ANALYSIS OF RIDGE AND BURIED OPTICAL WAVEGUIDE USING FDTD METHOD FOR BACKBONE OPTICAL COMMUNICATION

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Abstract

Optical waveguide is the fundamental element that interconnects the various devices of an optical integrated circuit. In this paper, the propagation characteristics of ridge and buried waveguides have been investigated on light intensity distribution within the structure. The analysis has been done by varying the thickness and also the width of both ridge and buried optical waveguide. The normalized propagation constant and effective refractive index conditions have been simulated in order to find the most suitable optical waveguide for backbone optical communication. The analysis and results are analyzed using numerical method based on finite difference method approach.

Index Terms: *buried, ridge, optical waveguide, light intensity.*

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1. INTRODUCTION

An optical waveguide is a physical structure that guides electromagnetic waves in the optical spectrum. Optical waveguide consists of a core, in which light is confined and a cladding or substrate surrounding the core [1]. Waveguides used at optical frequencies are typically dielectric waveguides, structure in which a dielectric material with high permittivity and high refraction index surrounded by a material with lower permittivity [2].

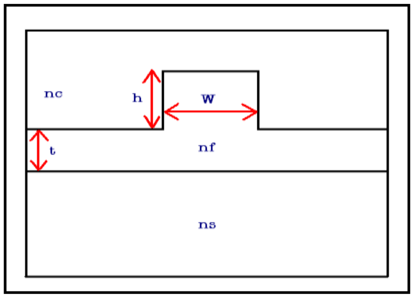


Figure 1: Schematic diagram of ridge waveguide

The properties of the guided waves are generally obtained through the properties of the modes of simple waveguide structures. The ridge waveguide consists of a core region that surrounded by a finite cladding [3].

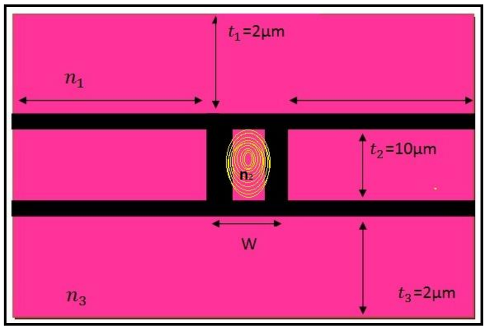
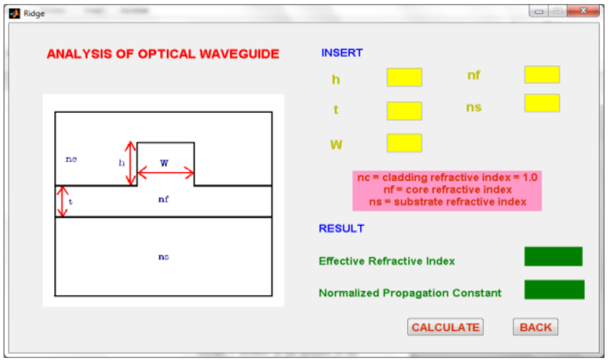


Figure 2: Structure of buried waveguide

Buried square waveguide channel have three refractive index which are n_1 is the upper cladding, n_2 is the core and n_3 is the lower cladding. Meanwhile t_1 represent the upper cladding thickness, t_2 is the core thickness and t_3 is the lower cladding thickness.

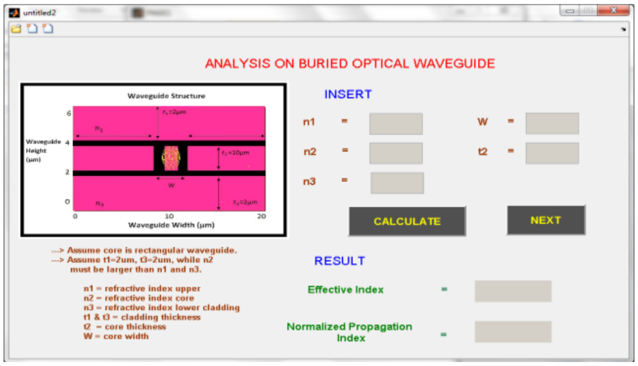
2. PROGAM DEVELOPMENT

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning and allow solving many technical computing problems, especially for matrix and vector formulations. A GUI (graphical user interface) allows user to perform tasks interactively through controls such as buttons and sliders [5].



