GUIDED WAVE STUDY OF PLANNER SLAB DIELECTRIC OPTICAL WAVEGUIDE

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Abstract

In this paper we establish the fundamental concept of guided wave. Due to the transcendental nature of the eighnvalue equation,. it is very difficulty to find eighnvalue . Practically implemented optical slab waveguide based on traditional techniques . Numerical methods are used to obtain guided wave characteristics. In this paper, we develop an analytical method for modal analysis includes Eigen modes electric and magnetic fields distribution.It is well known that the thin symmetric waveguide support at least one mode. The developed technique can be easily applied to special cases

Keywords:- planar slab dielctric optical waveguide, Eigenvalue equation.

I. INTRODUCTION

Optical waveguide already play important roles in communication system.Develpment in optical communication have demanded the development of new technologyies for performing signal transmission.The simplest optical waveguide structure is the step-index slab waveguide.The slab waveguide ,consists of a high-index dielectric layer surrounded on either side by lower-index mateial.The slab is infinete in extent in the yz palne,but finite in the x direction.The index of refraction of the guiding slab,n_f ,must be larger than that of the cover material,n_c ,or the substrat material,n_s ,in order for total internal reflection to occer at the interfaces.if the cover and substrate materials have the same index of refelation.the waveguide is called symmetric, otherwise the waveguide is called asymmetric.the symmetric waveguide is special case of the asymmectic waveguide. The slab waveguide is clearly an idealization of real waveguide,because real waveguide are not infinete in width.However ,the one-dimensional analysis is directly applicabel to many real problems,and the techniqe form the foundation for further understanding.The fabrication and performance of such waveguides,known as dielectric clad planar waveguide,we start by solving the wave equation using boundary condition for slab waveguide structure. we alwayes choose the direction of propagation to be alonge z-axis.in order to understand the performance of a inhomogeneous waveguide structure,it is necessary to understand the simplest planar slab waveguide structure.in this paper ,we derive wave eqyation which determine the modes .we will develop formal mode concepts such as orthogonality,completeness,and model expansion.we will see that a waveguide structure can support only a discrete number of guided modes.

II. MATHEMATICAL BACKGROUND

Consider the waveguide structure shown in fig.1.The three indices are chosen such that $n_f > n_s > n_c$ And the guiding layer has a thickness h.the choice of the coordinate system is critical in making the problem as simple as possible.the appropriate coordinate system for this planer problem is a rectilinear cartesian system, because the three components of the field E_x,E_y and E_z are not coupled by reflections. For example an electric field polarized in Y direction , E_y will still be E_y field upon reflection at either interface ; the reflection does not couple any of the vector field into the X or Z direction. Because this is an asymmetric waveguide structure , we place the X=0 coordinate at one of the interfaces choosing arbitrarily the top interface between n_f & n_c .

We must consider the two possible electric field polarization , transverse electric or transverse magnetic. The axis of the wave guide is oriented in the Z direction. The K vector of the guided wave will ZigZag down the Z axis, the electric field is transverse to the plane of incident established by the normal to the interface , and by the K vector. Because of different boundary conditions that control both fields , the TE and TM cases are distinguished in their mode characteristics as well as their polarization. We will consider the TE case leaving derivation of the TM case.

In the TE case the E field is polarized along the Y axis. We assume the waveguide is excited by a source with frequency w_0 and a vacuume wavevector of magnitude k_0 where $k0 = w0/c$. To find the allowed modes of wave guides we must first solve the wave equation in each dielectric region, and then use the boundary conditions to connect these solutions. For sine wave with angular frequency w_0 the wave equation in each region can be put in scalar form :

$$\frac{\partial^2 E_y}{\partial x^2} + k_0^2 n_i^2 E_y = 0 \quad (1)$$

Where $n_i = n_f$, n_s or n_c depending on the location . $E_y(x,z)$ is a function of both x and z because the slab is infinite in y direction so E_y is independent of y. due to translational invariance of the structure in the Z plane we do not expect the amplitude to vary along the Z axis but we do expect the phase varies. The solution to the above equation can be written as:

$$E_y(x,z) = E_y(y)e^{-j\beta z} \quad (2)$$

β is the propagation constant along the Z direction putting this solution to the above equation noting that $d^2E_y/dy^2=0$,

$$\frac{\partial^2 E_y}{\partial x^2} + (k_0^2 n_i^2 - \beta^2)E_y = 0 \quad (3)$$

The choice of n_i depends on the position of X. for X>0, we would use n_c while for 0>X>-h, we use n_f etc. the general solution to the above equation will depend on the relative magnitude β with respect to k_0n_i. consider the case where $\beta > k_0 n_i$. the transverse wave equation have the general solution with real exponential form :

$$E_y(x) = E_0 e^{\pm\sqrt{\beta^2 - k_0^2 n_i^2}\,x} \quad \text{for } \beta > k_0 n_i \quad (4)$$

Where E_0 is the field amplitude at x=0. We always choose the negatively decaying branch of the above equation.
In case of $\beta < k_0 n_i$ the solution has oscillatory form :

$$E_y(x) = E_0 e^{\pm j\sqrt{k_0^2 n_i^2 - \beta^2}\,x} \quad \text{for } \beta < k_0 n_i \quad (5)$$

So depending on the values of β the solution can be oscillatory or exponentially decaying. If $\beta > k_0 n_i$ we define an attenuation coefficient as ;

$$= \sqrt{\beta^2 - k_0^2 n_i^2} \quad (6)$$

And describe the field as $E_y(x) = E_0 e^{-\sigma x}$ Compare this equation for evanescent field of a TIR wave. If $\beta < k_0 n_i$ then we define a transverse wave vector K as

$$K = \sqrt{k_0^2 n_f^2 - \beta^2} \quad (7)$$

So $E_y(x)=$ we see that β and K can be geometrically related to the total wavevector $K = k_0 n_f$ in the guiding film.

