# CROSSTALK EFFECT IN THE CASE OF THREE MONOMODE PLAN WAVE GUIDES

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**Abstract.** In this paper, we examined the crosstalk effect in the case of three monomode propagating wave in three plan wave guides.

On the basis of solving propagating wave equations, we have received the influence of structure parameter as the refractive index difference, the lengths of propagating waves, the diameter of wave guides, the separated distance between two adjacent wave guides etc... on the crosstalk effect.

Key words: wave guides optics, optical communication.

## 1. Introduction

Since the nineties of last century, mankind has gone into the period of info-break out. By the technique WDM, one can obtain a large gigabit at far interval of optical transmission line. However, one of the defects in this multicanal communication is the exhibition of crosstalk effect - the power exchange between the two waves propagating in two adjacent canals. This phenomenon results in the noise of information which needed exclude.

The crosstalk effect has been studied in the case of two adjacent canals that may be considered as two plan wave guides [1-4]

In this paper, we have enlarged the research to the case three adjacent plan wave guides. On the basis of resolving the propagating wave equations presented in section 2, we have made a study of the influence of structure parameters of wave guides as the different of refractive index, the length of propagating wave, the diameter of wave guide etc... on the crosstalk interval - a characteristic quantity of crosstalk effect. These research's results have been indicated in section 3. At last, discussion and conclusions have given in section 4.

## 2. Basic equations

We supposed there are three plan wave guides in which the plan waves propagate following the 0z direction as seen in fig 1

These wave guides have the widths of $l_1$, $l_2$, $l_3$, the refractive index $n_1$, $n_2$, $n_3$ and separating distances of $d_1$, $d_2$.

The propagating waves have forms:

$$E_1(y,z) = a_1 u_1(y) e^{-j\beta_1 z} \tag{1}$$

$$E_2(y,z) = a_2 u_2(y) e^{-j\beta_2 z} \tag{2}$$

$$E_3(y,z) = a_3 u_3(y) e^{-j\beta_3 z} \tag{3}$$

Here $a_1$, $a_2$, $a_3$ – constants, $\beta_1$, $\beta_2$, $\beta_3$ - propagation constants, $u_1(y)$, $u_2(y)$, $u_3(y)$ – amplitude functions of waves.

When the power exchange between the wave guides appeared, constants $a_i$ become functions slowly changed by $z$.

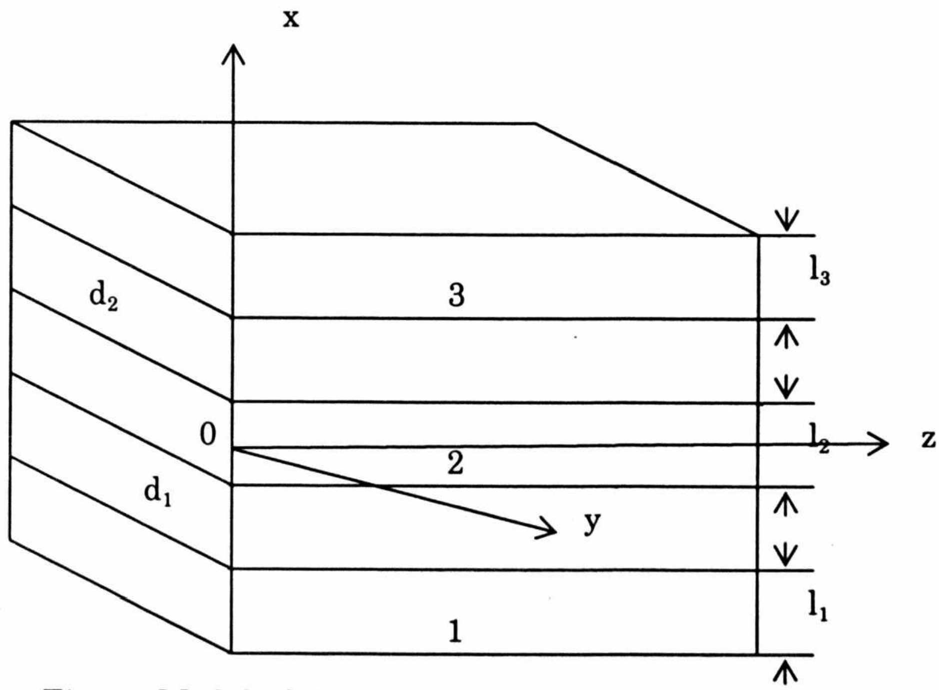


*Fig. 1* . Model of three monomode plan wave guides.

