

**A DESIGN OF POLARIZATION FILTER BASED ON PHOTONIC CRYSTAL WITH TWO WAVELENGTH USING FEM METHOD**V.Parimala¹, N.Aravindhan², A.Sivanantharaja³ and T.K.Shanthi⁴

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Abstract— Photonic Crystal Fiber is a kind of optical fiber that uses photonic crystals to form the cladding around the core of the cable. It is a low loss periodic dielectric medium constructed using a periodic array of microscopic air holes that run along the entire fiber length. Due to the special characteristics of photonic crystal fiber, it has becoming a trend to use Polarization Switch, Rotator, Filter and Multiplexer. Polarizing filter based on Photonic Crystal fiber has many impacts in all fiber communication. Thus, single polarizing filter based on dual wavelength photonic crystal fiber is designed with silver-coated large holes. The type of photonic crystal fiber used is solid core for polarization filter in order to darken skies, manage reflections, or suppress glare from the surface of lakes or the sea application using finite element method. Probably Silver exhibits the highest conductivity of all metals. When the material wavelength is changed, correspondingly effective index of the material is also varied (i.e) effective index is depends on input wavelength. Thus, the dual-wavelength single Polarization filter is between 1310nm to 1550nm and their polarization direction of optical output is independent of the wavelength of incident light.

Keywords— Photonic crystal fiber, effective mode index

1. INTRODUCTION

Photonic crystal fibers are special class of optical fibers that are capable of confining light in hollow cores and they differ from normal conventional fibers [1]. The PCF has large number of air holes in cladding that periodically runs throughout the fiber length and these air holes are responsible to confine the light in core region of fiber. PCF are categorized based on guiding mechanism into two types as index-guided PCF and hollow core PCF. In the index-guiding PCF, confinement of light occurs through modified total internal reflection. The index-guiding PCF core is also called as “solid core”. In the hollow core, the confinement of light occurs by photonic bandgap effect (PBG) [2]. A photonic crystal provides different properties such as photonic bandgap [3], dispersion control [4], endless single mode operation [5], and supercontinuum generation [6]. The air holes can be arranged according to different sequences such as hexagonal, octagonal, square, rectangular, etc. With a suitable combination of the geometry of the fiber, air-hole diameter and the pitch, the PCF acquires a number of distinctive properties including a wide single-mode wavelength range, unusual group-velocity dispersion in visible and near-infrared wavelength ranges.

When comparing with single mode fiber, PCF have many tunable properties for example: air hole diameter, pitch, cladding, background material doped core and it leads to better control over non-linearity, dispersion slope, birefringence, splice loss and confinement loss. In 1995, T.A. Birks et al has analyzed that 2D bandgaps can exist in silica/air PCF for $n_{ax} < 1$ [7]. In 1996, J.C.Knight et al has developed first solid core PCF [8]. In 1997, J.C.Knight, T.A. Birks and P.St J.Russell has combined found that endlessly single mode concept [9]. In 1998, J.C.Knight et al found that PCF could capable of having ultra large mode area [10]. In 1999 R.F. Cregan et al has developed first hollow core photonic bandgap PCF [11]. In 2000, B.J Mangan et al have found multi-core PCF. In 2000, polarization-maintaining PCF, rare earth doped PCF laser, supercontinuum generation were found [12-14]. In 2001, carbon-dioxide laser processing PCF, four-wave mixing, polymer PCF, soliton self-frequency shift has been proposed [15-18]. In 2002, laser-tweezer guidance of particles in hollow core PCF, long period gratings, stimulated Raman scattering in hydrogen and PCF made from schott SF6 glass for SC generation were found [19-22]. In 2004, J.E. Sharping et al has found twin photon generation in PCF. In 2005, A.H. Al-janabi, and E.Wintner were found high-energy transmission in hollow core PCF [23]. The surface-Plasmon (SP) is essentially the electromagnetic wave that is located at the metal-dielectric interface because of the interaction with the free electrons of the conductor [24]. Since SP is extremely sensitive to changes in the refractive index of the dielectric, the principle of surface-Plasmon resonance (SPR) is widely used in bio molecular interaction analysis. Polarization is a fundamental property of light and there are three different types of polarization states: linear, circular and elliptical. The polarization of light is defined in terms of the direction of oscillation of the electric field vectors. If the phase relationship is constant, the light is completely polarized. More specifically, if the phase difference is 0 or 180 degrees, the light is linearly polarized. If the phase difference is 90 or 270 degrees and both components have the same amplitude, the light is circularly polarized. If a constant phase difference other than 0, 90, 180 or 270 degrees exists and/or the amplitudes of the components are not equal, then the light is elliptically polarized.

