High Power efficiency in optical logic X-OR gate structure

Mutmainnah [1)] & Yono Hadi Pramono [2)]
[1]Physics Department, Faculty of Mathematics and Natural Sciences, University of Jember
[2]Physics Department, Faculty of Mathematics and Natural Sciences,
Sepuluh Nopember Technology Institute

ABSTRACT

A High Power Efficiency of Optical Waveguide for Logic X-OR gate has been investigated numerically by means of FD-BPM (Finite Difference Beam Propagation Method). The proposed structure is designed by using of three Y-branches. Two of Y-branches structure is parallel combined in the input section and the other one is located with the opposite direction of the output section. The whole guiding structure is called 2x3 channel which having two-input ports and three-output ports. One of the gap between three output arms in the cladding region is assumed to be a nonlinear materials which will produce the phase shifting between its output optical fields. The magnitude of phase shifting is depending on the nonlinearity of material and the optical input power. Y-branch leg angle is also a significant parameter to increase efficiency of optical power switch. The numerical schemes showed that the proposed structure is suitable for optical switching especially for logic X-OR gate.

Keywords: Cladding, nonlinear, optical switching, gate, FD-BPM

INTRODUCTION

All-optical switches and gates structure have recently become serious topics of research (Pramono *et al.* 1996, 1999, 2001). The prototype of optical logic X-OR gate structure was investigated (Mutmainah & Pramono 2006). This prototype is still possible to be redesigned in order to increase its efficiency of the optical output power by variation of Y-branch leg angle. We still employ the FD-BPM (Chung & Dagli 1990) to analyze its beam propagation and output power. The proposed structure is designed by using of three Y-branches. Two of Y-branches structure are combined parallel in the input section and the other one is located with the opposite direction in the output section. The whole guiding structure is called 2x3 channel which having two-input ports and three-output ports with an identical film thickness. One of the gap between three output arms in the cladding region is assumed to be a Kerr-like nonlinear material, is embedded in a homogenous linear material. This part of nonlinear material region by change of optical input power will produce the phase shifting between its output optical fields. The magnitude of phase shifting is depending on the nonlinearity of material and the optical input power. Y-branch leg angle is also a significant parameter to increase their efficiencies of optical output switch. How the numerical schemes showing the agreement results for X-OR gate with high efficiency will be discussed detail in the following. We wish the proposed 2x3 structure can be favorable to apply in the OEIC (OptoElectronics Integrated Circuit) for any logical data processor.

METHODS

The Fixed parameters of 2x3 channels as in Figure.1 are the wavelength λ = 0.51545 m (LASER Ar+), refractive indices nfl =1.552 and nc =1.550, nonlinear coefficient α=6.377x10-12 m2/V2 (Liquid crystal MBBA), single –mode supporting film thicknesses w1=w2= w3=w4=w5= 2,0 μm and multimode Y branch leg film thicknesses w6=w7= 4 μm at the present wavelength, waveguides lengths l1=1330μm , l2= 4000μm in the input section, and l3 =2000μm , l4=800μm in the output section. Y-branch leg angle is θ= 0.0859o. The propagation constant of the TEo mode in the input port is calculated as β/ko =1,55087373 (ko =free space wave number) when w =2.0 and α =0. We carry out the BPM analysis in the region lxl< xmax(=25 μm) with calculating grids of homogeneous intervals Δx = 0,05μm and Δz =1.0 μm in the propagation direction.

The input power is evaluated by using integral of electrical fields resulted by the process of iterating in all x-axis in the device region, and the output power is evaluated from width of each three-channels (Pramono. et al 1996). In this case of X-OR gate, the efficiency η is calculated only from the output power maximum ("1" state) of port 4 related to the given input power as follows:

η= (P4/ Pin) x 100% ……………(1)

where: P4 = output power from port 4
Pin = input power

RESULTS AND DISCUSSION

The characteristics of the output power P4 as a function of both input power channels should be identified first. The logical X-OR gates need input "1" and "1" states should be a "0" state in the output. Furthermore, we must find the threshold of the given input power where P4 begining drop to zero. As shown in Figure 2 that the threshold input power is about 8 W/m. This value gives a significant meaning that interaction between nonlinear material and the input power begin to happen.

