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MEASUREMENTS OF EXCESS LOSS OF THE CROSSED WAVEGUIDE IN ANISOTROPIC DIELECTRIC INNER COATING PLASMA MEDIUM THROUGH MILLIMETER WAVE PROPAGATION

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ABSTRACT

In the present paper, an attempt has been carried out to measure the excess loss of the crossed wave guide. Crossed waveguide is widely used in optical devices, whose excess loss has a strong impact on mulltiturn optical wave guide. Based on the extended Huygen's-Fresnel integral formulae for the average irradiance of circular and elliptical propagating are derived. It is found that circular and elliptical anomalous hollow beams at short-propagation distance in turbulent atmosphere, which is much different from their propagation properties in free space. The thickness of the dielectric and its location in the waveguide are studied with respect to their effects on the number of spectra observed. Finally, the excess loss of the anistropic and isotropic dielectric have been investigated.

Key words: Excess loss, Crossed wave guide, Anisotropic medium, Millimeter wave.

INTRODUCTION

There is a crossed waveguides region in the multiturn OWRR of planer integrated optical circuits. Many publications have demonstrated to assess these parameters through measuring the resonance characteristics, but the coupling loss is taken to be zero. We have studied the propagation properties of circular and elliptical anomalous hollow beams in a turbulent atmosphere through millimeter propagation, where analytical propagation

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formula is denied and using this concept of measurement, some numerical examples are given. Comparisons of the results with those of the free space are also carried out in the present work.

Theory

Neglecting the temporal coherence of the laser, the resonance curve of a ring resonator is written as[1, 2] –

$$R = 10^{-\frac{2}{10}} \frac{T^2 - 2TV\cos\delta + V^2}{1 - 2TV\cos\delta + T^2V^2} \quad \ldots(1)$$

With V and T as substitute variable. T = $\sqrt{1-k}$; V = $10^2 + \alpha_R$, where α_R is propagation loss in the OWNR including the propagation of the silica wave guide and the excess loss of the crossed wave guide in multiturn with the coupling coefficient and coupling loss of the directional coupler, respectively.

The waveguide propagation loss α_R and coupling loss α_C are both given in dB. Hence, δ is the round to optical phase shift within the ring resonator.

Using the extreme values of the resonance curve, the excitation ratio ρ can be written as –

$$\rho = 1 - \frac{(T-V)^2}{(T+V)^2} \frac{(1+TV)^2}{(1-TV)^2} \quad \ldots(2)$$

Using the equation (1), F can be written as –

$$F = \frac{\pi}{arc\cos\frac{2TV}{1+T^2V^2}} \quad \ldots(3)$$

By measuring the relationship of R with δ, both F and ρ can be obtained, so those three basic element parameters can be calculated as follows –

$$K = \frac{1-b^2}{ab+1} 10^{-\frac{(\alpha_C+\alpha_R)}{10}} = \frac{ab^2 - b}{a+b} \quad \ldots(4)$$

Here, a and b are substitute variables.

$$a = \frac{1+\sqrt{1-\rho}}{1-\sqrt{1-\rho}}$$

$$b = 1 - \sin(\pi - F)$$

Making use of Maxwell's equations, to obtain the dispersion relation, We obtain –

$$\nabla \times \mathbf{B} = \frac{1}{c}\frac{\partial(\overline{\in} E)}{\partial t}$$

$$\nabla \times \mathbf{E} = -\frac{1}{c}\frac{\partial B}{\partial t}$$

$$\nabla . \mathbf{B} = 0$$

$$\nabla . \mathbf{E} = 0$$

Where $\overline{\in}$ is the dielectric tensor and E and B are the perturbed values of the electric and magnetic fields, respectively. In general, the crossed waveguide in anisotropic dielectric inner coating through millimeter wave propagation –

$$\in_{jk} = \in_0 \left(\delta_{jk} + X_{jk}\right)$$

Where,

$$X_{jk} = \frac{-\omega_{pe}^2}{\omega^2\left(\omega^2 - \Omega_e^2\right)}\left[\omega^2 \delta_{jk} - \Omega_e^2 b_j b_k + i\omega\Omega_e \in_{jkl} b\,l\right] \quad \ldots(5)$$

