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Simulating Photonic Crystal Fibers based on the 1D approach

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Abstract - *Over the years, high capacity data transmission experiments have been demonstrated over low-nonlinearity/low-loss dispersion un shifted fibers. Photonic-crystal fiber (PCF) is a new class of optical fiber meant for high data rate in electronic devices and telecommunications systems. One-dimensional (1D) photonic crystals are presently used in Optical communication applications. In this paper propagation properties are evaluated based on the 1D.*

1. INTRODUCTION

Photonics is the study of the detection, control and creation of photons. The topic is growing interest because the projected cost of the new type of computing and sensor devices. For more learned about the field and its applications in the research for the great support. The field was expanded to discovery an optical fiber in 1970's. The optical fiber functioned as a transmission of light in a medium (1). Light guides and optical fibers confine and direct the propagation of light beams based on the basis of the refractive index differences between the core and cladding. Light rays within the principle of total internal reflection are described as Total Internal Reflection (TIR). Russell *et al*. Proposed the optical fibers with a periodic configuration constitute of air and silica [2]. These included a silica core, and guided by the light beams as the TIR of conventional optical fibers. Photons with a certain level of energy, ie a certain wavelength of light rays cannot enter the media, but repelled by it (usually artificial medium), having the same wavelengths of light and relatively large refractive index changes. A single-mode propagated through the core only, no Photonic Band Gap (PBG) was observed. Recently, a new principle of limiting and controlling light beams, termed PBG has already proposed [3]. Photons with different energy levels pass through the medium phenomena uses the PBG. This is similar to the semiconductor energy band gap phenomena. The imitation medium with the periodic formation similar to that of light wavelengths, which are forbidden to access the photons, is called a photonic band crystal or PBG structured medium [4]. In this paper, 1D model is considered to calculate the propagation properties such as group velocity dispersion, normalised propagation constant, effective area and field distribution. The performance of PCF yields better characteristics when compared to the conventional optical fibre.

Photonic Crystal Fibre

Photonic Crystal and conventional optical fiber have many similarities, but also have some differences in some factors. Normal optical fiber depends on the index of TIR difference between the core and cladding materials while the PCF has air holes to create an effective indicator of change. In the photonic crystal fiber, air holes can be efficiently indexed create or change, or if proper spaced apart along with exact dimensions of a photonic band gap will be generated. The photonic band gaps can guide only certain frequencies of light. The air holes and their different configurations tends photonic crystal fiber nonlinear processes useful [5] [6]. Materials with periodicity on the order of the wavelength of light materials, photonic crystals (PCs) having alternating regions of high dielectric photonic band gaps difference has been exposed to exhibit (PBGs), or forbidden range of EM frequencies (Figure 1)[7]

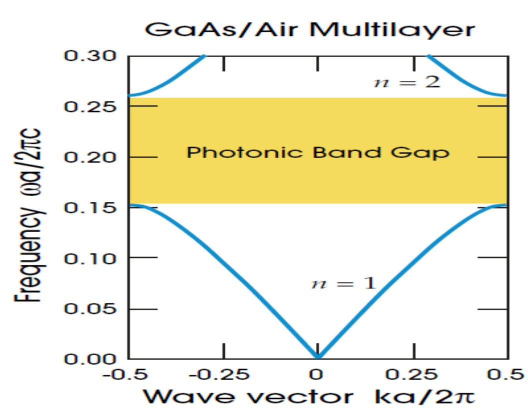

Figure 1 Frequency vs wave vector with omni directional PBG

Diffraction is the basic principle behind the photonic crystal function. Diffraction refers to various wave propagation characteristics, such as bending, spreading and interference. Diffraction effects occur when the medium wave and affects the structure of the same scale

Structures are on the same scale. The visible spectrum occurs on the 400- to 700-nm wavelength scale. As a result, the feature periodicity of the photonic crystals must also exist on this scale. Photonic crystals can affect the propagation in 1-D, 2-D and 3-D, as shown in figure 2. The periodic structure and dielectric nature of the crystal determine its ability to produce a band gap.

