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ANALYSIS OF FIELD DISTRIBUTION OF OPTICAL WAVEGUIDE USING LINEAR FINITE ELEMENT METHOD

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ABSTRACT

Understanding the propagation properties, the field distribution, and how these depend on the manufacturing parameters is necessary for optimizing optical waveguide performance. The necessity for computer analysis grows as the variety of directing structures and the relying parameters expand and become more complex. Theoretical approaches to waveguide analysis are therefore of great interest. The complex and thorough study of waveguide problems in all dimensions is provided by the Finite Element Method (FEM). The propagation modes of an optical fibre can be calculated using the method shown in this project. The Maxwell equation is reduced to a conventional eigen value equation with symmetric tri-diagonal matrices by finite element method analysis.

Keywords: Eigenvalue, Eigenvector, FEM, Field distribution, Open boundary problem.

1. INTRODUCTION

The investigation of propagation properties of circular waveguides with arbitrary refractive index profiles using a finite element analysis method has recently caught the interest of numerous academics. By using symmetric tri-diagonal matrices, the finite element approach reduces Maxwell's equation to a common eigen value equation. The waveforms, propagation constants, and delays (per unit length) of the modes are calculated by routines using their eigen values and eigenvectors. Throughout engineering, the approach develops into a potent tool [9]. The typical definition of an optical fibre is a dielectric waveguide that works at optical frequencies. In the form of light, it confines electromagnetic energy. The light is directed in a direction parallel to the optical fiber's axis.

2. TYPES OF ANALYSIS

Analysis of optical waveguide is divided into two types:
i) Analytical method
ii) Numerical method

I) Analytical Method

The analysis's precise solution is provided by analytical method. Scalar wave equation is derived using this way from Maxwell's equations. Maxwell's equation can be used to solve the optical fiber's mode field distribution. In spite of providing an accurate solution, the procedure is more complex than a numerical one.

Ii) Numerical Method

Another technique for the same goal is the numerical approach. One variety of this technique is the finite element method. The investigation of propagation properties of circular waveguides with arbitrary refractive index profiles using a finite element analysis method has recently caught the interest of numerous academics. By using symmetric tri-diagonal matrices, the finite element approach reduces Maxwell's equation to a common eigen value equation. Waveforms, propagation constants, and delays (per unit length) of the modes are calculated by routines using their eigen values and eigenvectors. Throughout engineering, the approach develops into a potent instrument.

An integral or differential equation can be solved numerically using the finite element method (FEM). It has been used to solve a variety of physical issues where underlying differential equations are known. In essence, method entails assuming piecewise continuous function for the solution and determining the parameters of the functions in a way that minimizes error in the solution. This article offers a succinct introduction to the finite element approach.

3. FINITE ELEMENT METHOD:

Clough originally used the term "finite element" in 1960. Engineers employed the approach in the early 1960s to approximately solve issues in stress analysis, fluid flow, heat transfer, and other fields. Zienkiewicz and Chung published their first book on the FEM in 1967. The FEM was used to solve a wide range of technical issues in the late 1960s and early 1970s.

As though nodes were pins or drops of glue holding elements together, FEM divides a structure into numerous elements (parts of the structure) and then links components at "nodes." A group of simultaneous algebraic equations are produced by this technique. Maxwell's equation is reduced to a common Eigen value equation utilizing symmetric tridiagonal matrices through finite element technique analysis. The process is efficient and trustworthy. It works with both single-mode and multimode fibres.

A numerical method for solving a differential or integral problem is the finite element method (FEM). Where the governing differential equations are accessible, it has been used to solve a number of physical issues. The method basically entails assuming the piecewise continuous function for the answer and locating the parameters of the functions in a way that minimizes answer mistake. An overview of the finite element approach is given in this article. The plane stress and plane strain formulation is used to explain the method.

A linear differential equation of FEM formulation can have the following form:

$$Lu + q = 0 \qquad (1)$$

Where L is the differential operator, q is the vector of known functions, and u is the vector of the problem's fundamental variables, which are functions of the coordinates. Boundary conditions will be applied to this differential equation, and they often come in two flavors.