2. STRUCTURE AND ITS THEORY

Dual wavelength single polarizing filter is designed based on the availability of technology and PCF good polarization characteristics. To control the core mode and Surface Plasma Polarization mode, two big air holes are introduced around the fiber core and metal film. To obtain good polarization and low crosstalk, the sizes of air holes around the fiber core and metal film are regulated. The crystal structure is simple hexagonal crystal structure which is suitable for coating and three big air holes with the shape of equilateral triangle are introduced in the center as shown in Fig 1.(a). In fig1.(a), the separation distance between air holes is represented by Λ and it is $3\mu\text{m}$ remains constant for fabricating by stack draw method. The diameter of two big air holes around the fiber core is represented by d_1 . The diameter of air holes that is coated silver metal on the inner wall is represented by ' d_a '. The coating thickness is represented by ' t '. The diameter of two big air holes around the fiber core is said to be ' d_2 '. while two small holes above the core is designated as ' d_3 '. The diameter of the other holes are represented as ' d_c '.

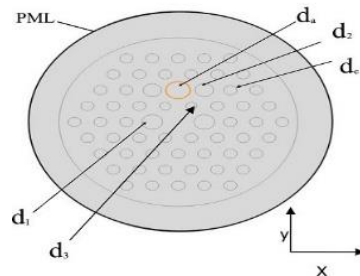


Fig1. (a) Cross section of the polarization filter with the silver layers.

To achieve single mode transmission of Photonic Crystal Fiber, set $d_c = 0.5\Lambda$. The separation distance between two big air holes, i.e. $d_2 = 0.7\Lambda$. The dispersion relation of pure silica glass and silver can be known through the sellemier equation and drude Lorentz that helps to find confinement loss in x-direction and y-direction. A perfectly matched layer(PML) is placed at the outmost ring to avert reflection. To decrease the energy loss, a perfectly matched layer and a scattering boundary condition are used in the calculation.

2.1 SIMULATION OF POLARIZING FILTER USING COMSOL MULTIPHYSICS

The polarizing filter is designed using COMSOL MULTIPHYSICS 5.2(formerly FEM software). Polarizing filter is capable of finding parameters like confinement loss, effective mode index.

2.2 CONFINEMENT LOSS

Confinement loss is a microstructured cladding property that cannot be properly understood using a naïve "homogenized" description. In single mode fiber and bandgap fiber, its impact is in terms of defining the air fraction or number of rings of holes that are required to reduce loss at the desired levels. The degree of confinement loss can vary over several orders of magnitude for different modes. confinement loss is caused by putting your mode in a small space which causes the mode to also propagate partially out of you fiber (meaning not in the center of the fiber). Confinement losses are the losses arising from the leaky nature of the modes and the non-perfect structure of the PCF fiber. Then, depending on the wavelength, number of holes rings, and hole size, modes will be guided with a structure dependent loss.

$$L = 8.686 \times 2\pi/\lambda \text{ Im}(n_{\text{eff}}) \times 10^4$$

Where $\text{Im}(n_{\text{eff}})$ - imaginary part of effective refractive index.COMSOL Multiphysics (the name is meant to be an acronym of COMmon SOLution) is a cross-platform finite element analysis, solver and multiphysics simulation software.

2.3 EFFECTIVE INDEX

Modal index is also called as effective index. Effective index is propagation constant of the mode divided by the free space number (k) where $k = 2\pi/\lambda$ divided by the wavelength. Effective index is the quotient of two wavenumbers and it is dimensionless, like refractive index. In other words, effective index can also defined as number that represents characterizing material when a 2D will be used to approximate propagation on a 3D structure.

