps with a contrast ratio of 5.74 dB, whereas the latter AND gate offers a bit rate of 3.58 Tbps whose contrast ratio is 9.66 dB. It can be expected that these small size T-shaped structures are suitable for large-scale integration and can potentially be used in on-chip photonic integrated circuits.

The significance of the reference input in improving the functional performance of the AND gate and the method of optimizing parameter for determining the high contrast ratio are explored. The AND logic gate without the reference input provides a bit rate of 6.26 Tbps with a minimum contrast ratio of 5.74 dB. The AND gate with probe input provides a bit rate of 3.58 Tbps with a minimum contrast ratio of 9.66 dB.

Junjie Bao et al., (2014) "All-optical NOR and NAND gates based on photonic crystal ring resonator".

In this paper, a new configuration of all-optical logic gates based on two-dimensional (2D) square lattice photonic crystals (PCs) composed of silicon (Si) rods in Silica (SiO2). The proposed device is composed of cross-shaped waveguide and two photonic crystal ring resonators (PCRRs) without nonlinear materials and optical amplifiers. The gate has been simulated and analyzed by finite difference time domain (FDTD) and plane wave expansion

(PWE) methods. The simulation results show that the proposed all-optical logic gates could really function as NOR and NAND logic gates. This new device can potentially be used in large-scale optical integration and on-chip photonic logic integrated circuits. new ultra- compact photonic crystal logic NOR and NAND gates have been demonstrated. The definitions of logic 1 and 0 were also introduced. The dimension of the logic gate is not more than 6.8μm. Compared with nonlinear material logic gate, the proposed logic gate which is based on linear characteristics of the material can operate at low powers. It is expected that these new structures will make PCRRs have new applications for all-optical logic circuits and ultra-compact high density photonic integration.

Jayanta Kumar et al., (2014) "Micro-ring resonator based all-optical reconfigurable logic operations".

An all-optical reconfigurable logic operation essentially constitutes a key technology for performing various processing tasks with ultrafast signal-processing technologies. We present designs and simulations for highly cascadable all-optical reconfigurable logic operations using GaAs–AlGaAs micro-ring resonator based optical switches and multiplexers. The switching action of the ring resonator is achieved through variation in the refractive index of the ring resonator produced by the two-photon absorption (TPA) effect through the application of optical pump pulse. The proposed circuit can perform any of the four digital logic operations (NOT, NOR, XOR, AND) by using the appropriate optical pump signal at the selection port of the multiplexer. We have tried to exploit the advantages of micro-ring resonator based all optical switch to design an all-optical circuit. The reconfigurable nature of the circuit offers maximum flexibility for the end user since the entire application can be changed simply by adjusting the multiplexer select line signals. Numerical simulation confirming described methods is given in this paper, they reported and explained the attractive and powerful method

to design all-optical reconfigurable logic operations (NOT NOR, XOR and AND) using micro-ring resonator based switches through optical pumping with an average pump power of 2.29mW. This scheme can easily and successfully be extended and implemented for any higher number of input digits by proper incorporation of ring-resonator based switches and higher order of multiplexers. Numerical simulation results confirming the described method are given in this paper. In our proposed design we get the on –off ratio, contrast ratio, extinction ratio, amplitude modulation as 30dB, 31.6dB, 21.6dB and 0.066dB respectively at the optimum condition, which are more adequate for all-optical logic based information processing. The high value of PED(O) (¼88.2%) is also reported in this paper which indicates quite a good response of the circuit. The theoretical model developed and the numerically obtained results will be useful in future all-optical computing and information processing and is expected to play important roles in constructing future all-optical photonic networks.

Chunrong Tang et al., (2013) "Design of all-optical logic gates avoiding external phase shifters in a two-dimensional photonic crystal based on multi-mode interference for BPSK signals".

In this paper several new structures of all-optical logic gate in a two-dimensional photonic crystal (PC) based on multi-mode interference (MMI) are proposed and designed. $3\pi/2$ phase shift is introduced between two input ports in the photonic crystal devices through different lengths of the waveguide of two input ports, which makes the logic gates to be directly used for logic operations of binary-phase shift-keyed (BPSK) signals. XOR, XNOR, OR and NAND logic gates are realized. In order to simulate the performance of the proposed logic gates, the plane wave expansion method (PWEM) and finite difference time domain (FDTD) method are employed. Numerical results reveal that the contrast ratio between Logic 1 and Logic 0 logic-levels is more than 21 dB for XOR,17 dB for XNOR, and 13 dB for OR and NAND logic operations in the whole C-Band (1530–1565 nm). This kind of structure does not adopt nonlinear optical properties, and hence, the power consumption of the device is very low and the size of the device is very small. Therefore, the proposed logic gate has the potential to constitute photonic integrated components that will be used in all-optical signal processing, photonic computing and all-optical networks. On the basis of the XOR/XNOR logic gate with bends, an OR/NAND logic gate is realized by two parallel XOR/XNOR logic gate structures. The contrast ratio for OR and NAND logic operations is not less than 13dB in the whole C-Band. The proposed logic gates has small size and low power consumption, therefore it have the potential to be used in the photonic integrated circuits of all-optical signal processing, photonic computing and all-optical networks.

