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RECTANGULAR WAVEGUIDES

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INTRODUCTION

PREVIOUSLY WE SAW DIFFERENT METHODS TO ANALYSE RECTANGULAR CORE WAVEGUIDE :

Marcitilli's Method → Perturbation Method → Optimal Variational Method(VoPT)

ACCURACY INCREASES

WE USED VOPT METHOD TO ANALYSE RECTANGULAR WAVEGUIDES :

I. MODAL ANALYSIS OF RECTANGULAR WAVEGUIDE USING VOPT
II. APPLICATION OF RECTANGULAR WAVEGUIDES
III. IDENTICAL DIRECTIONAL COUPLER
IV. NON IDENTICAL DIRECTIONAL COUPLER
V. POWER DISTRIBUTION AT DIFFERENT LONGITUDINAL LENGTH OF DIRECTIONAL COUPLER
VI. MODAL ANALYSIS OF RIB WAVEGUIDE
VII. MODAL ANALYSIS OF EMBOSSED WAVEGUIDE

OPTIMAL VARIATIONAL METHOD(VOPT)

In this method no prior assumptions are required for the form of field. The field is generated by the method itself. Modes of a waveguide characterized by $n^2(x, y)$ satisfy the wave equation.

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + [k_0^2 n^2(x,y) - \beta^2]\psi(x,y) = 0 \quad \Rightarrow \quad (1)$$

The integral form of the above equation can be written as,

$$\beta^2 = \int\int k_0^2 n^2(x,y)|\psi(x,y)|^2 dxdy - \int\int |\nabla\psi|^2 dxdy \quad \Rightarrow \quad (2)$$

For the trial field $\psi_t(x,y)$ the estimated propagation constant is given as,

$$\beta_t^2 = \int\int k_0^2 n^2(x,y)|\psi_t(x,y)|^2 dxdy - \int\int |\nabla\psi_t|^2 dxdy \quad \Rightarrow \quad (3)$$

Most of the analytical trial functions assume the separability of the field in the x and y directions .

$$\psi_t(x,y) = X(x)Y(y) \quad \Rightarrow \quad (4)$$

The accuracy of the method is governed by two assumptions: the separability and the functional forms for the factors in Eq.(4). The separability is still assumed but no functional forms are assumed for X(x) and Y (y) These are generated numerically without any approximation. Thus, these two one-dimensional fields evolve with the iterations within the framework of the variational method and the accuracy obtained is the best under the assumption of separability. Thus Eq.(3) is written as,

$$\beta_t^2 = \int\int k_0^2 n^2(x,y)|X(x)|^2|Y(y)|^2 dxdy - \int\int \left|\frac{\partial X}{\partial x}\right|^2 dx - \left|\frac{\partial Y}{\partial y}\right|^2 dy \qquad \Longrightarrow \qquad (5)$$

The method is iterative and we assume, to start with, a planar index distribution $n^2(y)$(it could as well be $n^2(x)$). We introduce this index distribution into the variational expression of Eq.(5), which can be rewritten as.

$$\beta_t^2 = \int k_0^2 n_y^2(y)|Y(y)|^2 dy - \int \left|\frac{\partial Y}{\partial y}\right|^2 dy + \int k_0^2 \left[\int (n^2(x,y) - n_y^2(y))|Y(y)|^2 dy\right] |X(x)|^2 dx - \int \left|\frac{\partial X}{\partial x}\right|^2 dx \qquad \Longrightarrow \qquad (6)$$

However writing the equation in this manner, we have separated RHS into two variables. We will show in the following that each of these terms is positive and can be individually maximized giving, thus, the maximum value of βt.The first term,

$$\beta_y^2 = \int k_0^2 n^2(y)|Y(y)|^2 dy - \int \left|\frac{\partial Y}{\partial y}\right|^2 dy \qquad \Longrightarrow \qquad (7)$$

The second term of Eq.(6) is also in the form of the variational expression for a planar index distribution, $n_x^2(x)$, which is defined as,

$$n_x^2(x) = \int [n^2(x,y) - n_y^2(y)]|Y(y)|^2 dy \qquad \Longrightarrow \qquad (8)$$

Break the Eq.(5) in terms of $n_x^2(x)$ (this time use the calculated value of $n_x^2(x)$) then follow the same steps and find β_x^2 and $n_y^2(y)$ name them Eq.(9) and Eq.(10) .