3.RESULTS AND DISCUSSION

The simulated results have been shown by varying the different parameters of PCF such as number of small holes and large holes, diameter of the holes and wavelength below. Effective index for different wavelength can be calculated using Finite Element Method. Polarization Filter is designed using silver,silica glass,air as coating material. Thus meshing of these materials is shown as Fig 3.1 using Finite Element Method.

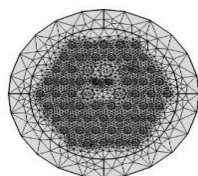


Fig 3.1 Meshing of Polarizing Filter

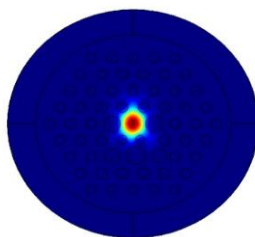


Fig 3.2(a) effective index=0.97182
 @Wavelength=1550nm

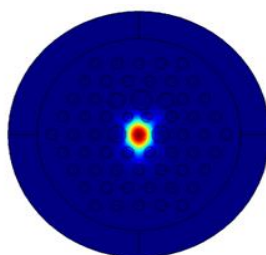


Fig 3.2(b) effective index=0.97856
 @wavelength=1330nm

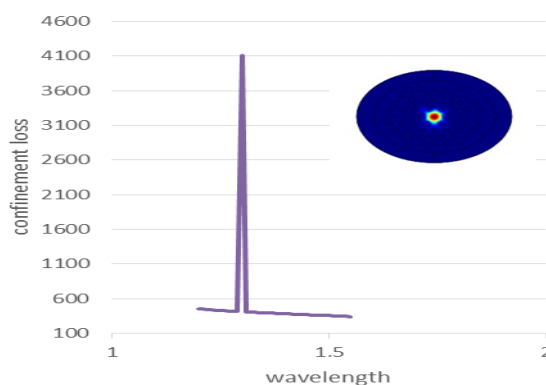


Fig 3.3 confinement loss of polarization filter.

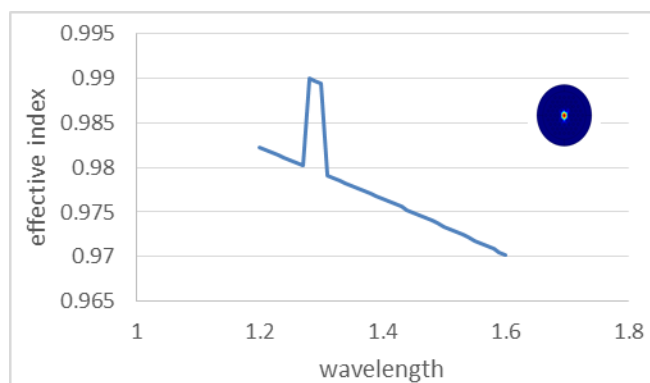


Fig 3.4 Effective index variations for different wavelength.

From the Fig 3.4, it concludes that confinement loss is decreased for increasing wavelength. The periodic cladding of PCF causes a decrease in optical confinement that is called as confinement loss. Thus, using silver material as coating material, confinement loss is 401dB/km at 1330nm and at 1550nm loss is 341 dB/km. The loss difference between two wavelengths is 60 dB/km. We have used silver as coating material due to excellent characteristics while compared with other materials. Silver is soft, white, lustrous transition metal, which exhibits the highest electrical conductivity, thermal conductivity, and reflectivity of any metal. It is found in the Earth's crust in the pure, free elemental form ("native silver"), as an alloy with gold and other metals, and in minerals such as argentite and chlorargyrite. Naturally occurring silver is composed of two stable isotopes, ¹⁰⁷Ag and ¹⁰⁹Ag, with ¹⁰⁷Ag being slightly more abundant (51.839% natural abundance). Silver is used in high quality connectors for RF, VHF, and higher frequencies, particularly in tuned circuits such as cavity filters where conductors cannot be scaled by more than 6%.

4. CONCLUSION

We have proposed polarization filter using finite element method. Polarization Filter has great impact in optical communication especially in photography. The confinement loss in 1330nm is 401dB/km and at 1550nm is 341dB/km. effective index is inversely proportional to wavelength. silver has been used for coating because it is used in high quality connectors for RF, VHF, and higher frequencies, particularly in tuned circuits such as cavity filters where conductors cannot be scaled by more than 6%.

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