ω_{pe} is the electron plasma frequency, Ω_e is the electron cyclotron frequency and b_l is a component of $\hat{b}$, a unit vector tensor. In magneto active cold plasma with ***b*** along the $\hat{Z}$ direction, the dielectric tensor can have the following form –

$$\in = \begin{pmatrix} \in_\perp & ig & 0 \\ -ig & \in_\perp & 0 \\ 0 & 0 & \in_\perp \end{pmatrix}$$

Where,

$$\in_\perp = 1 - \frac{\omega_{pe}^2}{\omega^2 - \Omega_e^2}$$

$$\in_{ll} = 1 - \frac{\omega_{pe}^2}{\omega^2}$$

$$g = \frac{-\omega_{pe}^2 \Omega_e}{\omega\left(\omega^2 - \Omega_e^2\right)}$$

For an ideal waveguide oriented along the z-axis, the dielectric tensor $\overline{\in}_d$ is only a function of the transverse coordinates, i.e,

$$\vec{\in}_d = \overline{\in}_d (r, \phi)$$

$$\overline{\in} = \begin{pmatrix} \in_{\perp d} & 0 & 0 \\ 0 & \in_{\perp d} & 0 \\ 0 & 0 & \in_{lld} \end{pmatrix}$$

Here, We assume that $\in_{\perp d}$ and $\in_{lld}$ are constants. In the linear approximation of perturbed field, B and E are assumed to be monochromatic plane wave.

$$B(r, \psi, z, t) = \sum_{i=1}^{3} \hat{e}_i \, B_i(r) \exp[-i(\omega t - k_2 z - m\psi)]$$

$$E(r, \psi, z, t) = \sum_{i=1}^{3} \hat{e}_i \, E_i(r) \exp[-i(\omega t - k_2 z - m\psi)]$$

Here $\hat{e}_i$ is a unit vector in cylindrical coordinates and m is an integer. The system of equations describing the general behavior of electric and magnetic fields in this geometry is obtained. The field components E_Z and B_Z are strongly coupled with each other as follows –

$$\left(x^2 + \frac{g^2 \omega^2}{\in_j^2 \; c^2}\right) \nabla_\perp^2 E_Z - \xi \frac{\in_{11}}{\in_\perp} E_Z = ik_Z \frac{\omega}{c} \frac{g}{\in_\perp} \nabla_\perp^2 B_Z$$

$$x^2 \nabla_\perp^2 B_Z - \xi B_Z = -ik_Z \frac{\omega}{c} g \nabla_\perp^2 E_Z$$

Where,

$$x^2 = k_Z^2 - \in_\perp \frac{\omega^2}{c^2}$$

$$\xi = x^4 - g^2 \frac{\omega^4}{c^4}$$

and the transverse Laplace operator is given by –

$$\nabla_\perp^2 = \left(\frac{1}{r}\right)\left(\frac{d}{dr}\right) r \left(\frac{d}{dr}\right) - \frac{m^2}{r^2}$$

Since, We have not considered a strongly magnetized plasma wave, g ≠ 0, can be separated only under the conditions $k_z = 0$ i.e., for azimuthal modes. In this case, the B-modes and E-modes with respective components (E_z, B_y, B_x) and (B_z, E_y, E_z) occur. These modes will be investigated separately in next section.

Isotropic case

In this situation, the perpendicular and parallel elements of the dielectric tensor are equal, $\in_{\perp d} = \in_{lld} = \in_d$. The ratio of radii of the annular plasma ($\alpha = R_b \mid R_a$) for two arbitrary electron plasma frequencies and two electron cyclotron frequencies in the low frequency region; where,

$$2\omega / \omega_{pe} < \left(\sqrt{4 + \Omega_e^2 / \omega_{pe}^2 - \Omega_e / \omega_{pe}}\right)$$

It is apparent that when α is approximately larger than 1.2, the number of spectrum solution decreases. The number of spectrum solutions increases as the electron cyclotron frequency decreases. The graph of ω/ω_{pe} versus ω_{pe} presented for two electron cyclotron frequencies. In contrast to an annular plasma waveguide with no surroundings dielectric, the number of spectra is more sensitive to the cyclotron frequency, than to the plasma frequency. Actually by increasing the electron cyclotron frequency the number of spectra is decreased. When the plasma column is surrounded by a metallic cylindrical lined waveguide for which no solution under the condition $\Omega_e = \omega_{pe} = 1\times10^{11}$ Hz was reported here. The numerical computations show that we have found the solutions for the frequency spectrum under the same condition.