STEPS FOR IMPLEMENTATION OF THE VOPT METHOD :

STEP 1: Choose an $n_y^2(y)$. A good choice is $n_y^2(y) = n^2(x = 0, y)$.

STEP 2: Obtain β_y^2 an $Y(y)$ numerically. Normalize $Y(y)$.

STEP 3: Obtain $n_x^2(x)$ using Eq.(8).

STEP 4: Obtain β_x^2 and $X(x)$ numerically for $n_x^2(x)$. Normalize $X(x)$.

STEP 5: Obtain $n_y^2(y)$ using Eq.(10).

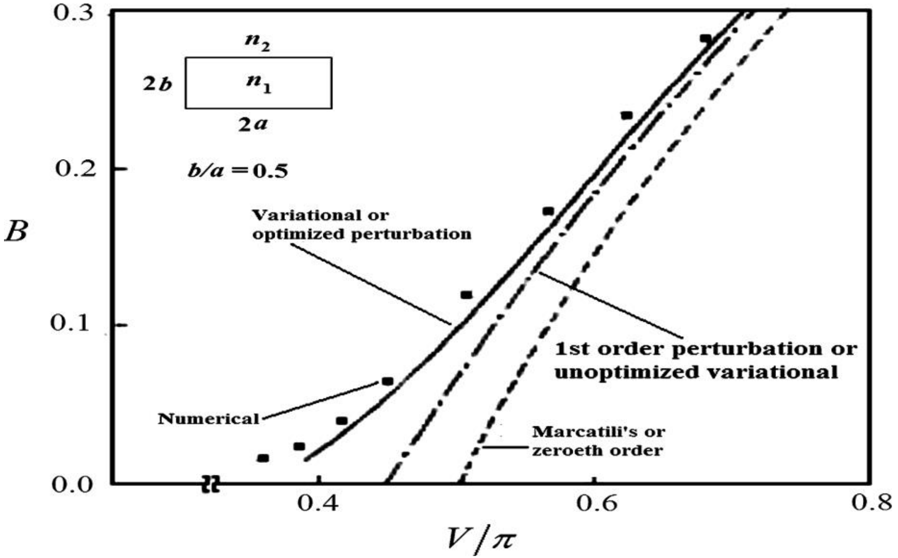
STEP 6: Obtain β_y^2 and $Y(y)$ numerically for $n_y^2(y)$. Normalize $Y(y)$.

STEP 7: Compute $\beta_t^2 = \beta_x^2 + \beta_y^2$. Check for convergence in β_t^2 .

IF Converged, GO TO STEP 8 ELSE GO TO STEP 3.

STEP 8: β_t^2 and $\psi_t(x, y) = X(x)Y(y)$ are the required propagation constant and modal field .