β and K are called the longitudinal and transverse wavevectors respectively inside the guiding film.

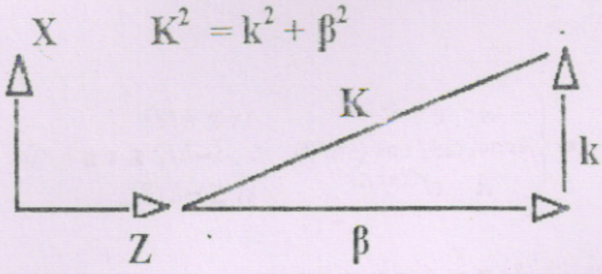

Fig. 1. β and k are the longitudinal and Transverse Component ,respectily ,of the wavevector k,

For $\beta < k_0 n_c$ the solution to the wave equation in all regions of space are oscillatory . if $\beta=0$ then the wave travels nearly perpendicular to the Z axis of the waveguide.
For the $k_0 n_c < \beta < k_0 n_s$ then total internal reflection at the film cover interface, but refracting at the lower substrate-film interface takes place. This condition is called substrate mode.
A guided wave must satisfy the condition,

$$K_0 n_s < \beta < k_0 n_f$$

Where it is assumed that $n_c \leq n_s$. This is a universal condition for any dielectric waveguide

III. THE SYMMERTRIC WAVEGUIDE

The index of refraction of the guiding slab,n_f ,must be larger than that of the cover material,n_c ,or the substrat material,n_s ,in order for total internal reflection to occer at the interfaces.if the cover and substrate materials have the same index of refelation,the waveguide is called symmetric.Guiding film with index n_f and thickness h is surround on both sides by an index n_s.It is convenient to place the coordinate system in the middle of this waveguide since the fienl will reflect the symmetry of structure.

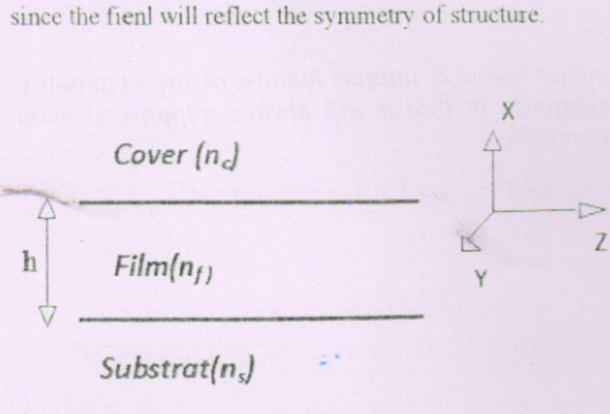

Fig.2. The Planar slab waveguide consist of three materials

General field description of a TE mode within the symmetric structure
Where

$$E_y = \begin{cases} A \quad e^{-\gamma(x-h/2)} & (x \geq h/2) \\ A\cos(\kappa x)/\cos(\kappa h/2) & (-h/2 \leq x \leq h/2) \\ A \quad e^{\gamma(x+h/2)} & (x \leq -h/2), \end{cases} \quad (8)$$

$$\tan(kh/2) = \frac{\gamma}{k} \text{ for even modes} \quad (9)$$

$$\tan(kh/2) = -\frac{k}{\gamma} \quad \text{for add} \quad (10)$$

Unique feature of the symmetric waveguide is that it can always support at least one mode

IV. RESULT AND DISCUSSION

=1.46000 , = 0
=1.47000 , = 10.^-6
=1.46000 , =0

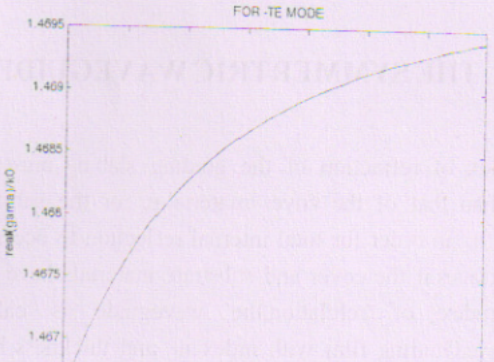

Fig.3.

A unique feature ***A unique feature of the symmetric waveguide is that it will always support at least one mode.***

=1.485 , =1.49 and

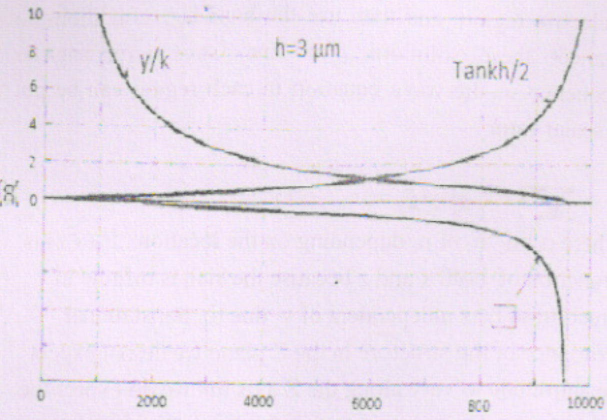

Fig.4. For thin waveguide,there is only one mode near k=6000cm

and difference in index between two layer is very small. wavwlenght 0.8 micrometter and h=3 micron.

fig.4 ,shown to even mode,begin a ∞ and terminate with a value of 0.the two curve will cross,so must be at least one mode.

V. CONCLUSION

In the conclusion, we have applied to solve the wave equation . we establish the fundamental concept of guided wave. Result shown the thin symmetric waveguide support at least one mode.

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