Partha Pratim Sahu et al., (2012) "All-optical switch using optically controlled two mode interference coupler".

In this paper, we have introduced optically controlled two-mode interference (OTMI) coupler having silicon core and GaAsInP cladding as an all-optical switch. By taking advantage of refractive index modulation by launching optical pulse into cladding region of TMI waveguide, we have shown optically controlled switching operation. We have studied optical pulse-controlled coupling characteristics of the proposed device by using a simple mathematical model on the basis of sinusoidal modes. The device length is less than that of previous work. It is also seen that the cross talk of the OTMI switch is not significantly increased with fabrication tolerances (δw) in comparison with previous work. Here, optically controlled coupling characteristics are used efficiently for getting the cross state and bar state of a TMI coupler, which is one of the basic components in integrated optical waveguide device. By modulating the refractive index of GaAsInP cladding of a TMI waveguide by launching an optical pulse in the same region, we have introduced extra phase change $\Delta\phi E$ between the two modes propagated in the TMI core forgetting all-optical switching operation. The optical pulse energy, E, required to get the bar state of the proposed OTMI switch is obtained as ∼21.6 pJ. The cross talk of the switch is obtained as − 20 dB, which is less than that of previous work on the TMI switch.

Yuhei Ishizaka et al., (2011) "Design of ultra compact all-optical XOR and AND logic gates with low power consumption".

In this paper they proposed ultra compact all-optical XOR and AND gates logic gates without using nonlinear optics. For this they choose photonic crystal waveguides (PCWs) based on multi-mode interference devices. The size of proposed XOR and AND logic gates are about 3 times smaller than previously reported designs. They evaluated the ON to OFF logic-level contrast ratio. results show that the operating bandwidth of the ON to OFF logic-level contrast ratio of not less than 6.79 dB is 35 nm for the XOR logic gate and 9 nm for the AND logic gate. In this paper they also shown that fabrication tolerances of the XOR logic gate and found that the optimized rod radii need to be controlled with not more than 5% fabrication error. Thus, logic gates have the potential to be key components for an optical packet switching system due to their small feature size and low power consumption. In fact, the optical logic gates that employ the phase of input-lights as logical value can be applied to label processing systems for phase-shift-keyed (PSK) modulations.

Niloy K. Dutta et al., (2010) "High speed all optical logic gates based on quantum dot semiconductor optical amplifiers".

A scheme to realize all-optical Boolean logic functions AND, XOR and NOT using semiconductor optical amplifiers with quantum-dot active layers is studied. nonlinear dynamics including carrier heating and spectral hole-burning are taken into account together with the rate equations scheme. Results show with QD excited state and wetting layer serving as dual-reservoir of carriers, as well as the ultra-fast carrier relaxation of the QD device, this scheme is suitable for high speed Boolean logic operations. Logic operation can be carried out up to speed of 250 Gb/s. In this paper we presented a model to simulate high speed all-optical logic gates using QD-SOA based Mach-Zehnder Interferometer. Results show that QD-SOA based MZI can perform logic operations such as AND, XOR and NOT at high bit-rate up to 250 Gb/s. The impact on the high speed output quality (Q-factor) by a number of parameters, including injected current density, transition lifetime τe-g, input pulse width and single pulse energy, are also studied and discussed. Results show that for operation speed as high as 250 Gb/s, the Q factor is typically above 7 and can reach 11 under best conditions**.**

Jibo Bai et al., (2009) "Photonic NOT and NOR gates based on a single compact photonic crystal ring resonator".

New all-optical NOT and NOR logic gates based on a single ultracompact photonic crystal ring resonator (PCRR) have been proposed. The PCRR was formed by removing the line defect along the ΓM direction instead of the conventional ΓM direction in a square-pattern cylindrical silicon-rod photonic crystal structure. The behavior of the proposed logic gates is qualitatively analyzed with the theory of beam interference and then numerically investigated by use of the two-dimensional finite-difference time-domain method. Nonlinear material is required with less than a 2:2µm effective ring radius. The wavelengths of the input signal and the probe signal are the same. This new device can potentially be used in on-chip photonic logic-integrated circuits. new ultracompact photonic crystal logic NOR and NOT gates have been demonstrated. Only one single ring is required with less than 2.2µm for a 1550nm optical communicationwindow.Thedefinitionsoflogic1and0werealso introduced. These findings make PCRRs potentially usable for all-optical logic circuits and ultracompact high density photonic integration.