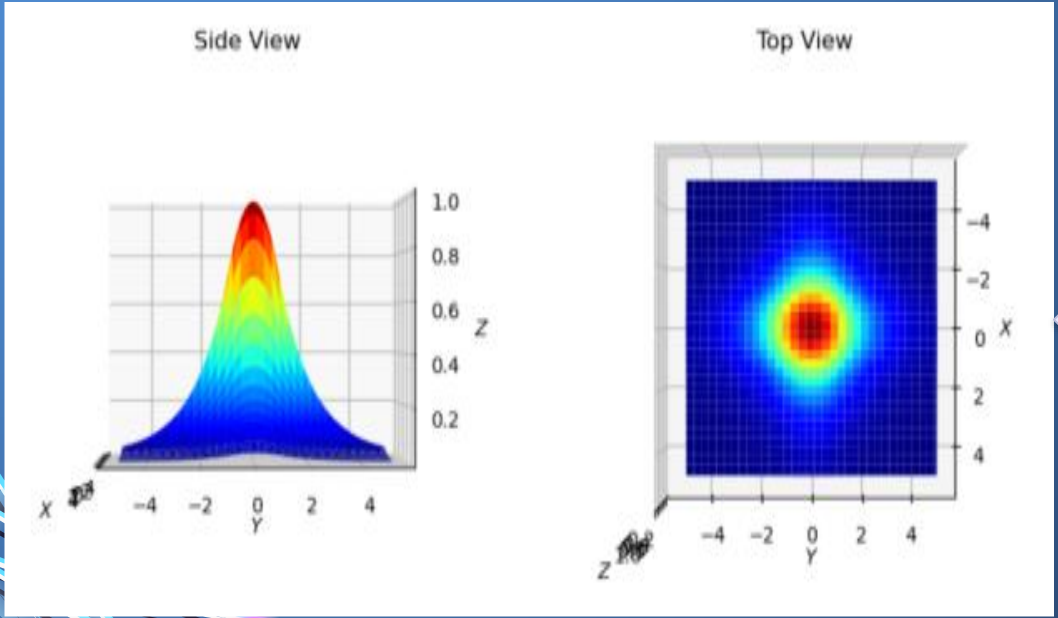
NORMALIZED PROPAGATION CONSTANT VS NORMALIZED FREQUENCY FOR DIFFERENT METHODS



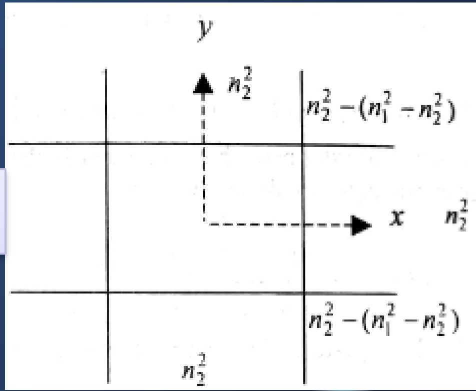
Variation of normalized propagation constant B with normalized frequency V for aspect ratio $a/_b = 2$ for a homogenous channel waveguide with $n_1 = 1.49$ and $n_2 = 1.48$. Comparisons with other methods .

MODAL ANALYSIS OF RECTANGULAR WAVEGUIDE USING VOPT :

We solved for following parameters (using a = 2μm, b = 1μm, n_1= 1.49 , n_2= 1.48 and λ = 1.5μm) and got the following field distribution using python programming language .

