An Analysis on Photonic Crystal: Arrangment And Utilization

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Abstract—Photonic crystals are higher class of optical media. It has some natural or artificial structure lattices with periodic changes in refractive index. This gives it some peculiar properties; hence provide us with opportunities for a number of implementations to be carried out. Coherent nature of light is being fully employed by photonic crystal and thus led to a series of experimentation and promise to a new era for the development of optical circuits. In today's era, the photonic crystal is an attracting technology which provides advanced mechanism in order to manipulate the photons. The concept behind photonic crystal is the anomalous absorption of light in a non-Uniform medium. In this paper, we review the early inspiration for photonic crystal. The classification and application of photonic crystal have also been described in the paper.

Index Terms—Photonic crystal, Bragg reflection, Bandgap, Lattice.

1 INTRODUCTION

The improvement of semiconductor technology led so many changes in our society but due to high resistance, these devices have a long time delay with the small feature size. In electronic devices due to fast transmission of data, synchronization problem has arrived. Hence, photonic devices will be going to take over the role of electronic devices because the light has high -frequency nature and the bandwidth of photonic devices is also much greater than traditional electronic devices. Light has greater energy density than electron system e.g. Lasers. in photonic devices the reduction of power can be minimized by selecting a proper medium, also thermal scattering is reduced by using the thermal expansion of materials [1].

The photonic crystals also are known as photonic band gap (PBG) materials are a new mass of optical materials with regular changes in director constant on the scale comparable to optical wavelengths as shown in figure1. The way semiconductor lattice affects the properties of the electron is the same for PBG.

According to the first journal published by Yablonowitch [2], lattice structure has a region of prohibited energy states for photons, this is photonic band gap.

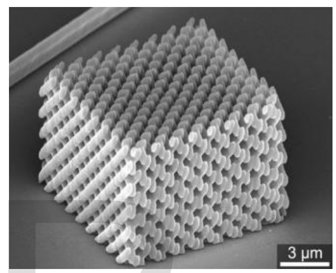

Fig. 1. The basic structure of photonic crystal with band gap of 3μm.

A complete control over light propagation can be attained through photonic crystal as when light falls in the gap of the crystal lattice, then the light is not able to propagate further. When light falls on the flat surface of the crystal, it reflects at a particular angle. Thus, this provides complete control over light propagation through the sharp bend with good efficiency.

The light propagation can be controlled through the lattice and direction of light as shown in figure 2. On basis of the lattice, they are 1-D, 2-D, 3-D.

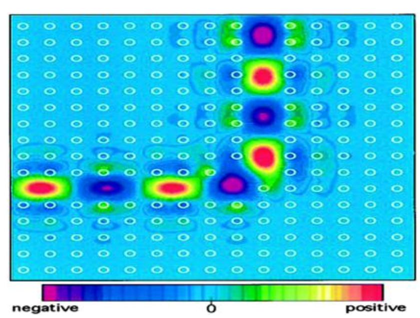

Fig. 2. Guiding of light in a photonic crystal.

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The most important factor in the photonic crystal is the band gap. The term band gap is a defect created intentionally in order to restrict the flow of light. The two types of irregularities can be created like point and line. When a line defect is created then an ultra-small waveguide can allow the propagation of light within that defect [3]. However, for a photonic nano-cavity, a point type irregularity is created in order to trap the propagating light. When these two defects are combined then an ultra small circuit based on photonics can be designed having various applications [4]. The function of different devices based on photonics can be controlled with the help of band gap, as it is responsible for the suppression of instinctive transmission of light.

2 Classification Of Photonic Crystals

The photonic crystal has achieved a great consideration from last few decades. The designing of photonic crystal includes an optical confinement which is very durable and it also provides an envelope to the high spectrum of frequency. In order to give an applicable building block the requirement of the confinement is necessary in the characteristics of transmission. On the basis of the lattice structure Photonic crystal are subdivided as1-D, 2-D and 3D. Structures of mentioned types of photonic crystals are described below

A. One Dimensional crystal

1-D PBG structure is one of the simplest possible crystal. It has alternate layers of materials adhered together. As it has only one dimension. It is periodic in one direction. And when we incident the light on a 1-D crystal lattice, it can be seen that, it is completely reflected as shown in figure 3.

Thus this act as a perfect mirror. The 1-D crystal found its use in microwave antenna substrate, frequency fitter etc.1-D crystal lattice can be fabricated using by depositing alternating layers of two different materials on a substrate.

These are also known as Bragg reflector constructive interference and reflectance can be achieved if the thickness of each layer is appropriately chosen.

They can reflect 100% of incident light as the absorption is very low in dielectric optical material but they only work for a limited range of angles.

The novel applications of 1D structure like optical buffering and optical TDM has also been demonstrated by the researchers [5].The application of one- dimensional photonic crystal is in the field of colour change and also in high reflection coating. The 1-D crystal also found its use in microwave antenna substrate, frequency fitter etc. These are also known as Bragg reflector constructive interference and reflectance can be achieved if the thickness of each layer is appropriately chosen.

The refractive index diversity is very low in FBG and thus the bandwidth is very limited and many periods are needed in order to achieve the considerable reflectance characteristics. As the device has very less variation in its structure, and to enhance the quality of an optical device the 1D device can also be used as an anti- reflecting coating.