The set of boundary conditions that are necessary for fully solving the differential equations is known as the essential boundary conditions I

The differential equation can only be fully solved by satisfying at least one necessary boundary condition, which is not possible with the natural boundary conditions, which are the boundary requirements containing higher order derivative terms.

For example, consider the differential equation:

$$\frac{\mathrm{d}}{\mathrm{d}x}\left(EA\frac{\mathrm{d}u}{\mathrm{d}x}\right)+q=0 \qquad (2)$$

Under either of the following two circumstances, this issue can be fully resolved:

It is required at both ends in I u.

(ii) At one end, u is prescribed, and at the same or another end, du/dx is prescribed.

However, if simply du/dx is recommended at both ends, the issue cannot be resolved. Therefore, we undoubtedly need a border condition that specifies u. Du/dx=(du/dx)* is a natural boundary condition for this problem, and u= u* is an essential boundary condition, where * denotes the specified value.

Think about the differential equation now:

$$\frac{d^2}{dx^2}\left(EI\frac{d^2w}{dx^2}\right)-q=0 \qquad (3)$$

4. ALALYTICAL METHOD USED FOR THE ANALYSIS

The precise answer is provided by the analytical technique employed to analyze the mode field distribution. Maxwell's equation is transformed into a scalar wave equation using analytical methods. For modes like LP 01 mode, LP 11 mode, LP 21 mode, and LP 31 mode, we can get varied field and contour distributions by varying the values of core radius (a).

5. RESULTS OF ANALYRICAL METHOD.

The following modes' mode field distribution is examined using an analytical method. The distribution plot for the mode field and associated contour plot are displayed below.