Yuanliang Zhang et al., (2007) "Optical switches and logic gates based on self-collimated beams in two-dimensional photonic Crystals".

A device for optical switches and logic gates is proposed in two-dimensional photonic crystals based on self-collimated beams. The main structure of the device is a line-defect- induced 3 dB

splitter. Operating principle, as revealed by both theoretical calculation and finite-difference time-domain simulation, is based on the interference of reflected and transmitted self-collimated beams. This device is potentially applicable for photonic integrated circuit based on line-defect-induced 3dB splitter of self-collimated beams in a 2D PC composed

of Si rods in air, is proposed and demonstrated. The switching and logical function, as revealed by both theoretical calculation and FDTD simulations, is based on the interference of the reflected and transmitted self-collimated beams and is applicable in frequency range 0.188 – 0.199(a/λ). The extinction ratio for the switch within the applicable frequencies is larger than 17 dB (maximum 20.1 dB). The device has simple geometric structure and clear operating principle, which shows that this device could be a strong candidate for future PICs.

Alireza Dolatabady et al., (2007) "All Optical Logic Gates Based on Two Dimensional Plasmonic Waveguides with Nanodisk Resonators".

In this paper they analyze and simulate the performances of some new plasmonic logic gates in two dimensional plasmonic waveguides with nanodisk resonators, using the numerical method of finite difference time domain (FDTD). These gates, including XOR, XNOR, NAND, and NOT, can provide the highly integrated optical logic circuits. Also, by cascading and combining these basic logic gates, any logic operation can be realized. These devices can be utilized significantly in optical processing and telecommunication devices. In this paper, some plasmonic logic gates such as XOR, XNOR, NAND, and NOT gates have been proposed and investigated using the numerical method of FDTD. These simple and compact devices can be utilized in photonic integrated circuits (PICs). Their behaviors and performances can be adjusted by variation of the structural parameters. The proposed XOR gate seems to be more advantageous, since it does not require any control ports, which can be regarded as a disadvantage. The proposed gates behaviors have been verified analytically. The simulation results have been in good agreement with those of the analytic ones.

Zhi-Hong Zhu et al., (2006) "High- contrast light-by-light switching and AND gate based on nonlinear photonic crystals".

In this paper they present a light-by-light photonic crystal configuration consisting of a bent waveguide with three embedded Kerr-type nonlinear rods and a T-branch waveguide. It show that configuration can also demonstrate all-optical AND gate operation with extremely high contrast between the OFF state and the ON state in its transmission. The photonic crystal configuration of all-optical light-by-light switching is simple and thus makes the fabrication easy for all-optical devices and further large-scale optical integration. The mechanism explained in this paper may be easily assume other photonic crystal configurations made of holes with some of them filled with a nonlinear material, which is more feasible in an experimental device. As the use of photonic crystal technology facilitates further large-scale optical integration, this practical light-by-light switching structure may become a key building block of a larger and more-complex all-optical switching device.

Dexiu Huang et al., (2004) "All-optical AND gate at 10 Gbit/s basedon cascaded single-port-coupled SOAs".

An all-optical logical AND gate at 10 Gbit/s based on cross-gain modulation (XGM) in two cascaded semiconductor optical amplifiers (SOAs) is demonstrated. Single-port-coupled SOAs are employed and specially designed to improve the output extinction ratio as well as the output performance of the logic operation. The output signal power and extinction ratio from the first-stage wavelength converter are critical to achieving all-optical logical AND operation. Owing to double-pass gain in the single-port coupled SOA and transmission loss in its rear facet, a high-output extinction ratio could be achieved in wavelength conversion based on single-port-coupled SOAs, and thus good logical AND operation output performance could be obtained. Output performance versus the input signal power was investigated experimentally. Large-input signal power is helpful for achieving improved output performance, and an incomplete logical AND operation result will be obtained when the input signal power is not large enough.

G. Guekos et al., (2002) "All-Optical AND Gate Implementation Using Cross-Polarization Modulation in a Semiconductor Optical Amplifier".

In this letter, we demonstrate experimentally a new design for an all-optical AND gate operating in the gigahertz regime using the cross-polarization modulation effect in a semiconductor optical amplifier. The efficiency of this effect was estimated by measuring the conversion coefficients TE TM and TM TE indicating the TE to TM mode conversion and vice versa when the amplifier is perturbed with a wavelength tunable control beam. The all-optical gate here described differ from others developed before using semiconductor optical amplifiers in its ability to operate on non degenerate input signals and to produce an output signal with an independent wavelength of the wavelengths of the input signals. We have used the cross-polarization modulation in an SOA to achieve an all-optical AND gate. The efficiency of this effect was increased when the wavelengths of the signals exciting it were near the gain curve peak. The input polarization of all signals introduced into the SOA were linear and coincided with the amplifier TM axis in order to obtain strong conversion coefficients produced by a SOA eigen modes modification.