The Helmholtz equation for each wave, in this case, has the following form:

$$\nabla^2 E_i + k_i^2 E_i = -S_m \qquad (i,m = 1,2,3) \tag{4}$$

Here the source $S_m$ demonstrates the field of one wave suffered the influence of the another wave. Following [1] we can give

$$S_m = (n_m^2 - n^2)k_0^2 E_m = (k_m^2 - k^2)E_m \tag{5}$$

With $k_0 = \dfrac{2\pi}{\lambda}$ - wave number, $\lambda$ - velocity of light in vacuum.

From (4), (5), we have the system of equations for three plan wave guides, as follows.

$$\nabla^2 E_1 + k_1^2 E_1 = -(k_2^2 - k^2)E_2 \tag{6}$$

$$\nabla^2 E_2 + k_2^2 E_2 = -\left[(k_3^2 - k^2)E_3 + (k_1^2 - k^2)E_1\right] \tag{7}$$

$$\nabla^2 E_3 + k_3^2 E_3 = -(k_2^2 - k^2)E_2 \tag{8}$$

Solving this system of equations after the approximation of neglecting $\dfrac{\partial^2 a_i}{\partial z^2}$ before $\dfrac{\partial a_i}{\partial z}$, we received a new system of equations:

$$\frac{da_1}{dz} = -jC_{21}a_2(z)e^{j\Delta\beta_1 z} \qquad (9)$$

$$\frac{da_3}{dz} = -jC_{23}a_2(z)e^{j\Delta\beta_3 z} \qquad (10)$$

$$\frac{da_2}{dz} = -jC_{12}a_1(z)e^{-j\Delta\beta_1 z} - jC_{32}a_3(z)e^{-j\Delta\beta_3 z} \qquad (11)$$

with

$$\Delta\beta_1 = \beta_1 - \beta_2, \Delta\beta_3 = \beta_3 - \beta_2$$

$$C_{21} = \frac{k_2^2 - k^2}{2\beta_1} \int_{-(l_1+d_1+\frac{l_2}{2})}^{-(\frac{l_2}{2}+d_1)} u_1(y)u_2(y)dy \qquad C_{12} = \frac{k_1^2 - k^2}{2\beta_2} \int_{-\frac{l_2}{2}}^{\frac{l_2}{2}} u_1(y)u_2(y)dy$$

$$C_{32} = \frac{k_3^2 - k^2}{2\beta_2} \int_{-\frac{l_2}{2}}^{\frac{l_2}{2}} u_3(y)u_2(y)dy \qquad C_{23} = \frac{k_2^2 - k^2}{2\beta_3} \int_{d_2+\frac{l_2}{2}}^{\frac{l_2}{2}+d_2+l_3} u_3(y)u_2(y)dy$$

This system is solved numerically for different cases, depending on the diverse forms of function $u_i(y)$.

## 3. The influence of structure parameter of wave guides on the crosstalk interval

***3.1 Definition***: Crosstalk interval $L_o$ is the interval determined since the transmission of light in one wave guide begins until the power exchange appears.

***3.2 Expression of function $u_i(y)$ and values of parameter***. We take for function $u_i(y)$ the following expressions

$$u_1(y) = Ae^{-\delta_1 y}; u_2(y) = Be^{-\delta_2 y}; u_3(y) = Ce^{-\delta_3 y} \qquad (12)$$

where $A = C = 1$, $B = 1$, $\delta_1 = \delta_3 = 1, \delta_2 = 2$.

Numerical values of parameters are chosen

$$\lambda_1 = \lambda_2 = \lambda_3 = 133\mu m, a_1 = a_2 = a_3 = 1\mu m, d_1 = d_2 = d_3 = 10^{-4} m$$
$$n_1 = n_2 = n_3 = 1.5; n = 1.4999$$

***3.3 The influence of refractive index difference on $L_0$***

Using Matlab language and starting from (9) - (12), we plotted the curves $|a_i(z)|^2$ versus z. In fig.2, are presented the curves $|a_i(z)|^2$ when $\Delta n = (n_1 - n) = (n_2 - n) = (n_3 - n)$ varies.