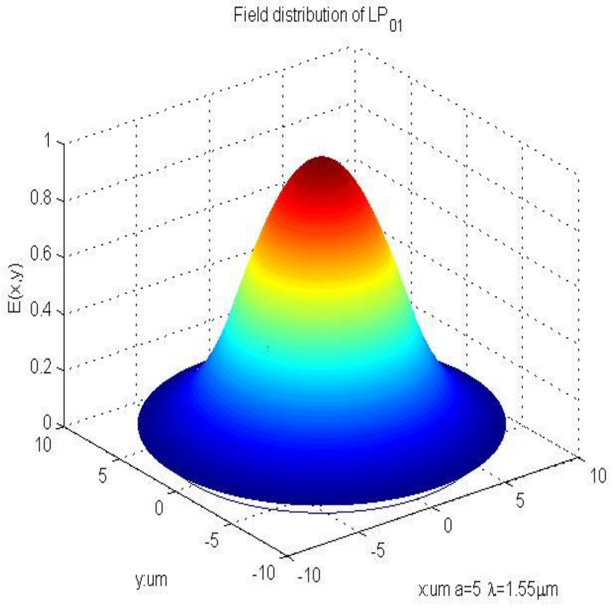

Fig. 4.1 Mode field distribution of LP 01 Mode

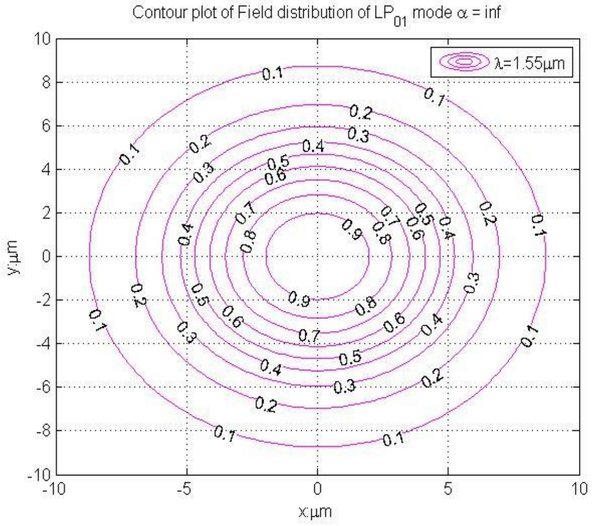

Fig. 4.2 Contour plot of Field distribution of LP 01 mode

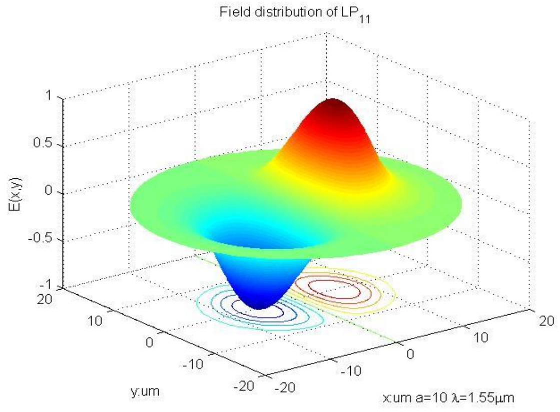

Fig. 4.3 Mode field distribution of LP 11 Mode

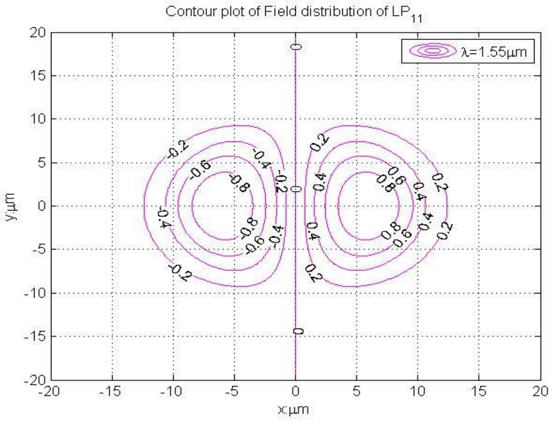

Fig. 4.4 Contour plot of Field distribution of LP 11 mode

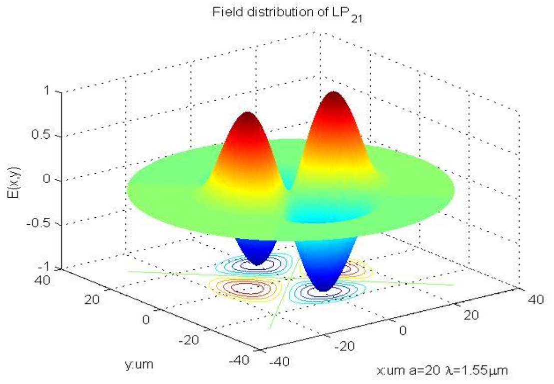

Fig.4.5. Mode field distribution of LP 21 Mode

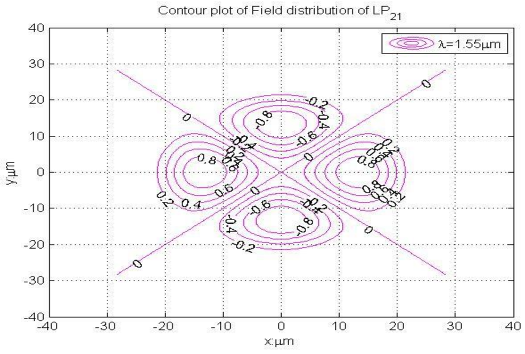

Fig.4.6 Contour plot of Field distribution of LP 21 mode

The finite element approach has the following benefits.
I. It handles extremely complex geometry with ease.
ii. The FEM's heart and soul can tackle a wide range of engineering issues, including solid mechanics and electrostatic issues.
This approach can deal with intricate restrictions.
iv. This technique helps simplify calculations that need complex mathematics.

6. CONCLUSION

The precise answer is provided by the analytical technique employed to analyse the mode field distribution. Maxwell's equation is transformed into a scalar wave equation using analytical methods. For modes like LP 01 mode, LP 11 mode, and LP 21 mode, we can get varied field and contour distributions by varying the values of core radius (a). To examine the modal quantities of an optical fibre, the finite element method (FEM) is applied. Maxwell's equation is transformed into a typical Eigen value equation through FEM analysis. The scalar wave equation has an approximation that the FEM offers. From linear to quadratic FEM, by increasing the number of elements, accuracy rises. Waveguide problems are elaborately and in-depthly analysed in all dimensions using the Finite Element Method (FEM).

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