CHAPTER 3

NAND, NOR &XNOR

3.1 INTRODUCTION

In digital electronics, a NAND gate (NOT-AND) is a logic gate which produces an output which is false only if all its inputs are true; thus its output is complement to that of an AND gate. A low (0) output results only if all the inputs to the gate are high (1); if any input is low (0), a high (1) output results. A NAND gate is made using transistors and junction diodes. By De Morgan's theorem, a two-input NAND gate's logic may be expressed as AB=A+B, making a NAND gate equivalent to inverters followed by an OR gate. The NAND gate is significant because any boolean function can be implemented by using a combination of NAND gates. This property is called functional completeness. It shares this property with the NOR gate. Digital systems employing certain logic circuits take advantage of NAND's functional completeness.

The NOR gate is a digital logic gate that implements logical NOR. It behaves according to the truth table. A high output (1) results if both the inputs to the gate are low (0); if one or both input is high (1), a low output (0) results. NOR is the result of the negation of the OR operator. It can also in some senses be seen as the inverse of an AND gate. NOR is a functionally complete operation NOR gates can be combined to generate any other logical function. It shares this property with the NAND gate. By contrast, the OR operator is monotonic as it can only change low to high but not vice versa. In most, but not all, circuit implementations, the negation comes for free including CMOS and TTL. In such logic families, OR is the more complicated operation; it may use a NOR followed by a NOT. A significant exception is some forms of the domino logic family.

Basically the “Exclusive-NOR” gate is a combination of the Exclusive-OR gate and the NOT gate but has a truth table similar to the standard NOR gate in that it has an output that is normally at logic level “1” and goes low to logic level “0” when any of its inputs are at logic level “1”. Then the output of a digital logic Exclusive-NOR gate only goes high when its two input terminals, A and B are at the same logic level which can be either at a logic level “1” or at a logic level “0”. In other words, an even number of logic “1’s” on its inputs gives a logic “1” at the output, otherwise is at logic level “0”. Then this type of gate gives and output “1” when its inputs are “logically equal” or “equivalent” to each other, which is why an Exclusive-NOR gate is sometimes called an Equivalence Gate.