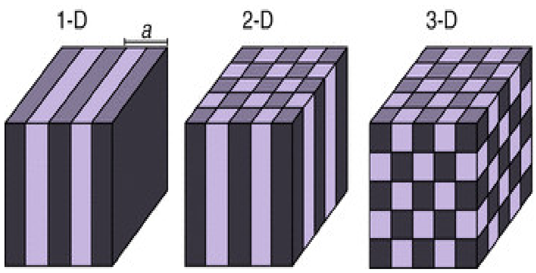

Figure 2. Shows the representation of one-, two-, and three-dimensional photonic crystals (1-D, 2-D, 3-D)

2. METHODOLOGY

Traditionally, theoretical descriptions of PCFs are based on numerical approaches such as Finite Element Method (FEM), plane wave expansion mode, multi-mode (MM), etc., due to the relatively complex cross section due to the absence of rotational symmetry PCF. Disadvantages of numerical simulations are time consuming and high cost. Recently, a method has been developed based on the parameter V (normalized frequency) is often used in the design of conventional optical fibers has been developed for index-guiding PCFs. Various unique properties of PCFs can be qualitatively understood with appropriate definition of the V parameter and well-defined in classical theories fiber without numerical calculations. Even though there is an easier way to design a V parameter proposed by the PCF, a constricting factor for obtaining accurate effective cladding index is still necessary numerical method. The design parameter for PCFs require empirical of V parameter (normalized cross-attenuation constant), which not only depends on the wavelength of the structural parameters [8] [9].

In this paper empirical model of V parameter PCFs which are based on primary geometrical parameters which are air hole diameter and pitch. The accuracy of the empirical-relations is with the results of full-vector FEM. By using the empirical relations, the fundamental properties of PCFs can be evaluated easily without the use of numerical computations.

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$$V = \frac{2\pi}{\lambda}\alpha_{eff}\sqrt{n_{co}^2 - n_{fsm}^2} = \sqrt{U^2 - W^2} \quad (1)$$

with

$$U = \frac{2\pi}{\lambda}\alpha_{eff}\sqrt{n_{co}^2 - n_{eff}^2} \quad (2)$$

$$W = \frac{2\pi}{\lambda}\alpha_{eff}\sqrt{n_{eff}^2 - n_{fsm}^2} \quad (3)$$

Where **λ** is the operating wavelength, nFSM is the cladding-index, nco is the core-index, neff is the effective- index of the fundamental guided mode, αeff is the effective core radius,U and W are the phase and attenuation constants [10]. V values can be considered through vector FEM as a function of $\frac{\lambda}{\Lambda}$ for $\frac{d}{\Lambda}$. This can be given by:

$$V\left(\frac{\lambda}{\Lambda}, \frac{d}{\Lambda}\right) = A_1 + \frac{A_2}{1 + A_3 \exp\left(\frac{A_4 \lambda}{\Lambda}\right)} \quad (4)$$

To achieve accurate fitting, the data observations are truncated at 0.85 for V. In Eq. (4), the fitting parameters Ai for (i=1 to 4) based on $\frac{d}{\Lambda}$. The data are well illustrated by eq.

$$A_i = a_{i0} + a_{i1}\left(\frac{d}{\Lambda}\right)^{bi1} + a_{i2}\left(\frac{d}{\Lambda}\right)^{bi2} + a_{i3}\left(\frac{d}{\Lambda}\right)^{bi3} \quad (5)$$

where ai0 to ai3 and bi1 to bi3 coefficients are given in Table 2. For $\frac{\lambda}{\Lambda} < 2$ and V > 0.85, Eq (4) provides the value of V which diverge less than 1.6 % from the modified values attained from Eq (1).

3. RESULTS AND DISCUSSION

The group velocity is the speed at which the change in the shape of a wave propagating through a medium. Group velocity can change in the shape of the wave's amplitude propagates through a medium. This corresponds to the slope of the dispersion curve. Figure 2 shows the 1-D normal modes for a monatomic and basis chain. The two functions of frequency, ω, are known as the two branches of the dispersion relation. The lower branch is known as the acoustic branch because its dispersion curve is in a form similar to sound waves. The upper branch is referred to as the optical branch because the longer wavelength optical modes in crystals can interact with electromagnetic radiation. The longer wavelength modes are also responsible for the optical characteristics of the crystal.