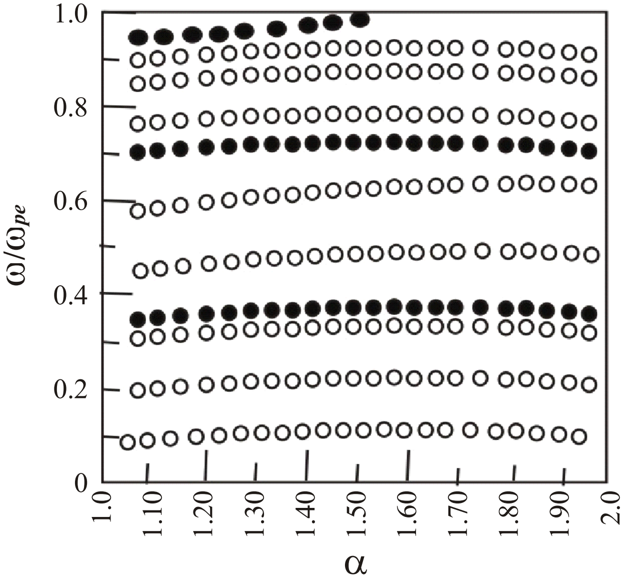

Fig. 1: Graph of the dispersion relation given for dominant modes (m = ± 1) verses $\alpha = R_b\ R_a$ (the ratio of the external to internal radii of the angular plasma) for two arbitrary electron plasma frequencies $\omega_{pe}\ \in_{lld} = 2.1$, $R_d = 7$ cm and $R_r = 12$ cm and $R_a = 1$ cm.

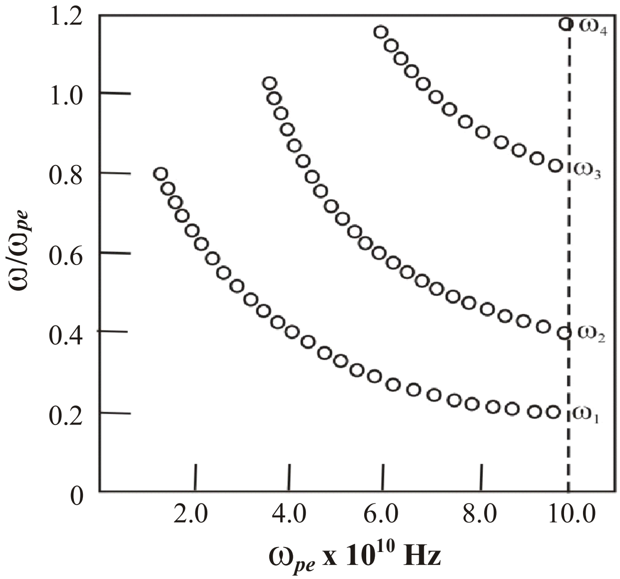

Fig. 2: Graph of ω/ω_{pe} versus the electron plasma frequency ω_{pe}

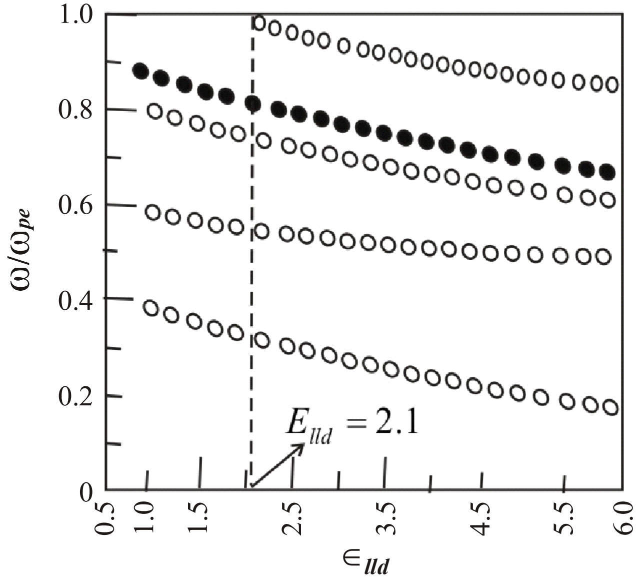

Fig. 3: Graph of ω/ω_{pe} verses the coaxial anisotropic dielectric permittivity constant $\in_{lld}$ for two electron plasma frequencies