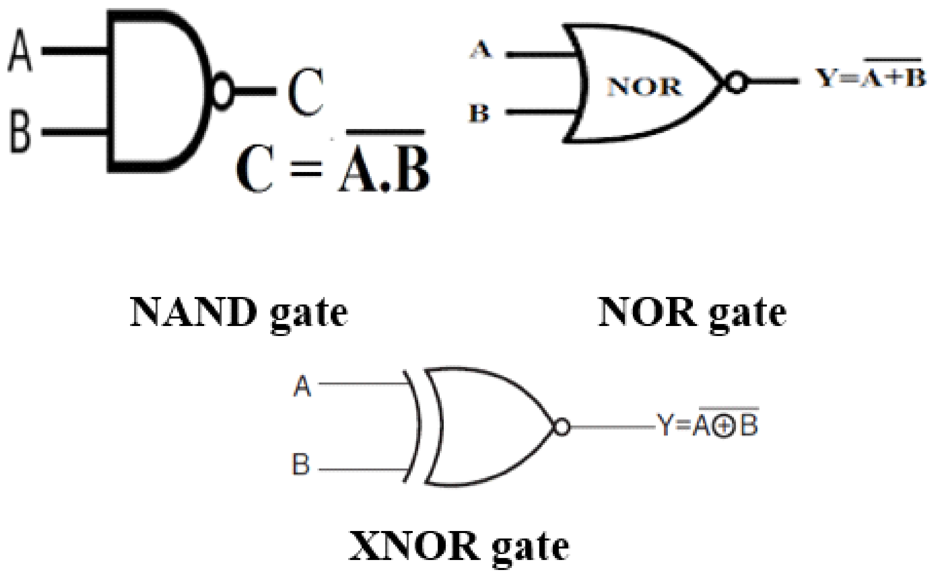


Figure 3.1: Symbols of logic NAND, NOR & XNOR

Table 3.1: Truth table for NAND, NOR & XNOR

Inputs		Outputs		
A	B	NAND	NOR	XNOR
0	0	1	1	1
0	1	1	0	0
1	0	1	0	0
1	1	0	0	1

3.2 OPTICAL NAND, NOR & XNOR

We can say a logic gate is an elementary building block of any circuit and have two or more inputs and one output. Logic levels i.e. 0 or 1 in binary logic system are physically represented by signal levels, which may be either voltage or current in electronics circuits. In case of optical circuits, logic levels are represented by signal intensity / phase / polarization, and are differentiated by different threshold. Digital data can be transmitted to electronic processors through an optical fiber with speed of light, but maximum speed of switching of electronic logic gates is 50ps for the average power 0.5mw per switching. It is also known that the switching speed of logic gates based on semiconductors is generally restricted by the capacitance of the p-n junctions. Even though the size of the modern semiconductor logic gates is small, their switching is limited by the interlinking capacitance. Alsoat the same time, the switching speed of the optical logic gates is limited only by velocity of light passing through it. By this it means that optical switches may switch data approximately 1000 times faster than their electronic counterparts. Photons with different wavelength can travel together in the same fiber or cross each other in the free space without any interference or cross-talk. This enables the possibility of parallelism in the optical processing. Generally optics provides higher bandwidth than electronics, which in turn enables more of the information to be carried out simultaneously and the ease of the data to be processed in parallel without any interference. The optical signal processing is immune to electromagnetic interference and free from electrical short circuits. Consequently in the developing of a family of optical logic devices with the Boolean functionality, an optical equivalent of the Transistor-Transistor Logic (TTL) is an important step in this direction.

Optical computing can have many advantages over electronic computing. They are immunity to electronic interference, lighter, more compact systems, immunity to short circuits, lower-loss transmission, significantly more bandwidth, easier/cheaper parallel computing. They find numerous applications in optical communication, optical signal processors, optical network, optical instrumentation, etc. Photonic crystals are attractive optical materials for controlling and manipulating light flow. One dimensional photonic crystals are already in widespread use, in the form of thin-film optics, with applications from low and high reflection coatings on lenses and mirrors to color and inks. Higher-dimensional. photonic crystals are of great interest for both fundamental and applied research, and the two dimensional ones are beginning to find commercial applications. The first commercial products involving two-dimensionally periodic photonic crystals are already available in the form of photonic-crystal fibers, which use a micro scale structure to confine light with radically different characteristics compared to conventional optical fiber for applications in nonlinear devices and guiding exotic wavelengths. The three-dimensional counterparts are still far from commercialization but may offer additional features such as optical nonlinearity required for the operation of optical transistors used in optical computers, when some technological aspects such as manufacturability and principal difficulties such as disorder are under control. An optical NAND, NOR & XNOR is used in designing Optical Arithmetic Logic Unit (ALU), Combinational Circuit design.

3.3 DESIGN OF OPTICAL NAND, NOR & XNOR GATES

In this wok, we have design an all-optical NAND, NOR and XNOR logic gates based on 2 dimensional PHCs. The proposed photonic crystal structures consists of 9a × 14a array of silicon (si) rods with air background, where ‘a’ is a lattice constant of value 0.6µm. The refractive index of silicon rods is 3.46µm including si rods. we also use reflecting rods with refractive index of 1.96µm. The proposed structure consists of input ports A, B and we have another input port that is reference port which is always in on condition and it is represented with R and the output port represented as Y. The present structure is composed of 2 T-shaped waveguides. Moreover the functional behaviour of this structure depends upon the beam interference principle The beam interference principle is of two types that are constructive interference and destructive interference .constructive interference happens when the path distance and phase difference are NY and 2nπ (where n=0, 1, 2… and y is free space wavelength of light). Destructive interference occurs when the phase difference and path difference are (2n+1) π and (2n+1) Y/2 respectively. By using these principle we can produce desired outputs for required logic gates. This structure includes one vertical and one horizontal T-shaped photonic crystal waveguides out of which two of them are considered as input ports indicated by port A and port B. One port has been indicated as reference port R which is used to create phase difference between the input signals resulting into either constructive or destructive interference. In this design left side horizontal waveguide represents input port ‘A’, upper side of vertical T-shaped waveguide represents input port ‘B’, lower side of vertical T-shape waveguide represents reference port ‘R’, right side horizontal waveguide represents output port ‘Y’ as shown in Fig.3.3.

