Dispersion through Optical Fibers under PEMC Boundary conditions

Muhammad Abuzar Baqir, Pankaj Kumar Choudhury

Institute of Microengineering and Nanoelectronics, Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor, Malaysia
E-mail: pankaj@ukm.my

1. Introduction

Optical behavior of waveguides can be tailored by suitably altering its geometry, medium and dimensions. Several forms of guides, composed of different shapes, geometries and media have been investigated [1–6]. In this stream, guides composed of metamaterials have many exotic characteristics [3–7] that are not found in ordinary mediums.

In this paper, we attempt to investigate waves through optical fibers with dispersive core. Perfect electromagnetic conductor (PEMC) [7] sheath helix wrap is put at the core-clad interface. The eigenvalue equation is useful to study the fiber dispersion behavior, deduced by applying the core-clad interface boundary conditions. By changing the pitch angle ψ and admittance M, dispersive behavior of fiber is investigated. The fiber geometry under consideration is similar to twisted clad optical fiber [1].

2. Theory and Discussion

We consider a circular fiber composed of two regions. The fiber core is composed of dispersive negative metamaterial. The outer clad section is composed of non-dispersive lossless, homogeneous, isotropic medium with RI 1.52. For the sake of simplicity the clad is assumed to be infinite along radial direction. Consider harmonic electromagnetic waves to be propagation along the z-axis, the axial component of electromagnetic fields will be

$$E_z = E(\rho,\varphi)e^{j(\omega t-\beta z+v\varphi)} \tag{1a}$$

$$H_z = H(\rho,\varphi)e^{j(\omega t-\beta z+v\varphi)} \tag{1b}$$

In eq. (1), ω is the angular frequency, β is the propagation constant and v is the azimuthal mode index. The transversal electromagnetic field components are achieved by incorporating the axial component into Maxwell's equations. The fiber core is dispersive in nature, which may be written as

$$\varepsilon_{co}(\omega) = 1-\frac{\omega_p^2}{\omega^2} \tag{2a}$$

$$\mu_{co}(\omega) = 1-\frac{\Gamma\omega^2}{\omega^2-\omega_0^2} \tag{2b}$$

Here ω is operating frequency, $\omega_p/2\pi = 10$ GHZ is plasma frequency, $\frac{\omega_0}{2\pi} = 4$ GHZ is the resonance frequency and $\Gamma = 0.56$ is the losses in medium. It has been reported that the left-handed materials have negative RI in the frequency range 4–6 GHZ [4], which is used in our computations. Figures 1 and 2, respectively, demonstrate the effective RIs of lower order H_{01} and H_{11} modes of fiber vs. frequency f, corresponding to pitch angles $\psi = 0°$ and $\psi = 90°$. Two different values of admittance $M = 0.2$S and $M = 2$S are taken into account for each value of pitch angle ψ. From figs. 1 and 2, it becomes obvious that the effective RI is changed by varying pitch angle and admittance parameter of helix structure. Moreover, the mode degeneracy is observed and its tendency is increased for higher value of admittance M, as shown in figs. 1 and 2.

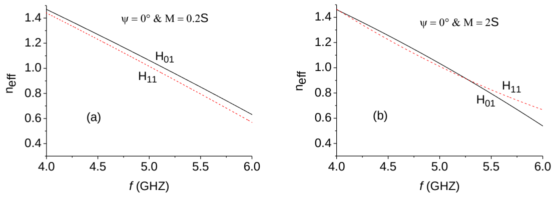

Fig. 1: Effective RI with f corresponding to $\psi = 0°$.

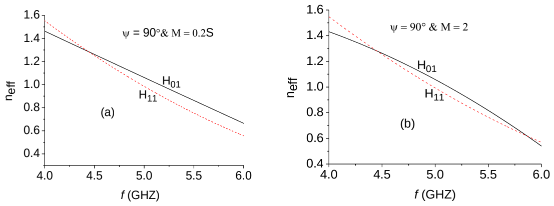

Fig. 2: Effective RI with f corresponding to $\psi = 90°$.

3. Conclusions

Based on the aforementioned discussions, we conclude that dispersive behavior of such optical fiber structure depends on the pitch of the twisted sheath helix and the admittance parameter of PEMC. Further, mode degeneracy has higher inclination for large admittance value. The property of the degeneracy of modes remains of great use in many optical systems wherein coupling of fields is specially needed.

References

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