From figure 2 and table 1, one can see that the diminution of $\Delta n$ results in the increase of $L_0$.

**Table 1**

| $\Delta n$ | 0.01 | 0.001 | 0.0001 |
|---|---|---|---|
| $L_0$(m) | 23.585 | 235.136 | 2350.8 |

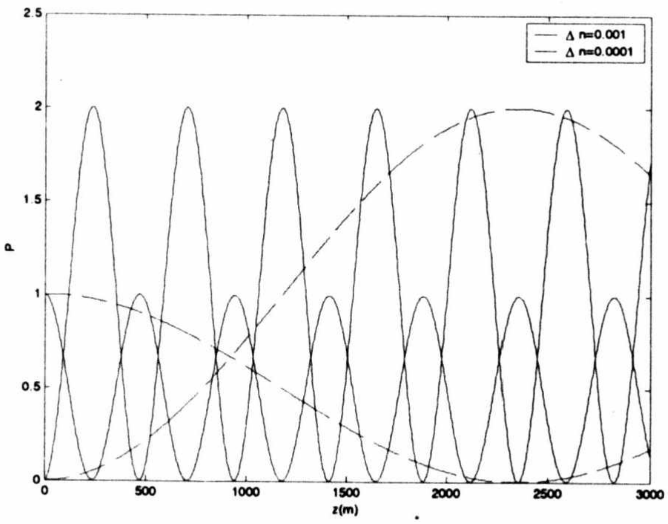


*Fig.2.* The diagram allows to determine the dependence of $L_0$ on $\Delta n$

### *3.4 The dependence of $L_0$ on separating distance $d_1$, $d_2$*

By the same method of calculation with all other parameters remaining unchanged but $d_i$ varies, we obtained fig.3 and table 2

**Table 2**

| $d_1$=$d_2$(m) | $10^{-5}$ | $10^{-4}$ | $10^{-3}$ | $10^{-2}$ |
|---|---|---|---|---|
| $L_0$(m) | 2351.2 | 2350.8 | 2353 | 2369.6 |

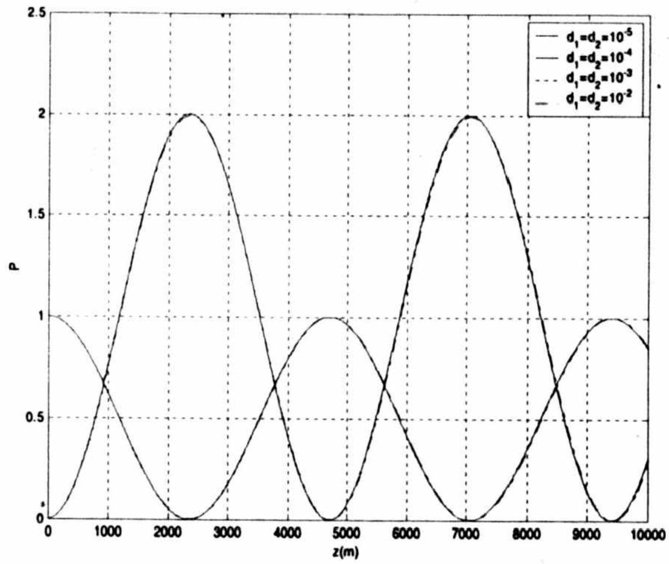


*Fig. 3.* The diagram allows to determine the dependence of $_0$ on $d_1$, $d_2$

The received results show that $L_0$ is almost unchanged when $d_1$ varies.

### *3.5 The influence of wave length on $L_0$*

In this case, we varied only the length of $\lambda_i$. The results from fig.4 and table 3 indicate that the increase of $\lambda_i$ will lead to in the augmentation of $L_0$ i.e. the crosstalk effect will diminish at longer wave lengths.