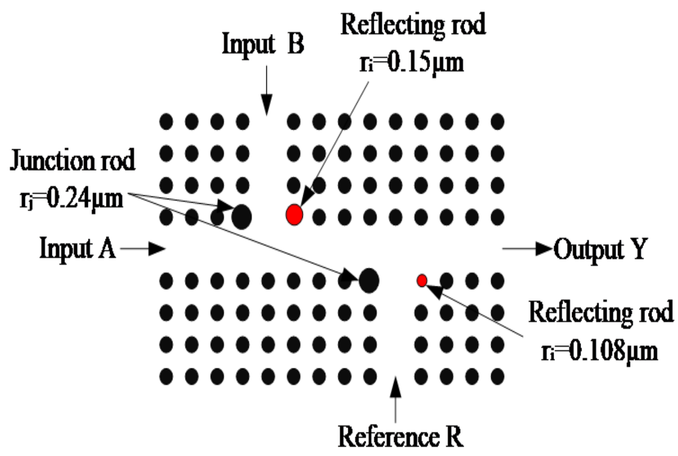


Figure 3.2: Proposed all-optical NAND, NOR & XNOR structure

3.4 PRINCIPAL AND WORKING OPERATION

The proposed structure of all-optical logic gate consisting of two T-shaped waveguides, here the dimension of the silicon wafer having length =14a, and width = 9a, where the lattice constant a=600µm, the size of the silicon wafer is given by .In the design, silicon rods with the radius 0.12. In the logic gate contains two input signal ports named as A and other is B, we have another input signal port that is reference signal which is always in on condition and helps in changing from “ON” state to “OFF” state and it is represented with R. however we have another port that is output port Y. In the proposed we are using beam interference principal, in physics, interference is a phenomenon in which two waves superpose to form a resultant wave of grater, lower, or the same amplitude. Constructive and destructive interference result from the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency. Interference effects can be observed with all types of waves.

The behaviour of this structure depends upon the beam interference principle The beam interference principle is of two types that are constructive interference and destructive interference .constructive interference happens when the path distance and phase difference are NY and 2nπ (where n=0, 1, 2… and y is free space wavelength of light). Destructive interference occurs when the phase difference and path difference are (2n+1) π and (2n+1) Y/2 respectively. The rods and are the key in the reduction of back reflection into the unemployed input ports and the operational behavior of the structure. The rod is the reflecting rod with refractive index 1.92, it is used to get a good interference can occur in between the light beams from port A or port B and reference input port. This value of refractive index will keep high contrast ratio. ‘1’. In this design, zero light intensity is considered as logic ‘0’. The phase value of the input light beam is determined in order to create a required type of the interference pattern to obtain a required output. Thus, in the structure, the logic ‘1’ has different values of phase for different input combinations as they are not representing the type of the logic input. Some input combinations needs to have light beam at both the input ports A and B. The phases of these light beams are taken such that a constructive interference can happen at the first T-junction and destructive interference can happen at the second T-junction. Moreover, the size of the proposed structure is small with 8.4µm × 5.4µm dimensions

CHAPTER 4

SIMULATION RESULTS

The performance of our anticipated NAND, NOR and XNOR logic gates are based on the beam interference principal (constructive and destructive interference) which is obtained by changing the light travelling path. This property of these logic gates make them more suitable application in optical communication system.

NAND gate:

Firstly, the function optical logic NAND gate has been verified. The design composed of 2 input signals A and B, one reference signal R and one output signal Y. The NAND logic gate works as follows:

Case-1: When none of the input ports (input A=0 and input B=0) have been excited and only the reference port R having phase angle ø= have been excited then logic 1 is obtained at the output port Y.

Case-2: When either of the input ports i.e. input port (input A=0 and input B=1) have been excited with phase angle ø=, along with the reference port R having phase angle ø= then also logic 1 is obtained at the output port Y.

Case-3: When both the input ports (input A=1 and input B=0) have been excited with phase angle ø= along with the reference port R having phase angle ø= then logic 1 is obtained at the output port Y.

Case-4: When both the input ports (input A=1 and input B=1) have been excited with phase angle ø= along with the reference port R having phase angle ø= then logic 0 is obtained at the output port Y.

