Research Paper PHYSICS

1-D Photonic Crystal and its Band Gap Significance

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ABSTRACT

Photonic crystals possess internally and alternately repeating regions of high value and low value dielectric constant regions such that between any two dielectric regions there exist gaps called as band gaps similar to that of periodic potential regions in a metal. By adding controlled amount of impurities in photonic band gaps the location, spontaneous emission of light and light processing can be can be controlled.

KEYWORDS photonic crystals, bandgap and dielectric material.

1.1.1: INTRODUCTION:

Naturally existing photonic crystals are gemstone opal and wings of butterfly. Due to the existence of photonic crystals on the wings of butterfly beautiful colours are produced and keep butterfly wings cooler.

In photonic crystals, the dielectric medium is periodically arranged such that between any two dielectric regions there exist gaps (or) separations called as band gaps similar to that of periodic potential regions in a metal. The study of motion of electron is described by kronig-penney model and Bloch theorem in periodic potential regions in a metal and the study of photonic crystals can be done by Bloch-Floquet theorem [4].

The propagation of light in photonic crystal can be studied by four Maxwell equations which are to be modified for the study of photonic crystals. Photonic crystal consists of regular arrays of materials with different dielectric constant with the period of order of optical wavelength and the spatial periodic distance of the crystal is called lattice constant 'a'. Photonic bands predict the behavior of light accurately. In photonic band gap, light cannot enter the crystal because the gap acts as an insulator of light and the light velocity will be changed from C to Zero similar to the situation of an electron motion in a periodic potential field [3] where velocity is changing along with the mass of the election, the mass may become infinite (increases) and electron behaves as a positive particle (it suffers Bragg's reflection). Such variation in mass is called effective mass. By making a suitable geometry of the periodic dielectric medium, a phonic crystal can be used as an optical fiber.

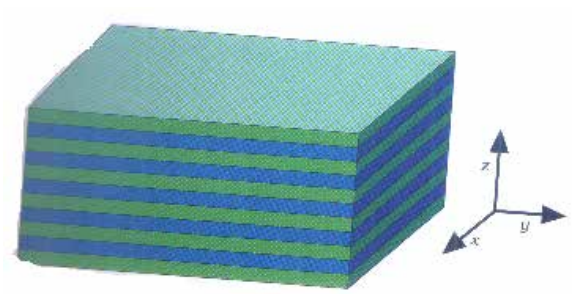
1.1.2: The mechanism and principle working of photonic band gap:

A photonic band gap (PBG) crystal is a structure that could manipulate beams of light in the same way semiconductors control electric currents. A semiconductor cannot support electrons of energy lying in the electronic band gap. Similarly, a photonic crystal cannot support photons lying in the photonic band gap. By preventing or allowing light to propagate through a crystal, light processing can be done.

1.1.3: Results and Discussion:

The multilayer thin film is a one-dimensional photonic crystal. The term "one-dimensional" refers to the fact that the dielectric is only periodic in one direction. It consists of alternating layers of materials with different dielectric constants, spaced by a distance a. The photonic band gap [6] exhibited by this material increases as the dielectric contrast increases.

Fig.1: one-dimensional photonic crystal



Source: Wikipedia.

The multilayer thin film show above is a one-dimensional photonic crystal. The term "one-dimensional" refers to the fact that the dielectric is only periodic in one direction. It consists of alternating layers of materials with different dielectric constants, spaced by a distance a. The photonic band gap exhibited by this material increases as the dielectric contrast increases.

The photonic gap appears as the electric field vectors of light and gap occurs at the edge of Brillouin zone. By electromagnetic variational theorem, the result shows that high dielectric constant regions concentrates low frequency (or) lower fraction of energy & similarly low dielectric constant regions Concentrates lower energy & thus there is a frequency difference and energy difference and this leads to the bands above and below the gap of high & low dielectric constant regions. It is observed that the photonic gap becomes larger as the dielectric contrast increases.

Also the band gap above photonic band gap is treated as air band and band below the gap can be treated as dielectric band gap which is similar to that of valence & conduction band gap in semiconductor.

Thus, the gap occurs at edge (or) centre of Brillouin zones and gap occurs for any dielectric constant such that the gap is small for small differences of dielectric constant and existence of the gap can be measured by the frequency width.

If the defect is introduced [1], it disturbs the periodicity and the multilayer films existing on both sides of defect behave like two mirrors and localize light within the regions and the

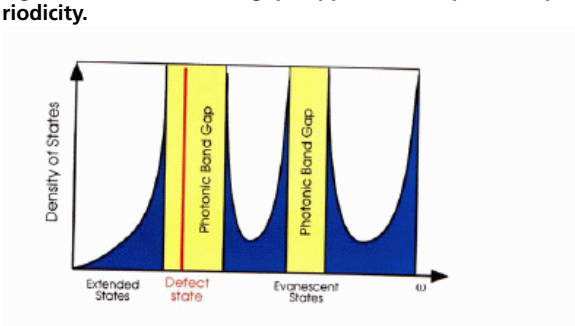
frequency modes one quantized.

If the thickness of defect is increased (or) doubled [2], the discrete modes are pulled down and it thickness kept constant (or) increased we observe the following change, a defect pulls modes from upper bands to lower bands and push modes from lower band to the gap.

The origin of the photonic band gap can be known from the consequences of periodicity for a simple one-dimensional system [6].

Figure below shows photonic band gaps [5] appearing in the plane of periodicity.

Figure.2: Photonic band gaps appear in the plane of periodicity.



Source: Hand book of photonic crystal.

CONCLUSIONS:

Photonic crystals usually consist of dielectric materials, that is, materials that serve as electrical insulators or in which an electromagnetic field can be propagated with low loss.

Holes (of the order of the relevant wavelength) are drilled into the dielectric in a lattice-like structure at regular intervals and the resulting holey crystal will have what is known as a photonic band gap within which a range of frequencies of specific wavelength of light could be blocked.

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