As known well in the wave interference theory that if one of the phases between two optical waves is affected or shifted, then the superposition event will be destructive. If the phase different 1800, it becomes a maximum destruction, as seen on the input power would be set 8,2 W/m.

Figure 3 shows the wave propagation when the input power for both port 1 and port 2 is about 8.2 W/m. As the above mention when the input power is about more than 8 W/m, Kerr-like nonlinear self-focusing phenomenon could change the profile refractive index in the cladding region. Hence, the profile electric field shown by refractive index matching is also changed in their phase to be 1800 with the electric field in the other arm. After such length of propagation in the output channel, superposition of these electric fields resulted in a destructive field for each other, which means no field distribution exist in the output port 4.

Figure 4 and Figure 5 show the waves propagation in the 2x3 structure when the input power 8.2W/m is launched into one side of input port 1 or 2 respectively. In these cases the nonlinear effect gives the contribution in a few losses only in the cladding region, nothing any significant perturbation would be occured.

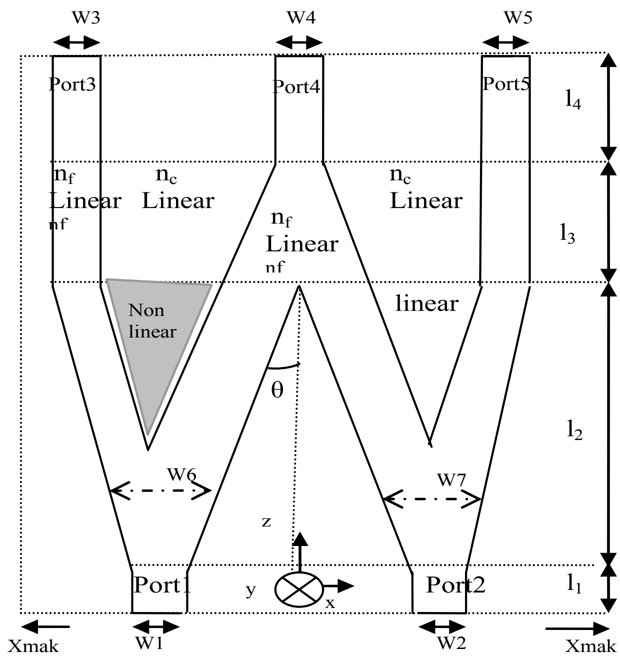

Figure 1. A 2x3 Structure waveguide with intersecting nonlinear material in cladding region.

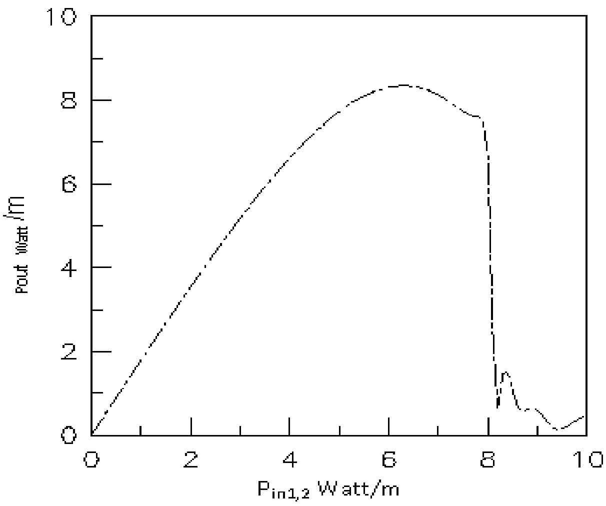

Figure 2. Characteristics of power output as input power function.