**Table 3**

| $\lambda$ (μm) | 1.08 | 1.33 | 1.55 |
|---|---|---|---|
| $L_0$(m) | 1909.1 | 2350.8 | 2739.4 |

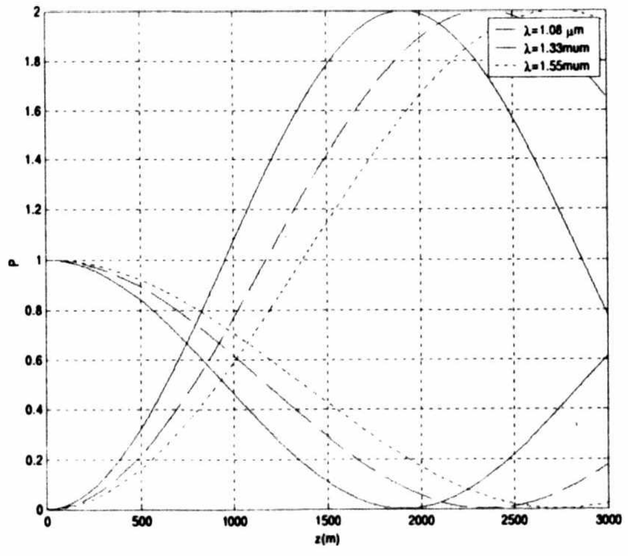


*Fig. 4.* The diagram allows to determine the dependence of $L_0$ on $\lambda$.

### *3.6 The charge of $L_0$ when amplitude of wave varies*

When the amplitude B of wave propagating in the second wave guide is varied, we obtained fig 5 and table 4.

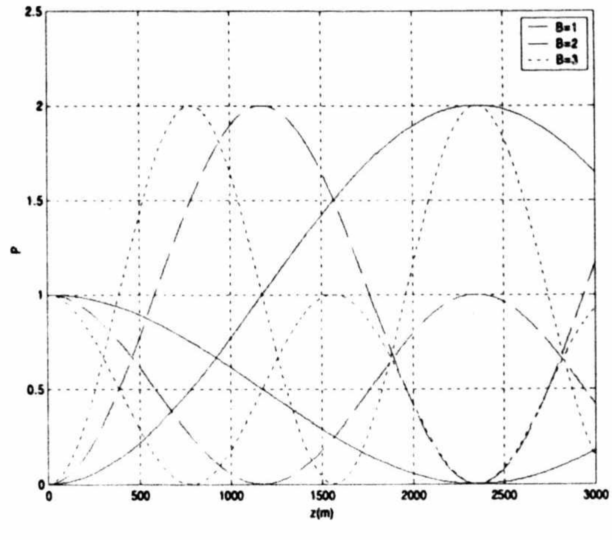


*Fig. 5.* The diagram allows to determine the dependence of $L_0$ on B

**Table 4**

| B | 1 | 2 | 3 |
|---|---|---|---|
| $L_0$(m) | 4707.5 | 2350.8 | 1567.2 |

From fig 5 and table 4, $L_0$ decreases by increasing $B$. This shows that the strong interaction between the waves propagating in 3 wave guides results in the increase of crosstalk effect.

## 4. Discussion and conclusions

From obtained results presented above, we could reveal some following conclusions:

- The crosstalk effect depends clearly on the change in the structure parameters of wave guides. The most sensitive parameters which diminish the influence of crosstalk effect are refractive index difference $\Delta n$ and wave length $\lambda_i$ propagating in wave guides.

- The distribution of amplitude functions $u_i$ can create the transformation of crosstalk effect. The obtained results also indicate that different wave functions will give diverse crosstalk effect and this point needs to be further examined.

- The method of calculation used in this paper may be applied to the case of more than 3 wave guides or the case of multimode wave guides.

## Reference:

1. A.Yariv, *Quantum Electronics Third Edition*, John Wiley & Sons, N.Y. 1988
2. H.Huang, *Couple Mode Theory as applied to Microwave and Optical Transmission*, Netherlands 1984.
3. T. Tamir, *Guided Wave Optoelectronics*, Springer-Verlag N.Y. 1990
4. B.E.A Saleh, M.C *Teich, Fundamentals of photonics*, John Willey & Sons N.Y. 1991.