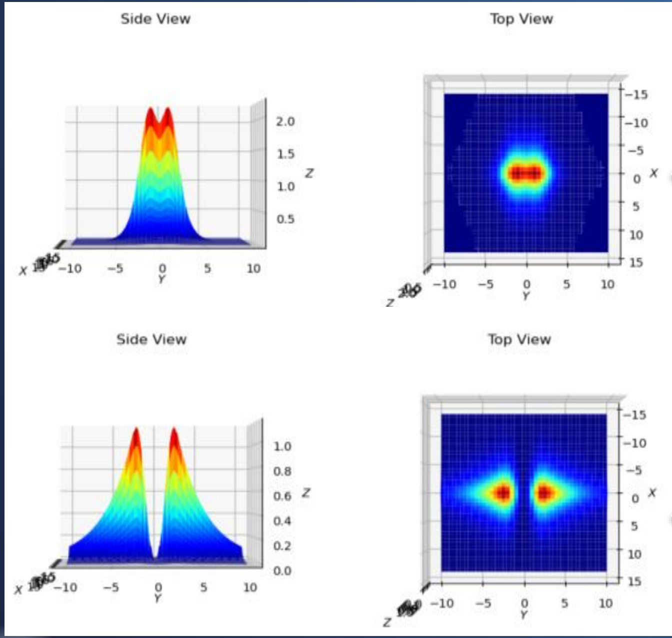


FUNDAMENTAL MODE

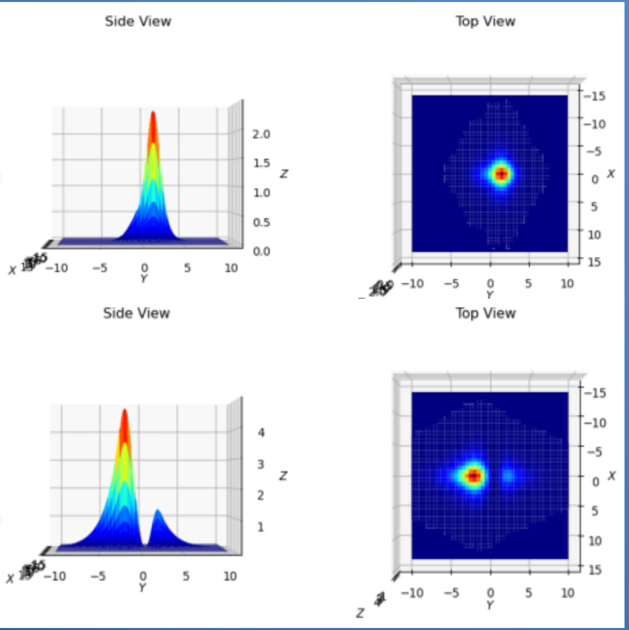


APPLICATION OF RECTANGULAR WAVEGUIDES

POWER DISTRIBUTION IN IDENTICAL DIRECTIONAL COUPLER



POWER DISTRIBUTION IN NON IDENTICAL DIRECTIONAL COUPLER

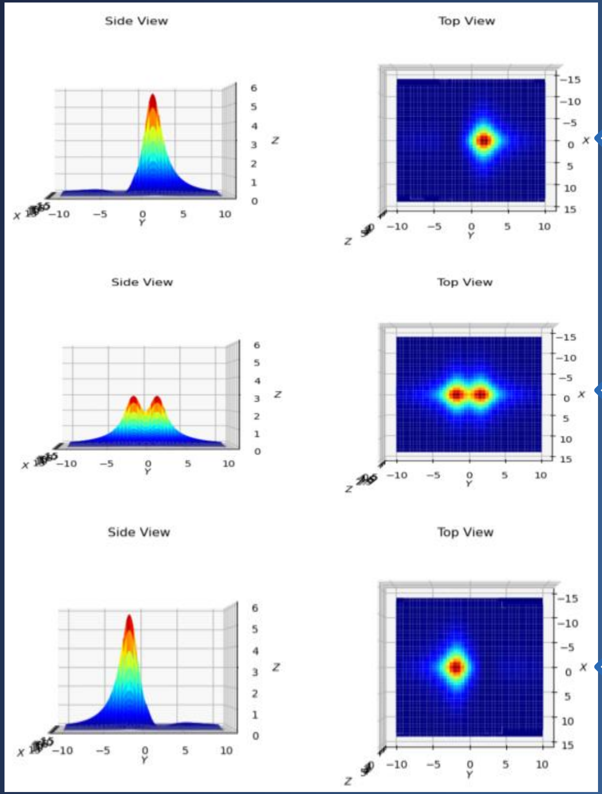


P.D IN SYMMETRIC MODE

P.D IN ANTISYMMETRIC MODE

POWER DISTRIBUTION AT DIFFERENT LONGITUDINAL LENGTHS

IDENTICAL DIRECTIONAL COUPLER

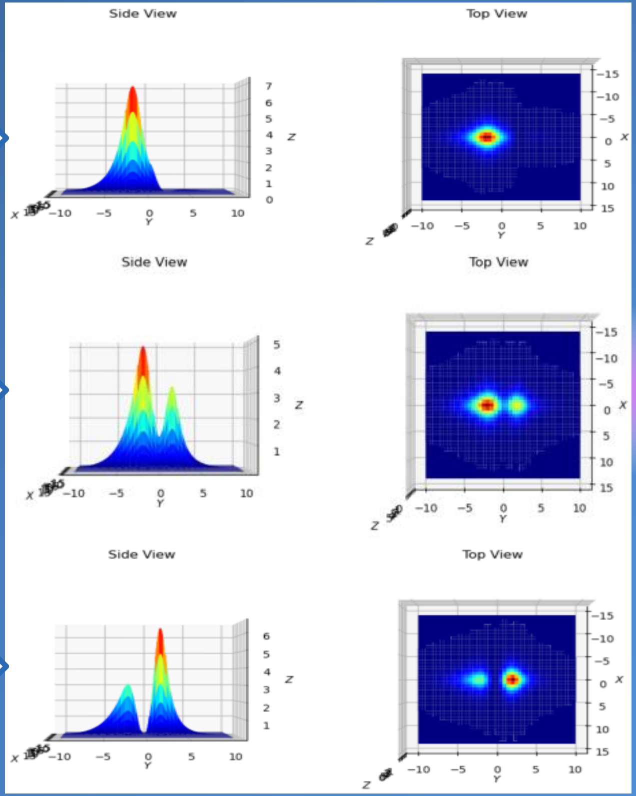