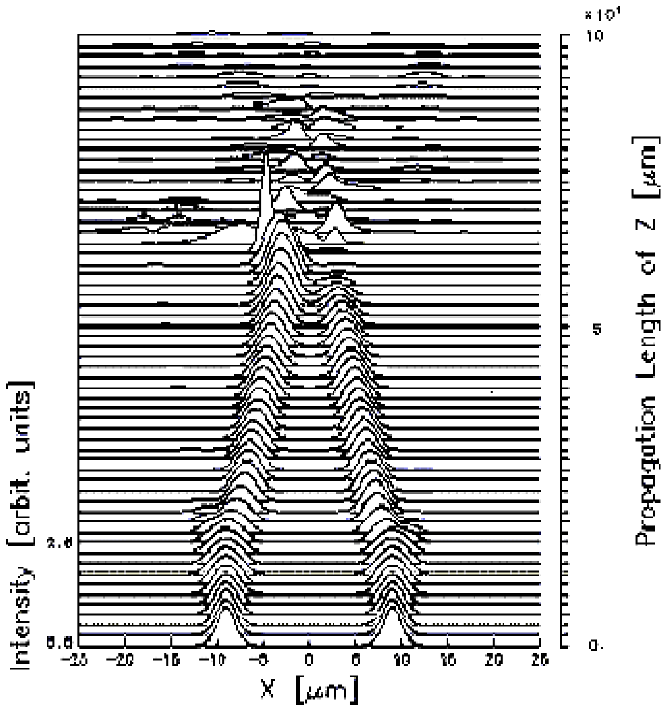

Figure 3. Scheme of intensity propagation when input power 8.2W/m from both port 1 and 2.

This fact was happened because the electric field which propagating inside Y-branch structure (note: opposite direction in the output section) only be excited and trapped in a larger arm of Y-branch in the output section. Hence, there is no reason to obtained phenomena of superposition of the electric field in this region. In other words, the inserting nonlinear material in the cladding region have not enough received minimum intensities from the input port in order to attain Kerr-like effect. On the other hand, the electric field will propagate finely without any perturbation into port 4.

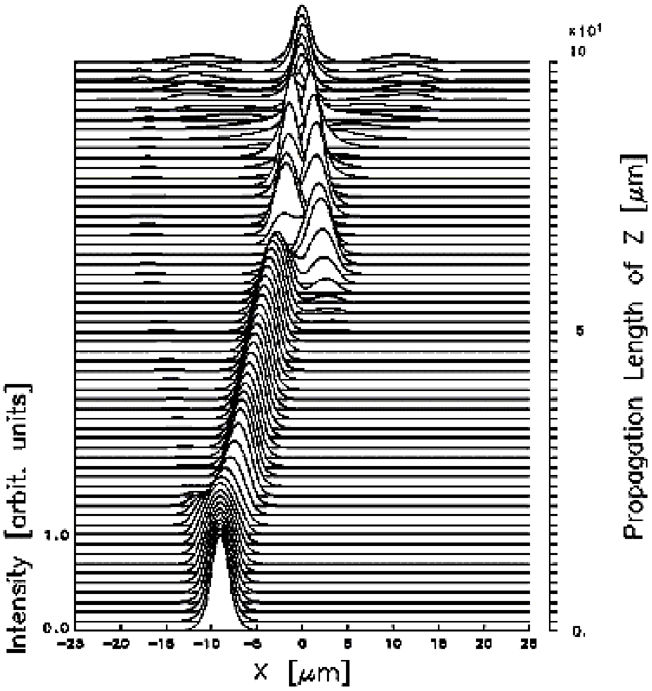

Figure 4. Scheme of intensity propagation when input power 8.2W/m from port 1.