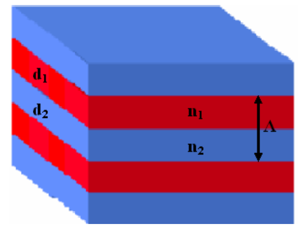

Fig. 3. Structure of One dimensional photonic crystal

B. Two Dimensional crystal

The second category, i.e. 2D has the periodicity in two directions whereas it has uniformity in the third direction. In the plane of periodicity, the band-gap occurs. When light travels in this structure then the harmonics modes can be divided into two independent polarizations and these two polarizations has their own band design [6]. The propagation of the wave in any direction can be stopped inside the plane which is not possible in 1D.

2-D crystal lattice has a square lattice array of parallel dielectrics. It is periodic along two axes and homogeneous along third one as shown in figure 4. A 2-D crystal can be divided into two polarizations. TE and TM modes.

2-D crystal can have Bragg reflection and index dispersion in 2-D plane. It is possible to have small structure and large bandwidth through a 2-D crystal.

The important application of 2-D crystal is superprism effect [7].

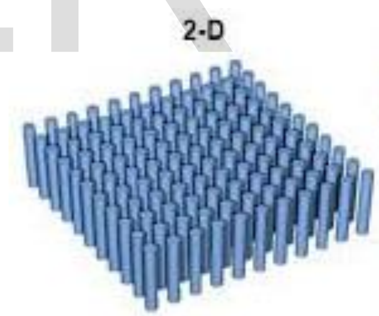

Fig. 4. Structure of Two-dimensional photonic crystal

B. Three Dimensional crystal

3-D photonic crystal show wide frequency range over which ordinary liner propagation is prohibits. They have complete photonic band gaps which allow the full control over the radioactive dynamics of active material as shown in figure 5.

The main reason for making 3-D crystals is to make a structure that can give spontaneous emission, which is interesting in many points of view. Lithograph techniques are used to create the structure that can be made using standard tools.
In a 3-D photonic crystal, there are so many self-assembling periodic structures which have a colloidal system and artificial opals.

The fabrication of 3D faces various problems as compared to the other two dimensions (1D and 2D). The 3D fabrication needs improvement in new techniques. Previously a design was computed to provide the band gap for every side and for every polarization when the 3D structure was proposed [8].

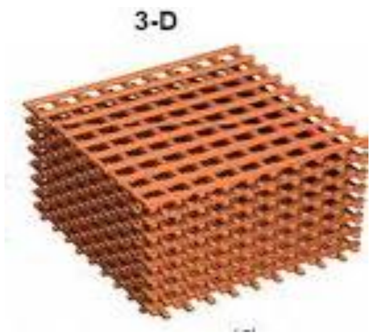

Fig. 5. Structure of Three Dimensional Photonic Crystal

The structures of 3-D provide and also endeavor various other characteristics as compared to one and two-dimensional structures. These newly added features may give rise to unique technology and along with this, it has been believed that it will offer a new gateway in the same manner when a material known as semiconductor gave rise to a transistor. Although the practical application of 3-D is miles away and this technology will ideally remain in future till there will be no solution to difficulties that are coming in its way.

3 Specifications And Characteristics of Photonic Crystals

In order to construct a photonic crystal with a particular band behavior, there are some crystal features and parameters.

A. Regularity
In Lattice the fundamental blocks required to design a photonic crystal are arranged in a symmetrical, for e.g. cubic, body and face-centered cubic, hexagonal closed and diamond structure.

B. Dimension
The photonic crystal according to the dimensional of the building stack is divided into three types, namely 1D, 2D and 3D dimensional photonic crystal.

C. Lattice Specification
It is defined as the distance of partition among dispersing building blocks. When a cubic lattice is considered then the sides of the cube are taken into account. The lattice specification is usually directly proportional to the range of wavelength.

D. Topology
When the building blocks are either impregnated or isolated then there is a variation in the topology of the band gap structure of a photonic crystal.

E. Effective Refractive Index
It is defined as the relationship among the volumes employed by every dielectric in correspondence to the complete volume of the composite. The effective refractive index is generally computed as the square root of the average dielectric constant.

F. Refractive Index Contrast
It is defined as the proportion between the refractive index of high and low material of dielectric constant. In other words, this term basically gives the study of scattered strength of crystal.

4 Applications Of Phtotonic Crystals

A. Photonic crystal devices give large potential in a generation of sharp angle wave guiding, single mode lasers, optical computing etc.

B. Photonic crystal band gap devices are used in high- speed optical communication network, in a production of optical circuits for DWDM (Dense wavelength Division multiplexing).

C. The photonic crystal is used in a light emitting diode structure which has the property to enhance the light extraction. Extraction efficiency is varied by using photonic crystal.

D. The Photonic crystal is used in optical fiber technology to produce fiber that carries light at high powers. The first photonic crystal fiber is known as "Holey fibers". In this Holes are act as a waveguide and the light is trapped by photonic crystal around the hole. Photonic crystal fibers are produced by pure silica tubes which heat in a furnace. Photonic crystal fibers are used in the telecommunication system and pollution sensing.

E. The metal -dielectric photonic crystal is used in UV blocking; IR reflective window and white band- pass filters.

F. Photonic crystal band gap material which has high value of refraction index can be used in making of perfect lens.

G. The naturally occurring photonic crystal is gemstone opal. The unique color of opal is due to reflection light which is caused by photonic band gap of the crystal.

5 Conclusion

During this time of century, we have electronic devices in our life. Even for high speed data transmission. But we can't deny the fact that nothing propagates faster than light. Through this paper, an analysis has been done on photonic crystals and we conclude that photonic crystals can take over semiconductor electronic devices, as in photonic crystals thermal scattering is prevented along with reduction in power loss. The paper has therefore given an analysis of landmark achievements in the field of research and advancement of photonic crystal along with its relative applications.

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