POWER DISTRIBUTION AT Z = 0

POWER DISTRIBUTION AT Z = $L_c/2$

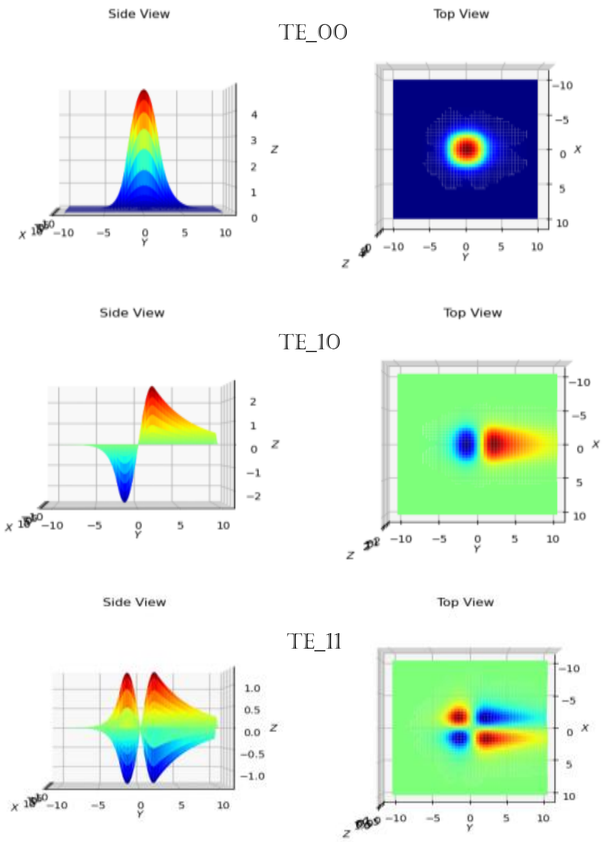
POWER DISTRIBUTION AT Z = L_c

NON-IDENTICAL DIRECTIONAL COUPLER

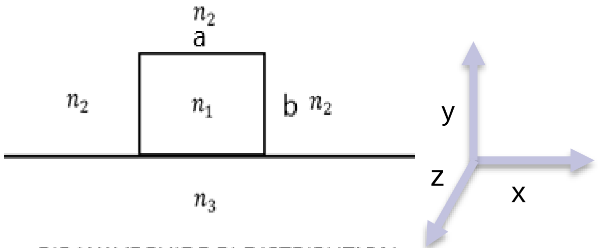


MODES OF A RIB WAVEGUIDE : Here we used VOPT method discussed above ,

We solved for following parameters (using a = 2µm, b = 1µm, n_1= 1.49 , n_2= 1 , n_3= 1.48 and λ = 1.5µm) and got the following field distribution using julia programming language .