nc = cladding refractive index = 1.0
nf = core refractive index
ns = substrate refractive index

Figure 3(b): Calculation part of ridge waveguide



---> Assume core is rectangular waveguide.
---> Assume t1=2um, t3=2um, while n2 must be larger than n1 and n3.

n1 = refractive index upper
n2 = refractive index core
n3 = refractive index lower cladding
t1 & t3 = cladding thickness
t2 = core thickness
W = core width

Figure 3(c): Calculation part of buried waveguide

3. RESULTS AND ANALYSIS

A. Ridge Optical Waveguide

Effects on thickness, t

Core refractive index (GaAS) =3.44 and substrate refractive index (GaAIAs) =3.36.

Guide types	t (µm)	h (µm)	w (µm)	n_{eff}	β
a	0.0	1.0	3	3.39475	0.431529
b	0.2	0.8	3	3.39509	0.435701
c	0.4	0.6	3	3.39578	0.444378
d	0.6	0.4	3	3.39695	0.458951
e	0.8	0.2	3	3.39865	0.480146
f	1.0	0.0	3	3.40091	0.508453

Table 1: Comparison with different structure waveguide with varies thickness

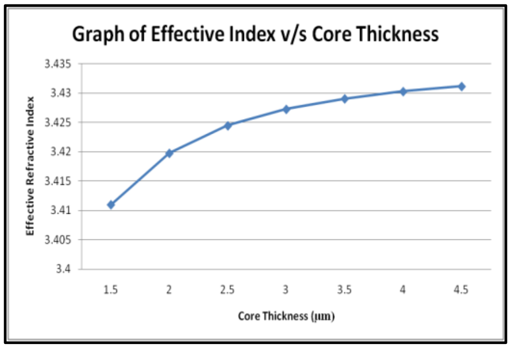


Figure 4: Graph of Effective Index vs. Core Thickness

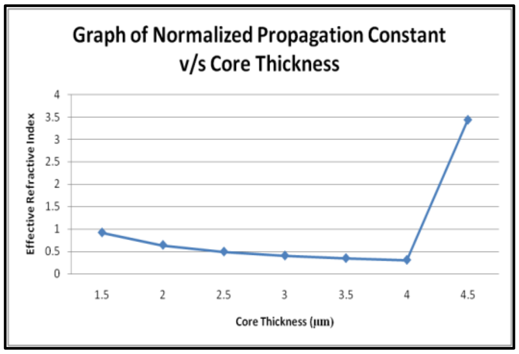


Figure 5: Graph of Normalized Propagation Constant vs. Core Thickness

From table 1, the values of normalized propagation constant, b increases as the thickness of the waveguide are increase. For the effective refractive index, as the thickness of the waveguide increases, the effective refractive index also increases slightly. Since the effective refractive index values are in range of in between the core refractive index and substrate refractive index, it is proving that it is in guided mode.

Effects on width, W

Core refractive index (GaAS) =3.44 and substrate refractive index (GaAIAs) =3.36.

Guide types	w (µm)	n_{eff}	β
g	1.5	3.37400	0.173339
h	2.0	3.38558	0.317167
i	2.5	3.39149	0.390790
j	3.0	3.39488	0.433166
k	3.5	3.39701	0.459717
l	4.0	3.39843	0.477431
m	4.5	3.39942	0.489824