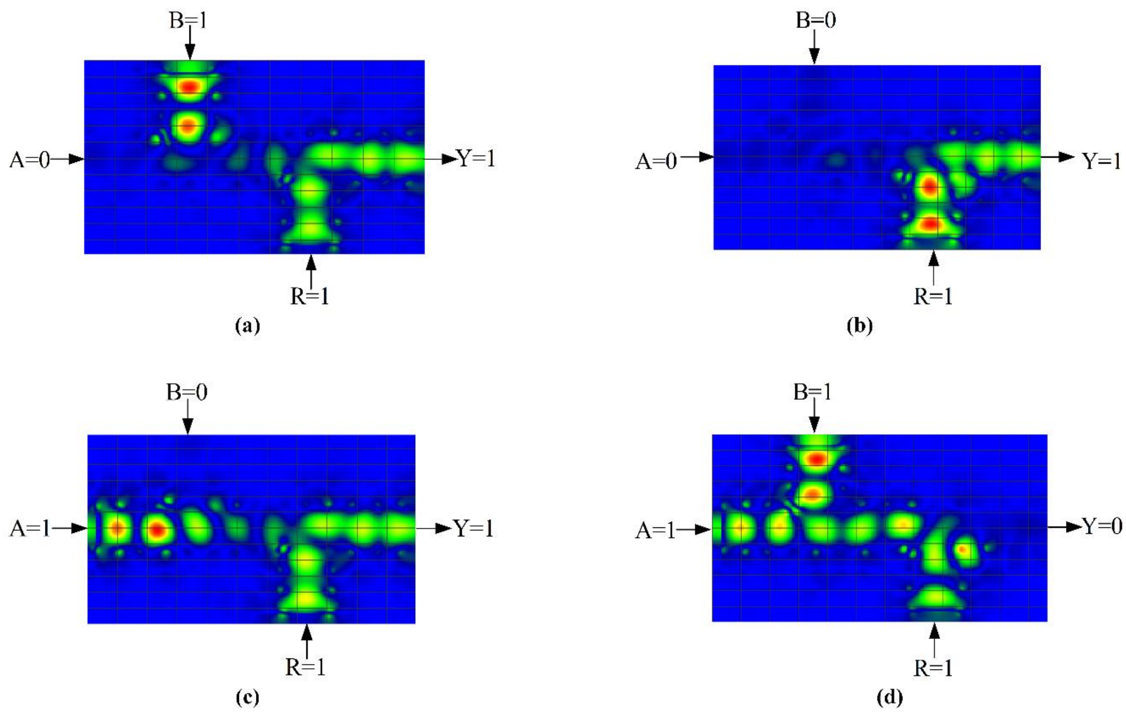


Figure 4.1: optical power levels for NAND gate

Table 4.1: Truth table and output power of optical NAND gate

INPUTS			OUTPUT(Y)	
A	B	R	Logical Value	Normalised Value
0	0	1	1	0.4
0	1	1	1	085
1	0	1	1	0.71
1	1	1	0	0.01

NOR gate:

Firstly, the function optical logic NOR gate has been verified. The design composed of 2 input signals A and B, one reference signal R and one output signal Y. The NOR logic gate works as follows:

Case-1: When none of the input ports (port A=0 and port B=0) have been excited and only the reference port R having phase angle ø= have been excited then logic 1 is obtained at the output port Y.

Case-2: When either of the input ports i.e. (input port A=0 and input port B=1) have been excited with phase angle ø=, along with the reference port R having phase angle ø= then also logic 0 is obtained at the output port Y.

Case-3: When both the input (input A=1 and input B=0) have been excited with phase angle ø= along with the reference port R having phase angle ø= then logic 0 is obtained at the output port Y.

Case-4: When both the input ports (input A=1 and input B=1) have been excited with phase angle ø= and along with the reference port R having phase angle ø= then logic 0 is obtained at the output port Y.

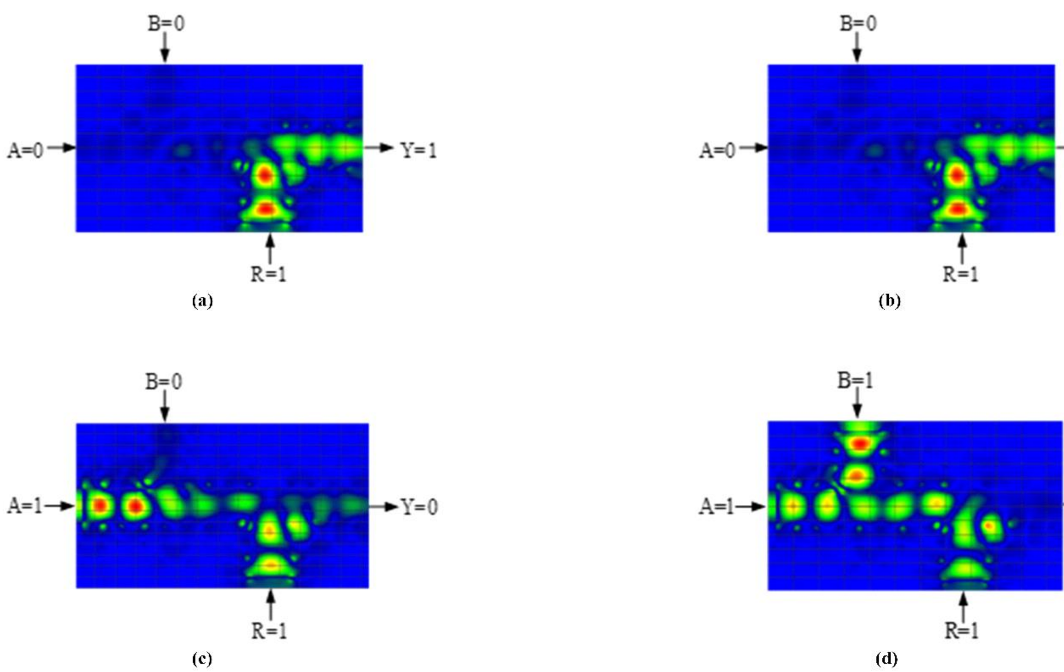


Figure 4.2: optical power levels for NOR gate

Table 4.2: truth table and output power of optical NOR gate

Inputs			Output(Y)	
A	B	R	Logical Values	Normalised Values
0	0	1	1	0.4
0	1	1	0	0.11
1	0	1	0	0.17
1	1	1	0	0.01

XNOR gate

Firstly, the function optical logic XNOR gate has been verified. The design composed of 2 input signals A and B, one reference signal R and one output signal Y. The XNOR logic gate works as follows:

Case-1: When both the input port (input A=0 and input B=0) have been excited with phase angle along with the reference port R having phase angle ø= then logic 1 is obtained at the output port Y.