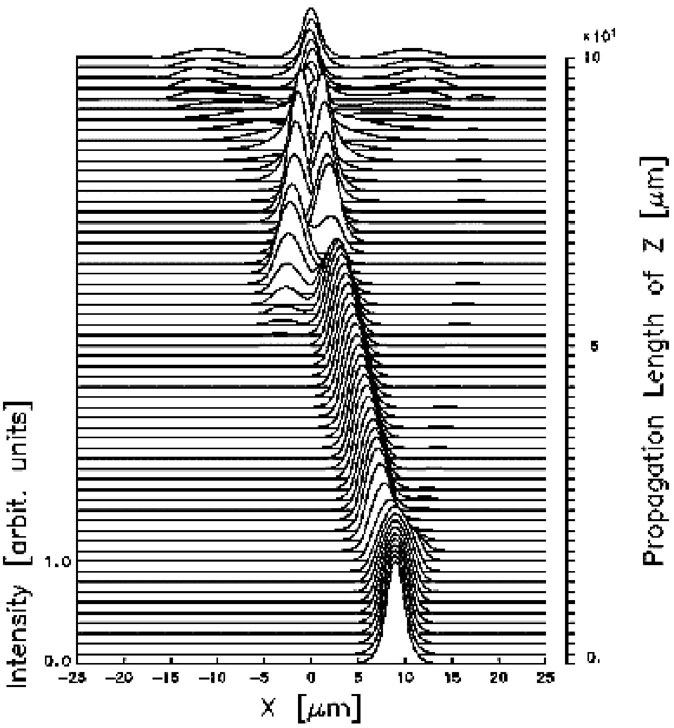

Figure 5. Scheme of intensity propagation when input power 8.2W/m from port 2.

Table 1. The Result On-Off and output power of X-OR Gate.

Port 1	Port 2	Port 4	
		State	Output power(W/m)
0	1	1	4.117
1	0	1	4.217
1	1	0	0.657
0	0	0	0

The propagation length of DC (Directional Coupler) in the output section also influences the condition of the power efficiency for port 4, the longer DC will decrease the efficiency but in this length we found the intensity more focused at the center of guiding port 4. The shorter of the length DC indicates that the maximum intensity is still focused on the right and the left inside port 4 which gives unfortunately in its phase when this device is arranged to be connected to other system in OEIC. Table 1 gives a resume of all results of the proposed 2x3 structure. The output port 4 is considered to be an output port of the logic X-OR gate with four states of the input power. The output power is calculated in W/m can be used to estimate the efficiency of output power.

We employ equation 1 to evaluate the power efficiency. The present efficiency η is about 50.2% for state “1” which indicate that the proposed 2x3 structure has higher in its efficiency than the first prototype of X-OR gate structure by changing parameter of the angle and the width of Y-branch (Mutmainnah & Pramono 2006).

CONCLUSION

We have proposed a 2x3 channel waveguide consisting apart of nonlinear material in the cladding for optical logic X-OR gate. We have shown the schemes of the propagation fields by FD-BPM. The characteristics of output power and its efficiency are in a good agreement for optical switches and optical signal processing.

REFERENCES

Chung Y & Dagli N. 1990. An Assessment of Finite Difference Beam Propagation Method. *IEEE J.Quantum Electron* **8**: 1335-1339.

Mutmainnah & Pramono YH. 2006. Characteristic Of Waveguide Optical by Array and Y-branch Model which Consisting Of Nonlinear Material In The Cladding For Optical Logic X-OR Gate. *Jurnal Ilmu Dasar* **7**:13-18.

Pramono YH, Geshiro M, Sawa S. 1996. Analisys of a Nonlinear 2x3 Intersecting Waveguide by a Finite Difference Methode. *Proc. Int. Symp. Antennas and Prop*. **3**:653-656.

Pramono YH, Geshiro M. Kitamura T, Sawa S. 1999. Self-switching in Crossing Waveguide With Three Chanel Consiting of Nonlinear Materia*l*. *IEICE Trans. Electron* **1**:111-118

Pramono YH & Endarko. 2001. Nonlinear Waveguides For Optical Logic And Computation. *Journal of Nonlinear Optical Physics & Materials*. **2**: 209-222