Table 2: Results for different width of the core ridge

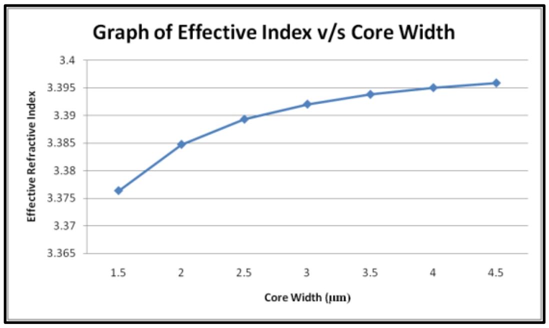


Figure 6: Graph of Effective Index vs. Core Width

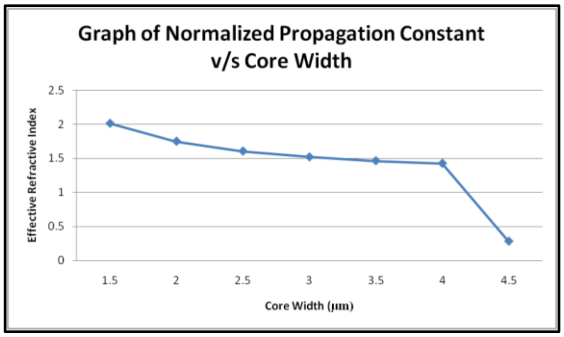


Figure 7: Graph of Normalized Propagation Constant vs. Core Width

From the analysis, the values of normalized propagation constant, b increases as the width of the waveguide are increase. For the effective refractive index, as the width of the waveguide increases, the effective refractive index also increases slightly also. So, the structures working in single mode for all the seven different waveguide analyzed.

Difference on material, core and refractive index
Top cladding air = 1, w=3µm, h = 0.5µm, t = 0.5µm

Structure	nf	ns	neff	β
BT1	**3.44 (GaAS)**	**3.36 (GaAIAs)**	**3.39630**	**0.450870**
BT2	**3.38 (InGaASP)**	**3.17 (InP)**	**3.32554**	**0.734485**

Table 3: Different core and substrate refractive index

From the results above, the BT2 structure waveguide have lower effective refractive index compare the BT1, and also have higher normalized propagation constant. Thus, the structure BT2 is better than BT1 in term of propagation mode of converge fielded into the core which gives excellent waveguide property.

B. Buried Optical Waveguide

Effect on core thickness, t_2
Upper cladding thickness, $t_1 = 2\mu m$
Lower cladding thickness, $t_3 = 2\mu m$
Core width, $W = 3\mu m$
Upper refractive index for cladding, $n_1 = 3.34$
Core refractive index, $n_2 = 3.44$
Lower refractive index for cladding, $n_3 = 3.34$
Wavelength, $\lambda = 1550\mu m$

Guide	Core thickness, t2 (µm)	Effective refractive index neff	Normalized propagation index, b
a	1.5	3.41098	0.921135
b	2.0	3.41975	0.643743
c	2.5	3.42445	0.494604
d	3.0	3.42725	0.405627
e	3.5	3.42905	0.348399
F	4.0	3.43028	0.309458
G	4.5	3.43115	0.281776

Table 4: Comparison with different structure when varies thickness

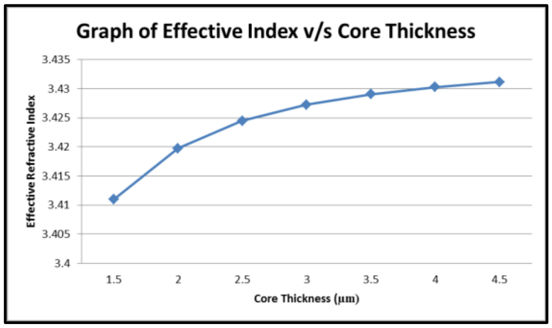


Figure 8: Graph of effective index vs. core thickness

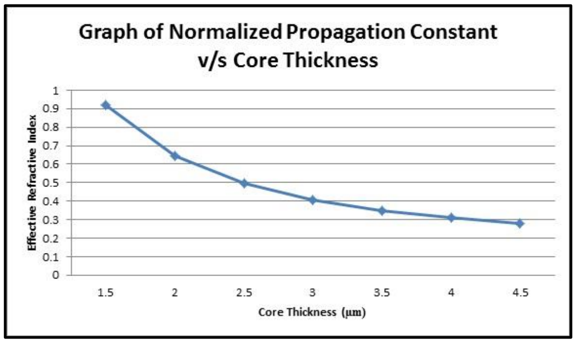


Figure 9: Graph of normalized propagation constant vs. core thickness

The core thickness is directly proportional to effective refractive index, meaning the higher the value of core thickness, the higher the effective refractive index. On the other hand, the normalized propagation index is inversely proportional to the core thickness. The higher the values of core thickness the lower the normalized propagation indexes.It can be seen from table 4thatthe values of the effective refractive indexes are around 3.4, the waveguide can be labeled as a guided mode waveguide (3.36 $<n_{eff}<$ 3.44). Therefore it has less losses and it is strongly optical confinement.