Case-2: When either of the input ports i.e. (input A=0 and input B=1) have been excited with phase angle ø=, along with the reference port R having phase angle ø= then logic 0 is obtained at the output port Y.

Case-3: When both the input ports (input A=1 and input B=0) have been excited with phase angle ø= along with the reference port R having phase angle ø= then logic 0 is obtained at the output port Y.

Case-4: When both the input ports (input A=1 and input B=1) have been excited with phase angle ø= and along with the reference port R having phase angle ø= then logic 1 is obtained at the output port Y.

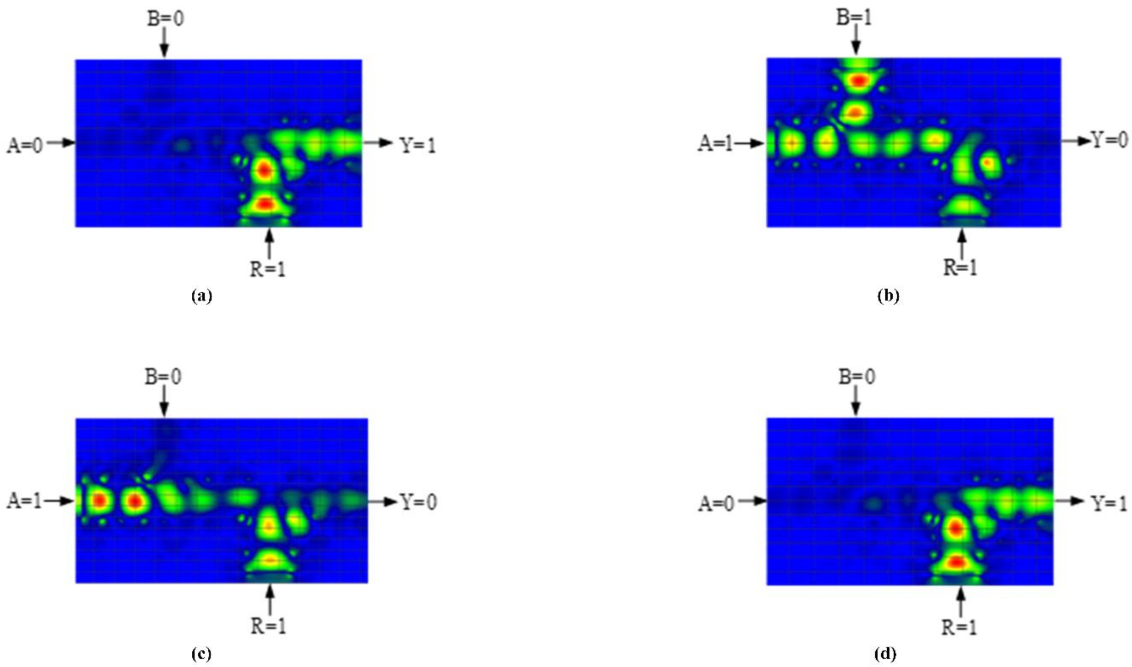


Figure 4.3: Optical power level for XNOR gate

Table 4.3: Truth table and output power of optical XNOR gate

Inputs			Output(Y)	
A	B	R	Logical Values	Normalised Values
0	0	1	1	0.4
0	1	1	0	0.11
1	0	1	0	0.17

1	1	1	1	1.29

CONCLUSION

In this paper three logic gates have been proposed and realized using two dimensional photonic crystals waveguides(PHCs) these gates are NAND,NOR and XNOR. The structure consists of two T-shaped waveguides. Because of using these T-shaped waveguides the design is small, hence these logic gates can be utilized in photonic integrated chips .The design is analyzed and simulated by using FDTD method. The proposed structure is based on beam interference principle (i.e., constructive and destructive interference) to produce desired outputs. Moreover, the high contrast ratio is obtained when compared to the previous design which is beneficial for maximum immunity to noise. The design is more suitable for broadband optical communication and for data processing.

FUTURE SCOPE

During the course of this study, several paths for continuation of this study became evident. The topics which were considered worthwhile are summarized below. These layouts of logic gate can be used to design complex logic circuits, future optical networks and communication system because these deigns have high extinction ratio, compatible, compact size and low power consumption.The proposed structure can be designed for a layout having a complete band gap for both TE and TM polarization. So, the design will work for both the polarizations.

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