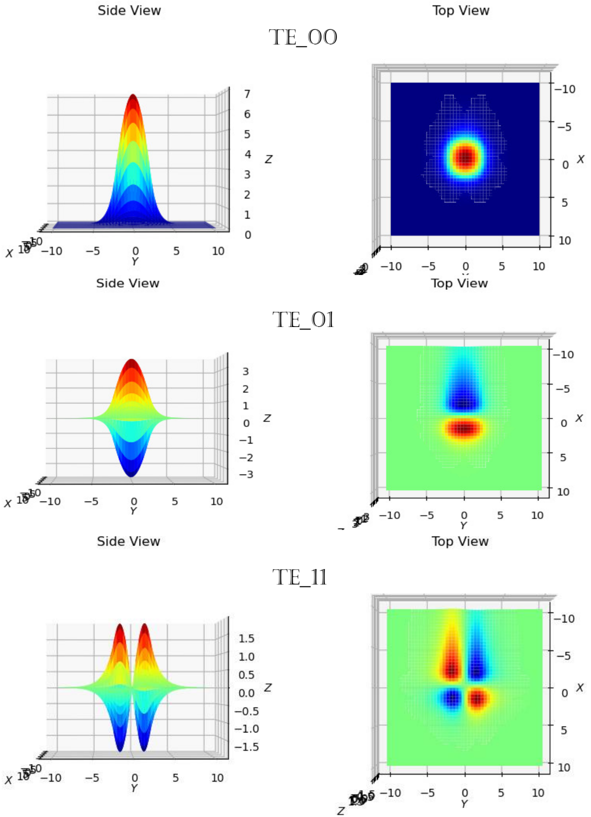
DIFFERENT MODES



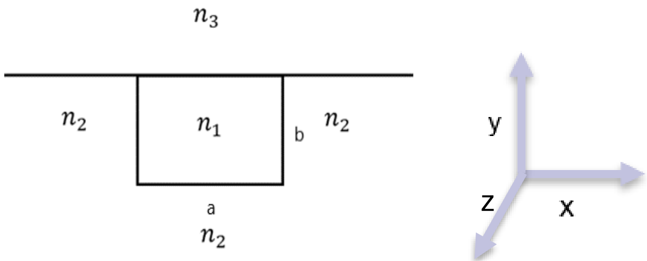
RIB WAVEGUIDE RI DISTRIBUTION

MODES OF AN EMBOSSED WAVEGUIDE : Here we used VOPT method discussed above ,

We solved for following parameters (using a = 2µm, b = 1µm, n_1 = 1.49 , n_2 = 1.48, n_3 = 1 and λ = 1.5µm) and got the following field distribution using julia programming language .



DIFFERENT MODES



EMBOSSED WAVEGUIDE RI DISTRIBUTION

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SCOPE FOR FUTURE WORK

Telecommunications : **In fiber-optic communication systems, optical waveguides are frequently employed to carry data over great distances. Networks for communications could become faster and more effective as a result of developments in waveguide design and fabrication .**

Optical Sensors : **In order to detect changes in the environment, such as those in temperature, pressure, or chemical composition, waveguides can be utilized as sensitive sensors. More precise and sensitive sensors for a number of applications may be made possible by advancements in waveguide design.**

REFFERENCES

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III. Sharma and S. Barai. Improved optimal variational method to analyze optical rib waveguides. Optics communications, 271:81–86, 03 2007 .

THANKS !