As the core thickness increases the Electrical field distribution decreases. This is because when the core thickness is small, most of the light is propagated through the center. This also explains why the contour lines are so close to each other at lower core thickness.

Effect of core width, W

All the parameters are kept the same except instead of varying the core thickness, we keep it constant, at t_2 = 1μm

Guide	Core width, w(μm)	Effective refractive index, n_{eff}	Normalized propagation index, b
A	1.5	3.37634	2.01055
B	2.0	3.38474	1.74756
C	2.5	3.38931	1.6041
D	3.0	3.39205	1.51784
E	3.5	3.39383	1.46208
F	4.0	3.39504	1.424
G	4.5	3.3959	1.39686

Table 5: Comparison with different structure when varies core width

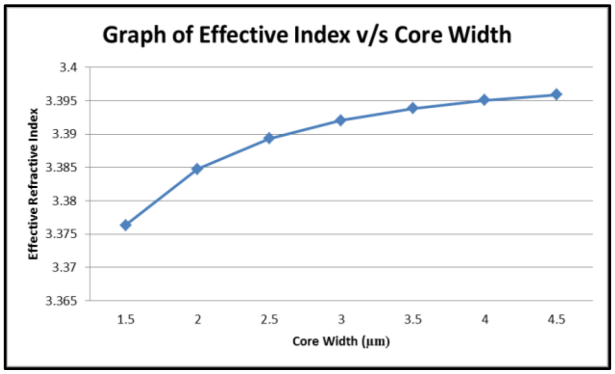


Figure 10: Graph of effective index vs. core width

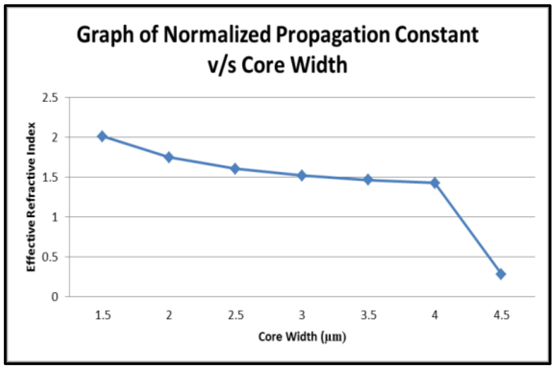


Figure 11: Graph of normalized propagation constant vs. core width

The core width is directly proportional to effective refractive index, meaning the higher the value of core thickness, the higher the effective refractive index. On the other hand, the normalized propagation index is inversely proportional to the core width. The higher the values of core width the lower the normalized propagation indexes.From table 5, the values of the effective refractive indexes are around 3.4, the waveguide can be labeled as a guided mode waveguide (3.36 $<n_{eff}<$ 3.44). Therefore it has less losses and it is strongly optical confinement.As the core width increases, the Electrical field distribution decreases. This is because when the core width is small, most of the light is propagated through the center. This also explains why the contour lines are so close to each other at lower core thickness.

3. CONCLUSION

The finite difference method is one of the methods that can used to study about electric field distribution. Based on this method, the constant value of refractive index for core and cladding waveguide are used to determine the propagation loss on straight waveguide. The varied parameters are core thickness and width waveguide. All these parameters will affect the value of effective refractive index and the value of normalized propagation constant. The small difference refractive index among core and cladding can give better performance of electromagnetic field pattern. So, electric field energy will radiate into core region and the single mode can propagate inside the waveguide. On the other hand, the normalized propagation constant b is more sensitivity than the value of β and that the reason normalized propagation constant b is always adopted to investigate this type of waveguide.

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BIOGRAPHIES

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