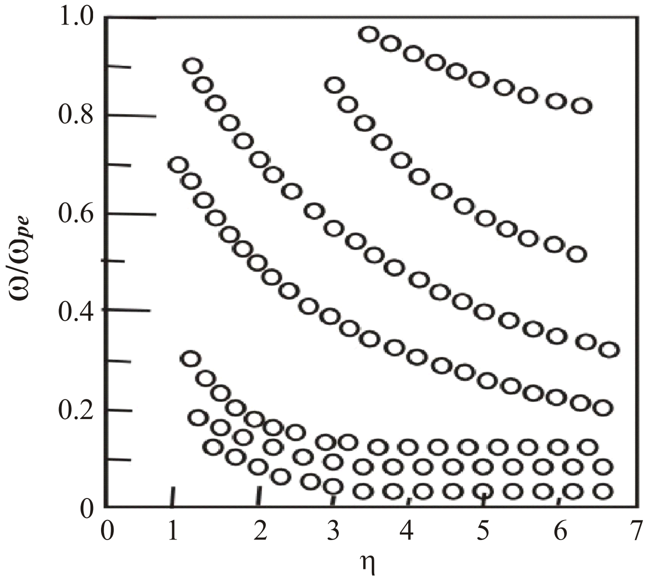

Fig. 4: Graph of ω/ω_{pe} verses the electron plasma frequency to electron cyclotron frequency, $\eta = \omega_{pe}/\Omega_e$

DISCUSSION AND CONCLUSION

In this work, the calculation and investigation of the excess loss was extended to include crossed waveguide in plasma medium in an anisotropic dielectric coating inside the metallic wall of the waveguide. Considering the azimuthal electromagnetic surface wave $k_z = 0$, the coupled wave is conserved into two independent modes (the E and B-modes), we have proposed and demonstrated a simple and non–destructive technique to assess, the excess loss of crossed waveguide in the multiturn dielectric inner coating. More importantly, it is not necessary to measure the refractive index of the ring waveguide and the group velocity of the light travelling in the resonator. It was seen that by adding the dielectric to the waveguide used in, the number of frequency spectra reported by Shokari and Jazi for an annular plasma with a small radius. Furthermore, it was shown that the number of frequency spectra versus the plasma frequency for the isotropic E-mode is more sensitive to the cyclotron frequency. The number of spectra for the anisotropic dielectric plasma medium considered the condition $\omega_{pe} = 3\times10^{10}$ Hz is decreased by decreasing Ω_e where as for the isotropic case, decreasing Ω_e lead to an increase in the number of spectra observed.

REFERENCES

1. S. Ezekiel and R. Balsamo, Appl. Phys. Lett., **30 (9)**, 478 (1977).
2. P. Mottier and P. Pouteau, Electron Lett., **33 (23)**, 1975 (1997).
3. H. Haavistro and A. Pajer, Opt. Lett. **5(12)**, 510 (1980).
4. J. Bismuth, P. Gildon, F. Revol and S. Valette, Electron Lett., **27(9)**, 723 (1991).
5. B. Jazi, B. Shokri and H. Arbab, Plasma Phys. Control Fusion, 48 (2006).
6. D. P. Giarusso and J. H. Haris, J. Opt. Soc. Am., **63**, 138 (1973).
7. J. Q. Wu, Phys. Plasmas, **4**, 3064 (1984).
8. S. Mu, P. Zhu and S. Z. Yang, J. Phys. D, Appl. Phys., **29**, 274 (1996).
9. J. D. Jackson, Classical Electrodynamics, New York, Wiley (1998).
10. E. C. Gamaly, Phys. Rev., E **48**, 516 (1993).

11. N. Prasad Paras, Introduction to Biophysics, Wiley (2003).
12. A. N. Grigorenko, P. I. Nikitien and A. V. Kabashin, Appl. Phys. Lett., **75**, 3917 (1999).
13. I. R. Hooper and J. R. Sambles, J. Appl. Phys., **96**, 3004 (2004).
14. X. Zhu, Appl. Opt., **33**, 3502 (1994).

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