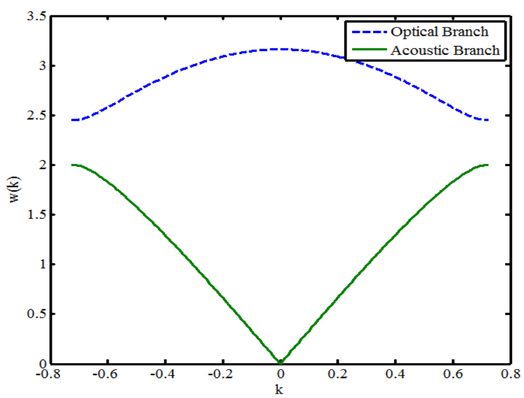

Figure 2 Dispersion curve for a 1-D chain with a basis

Table 1: Fitting Coefficients for V

	i=1	i=2	i=3	i=4
a_{i0}	0.65909	0.82122	0.18904	-0.92736
a_{i1}	6.401124	863194	2.567585	2.05476
a_{i2}	-11.432	49.46941	20.99486	2.23992
a_{i3}	9.2992	-480.15	-46.4318	4.98
b_{i0}	6	2.8	2.7	-0.9
b_{i1}	8	8.23	11	2.06
b_{i2}	10	23.9	16	15.5

The coefficients a_{i0} to a_{i3} and b_{i1} to b_{i3} as shown in Table 1. For $\frac{\lambda}{\Lambda} < 1.9$ and V > 0.90, Eq (4) gives the value of V which diverge less than 1.6% from the modified values attained from Eq (1) and (figure 3).

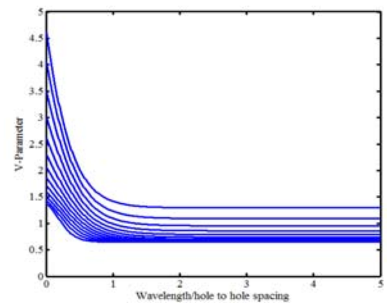

Figure 3: Effective V Parameter as a function of $\frac{\lambda}{\Lambda}$

By using a V parameter Eq (4), the effective cladding-index nFSM can be obtained without the need for numerical computations (Figure 4). Mortensen et al. recommended by the empirical expression for nFSM effective cladding-index should fit directly. However, the results are not very accurate. On the other hand, Eq (4), which shows the values nFSM deviation of less than 0.29% of the values obtained, although the vector FEM for <1.8 and V> 0.90.

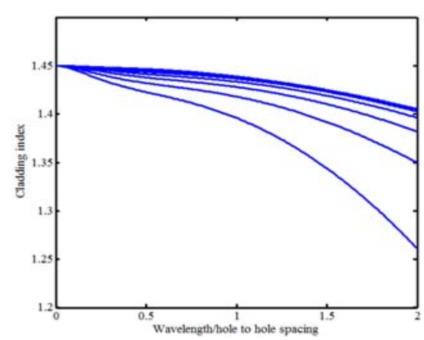

Figure 4: Shows the effective-index of the Fundamental Mode as a n_{eff} and $\frac{\lambda}{\Lambda}$

From Eq (4), the cutoff condition form Eq. (4) is specified as 2.60 for V, as in SIFs.
By using the empirical relationship between EQ (4) and in various resolutions of the V parameter found for SIFs, the fundamental properties of PCFs, such as mode field diameter, beam divergence, splice loss, etc., can be easily evaluated.

CONCLUSIONS

Currently for 1D cylindrical photonic crystal waveguides, studies and research might be able to extend to find similar step index fiber models for simpler and faster analytical and designing work. With a fixed core radius, the alternating index cladding could be replaced by an equivalent cladding with a constant index, neq, thus creating a step index fiber in this manner. This equivalent cladding index is a function of wavelength and parameters of this periodic cladding. 1D cylindrical photonic crystal waveguides are periodic index variations in the radial direction only. These type of waveguides consisting of a central core surrounded by a cladding that consists of alternating rings of equal thickness and index.

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