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Estimation of analytical model for enhancement and implementation of an electro-optic switch

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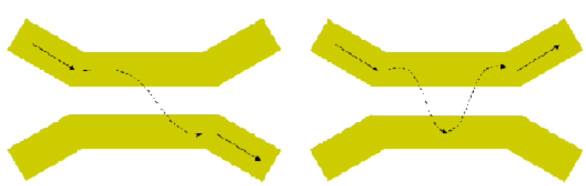
Abstract This research presents a technique of an electro optic effect for enhancement the an accomplishment of an electro optics switch using Mat lab simulation program . this technique includes design a mathematical model for evaluate the effect of different parameters such as refractive index (n), distance of separation between waveguides (d), length of electrodes (L), relative refractive index (Δn), and switching voltage (Vπ), on the DC bias voltage of an electro optics switch. In this work the investigation of performance of an electro optics switch by analysis of an effect of distance between waveguides and the changing of refractive index on the bias voltage (V), and which optimizes when the wavelength is from 1300 into 1550 nm. Finally, an electro-optic active switch is designed and optimized, using the analytical model and which considers important device in the modern optical communication system.

Key Words: Laser source, Electro optic switch, Optical Switch, Mach-Zehnder modulator

I. Introduction

Directional couplers can be utilized to make switches in the event that some component for changing the coupling length of the optical modes is presented. Normal strategies for hanging the coupling length are the thermo optic impact [1], charge infusion [1,2] [3], the electro-optic impact [1,4], X_3 non-linearity or mechanical tuning. with high hand the strategy for adjusting the optical parameters of the directional coupler, the fundamental operation continues as before. In one state - call it the Bar state - light couples from one waveguide to the next and back again some number, N, times and in the end is yield into the bar arm of the directional coupler (see Fig. 1)[1].



Cross state Bar state

Fig.(1): This figure shows the difference between the bar and cross states of a directional coupler

At the point when the coupling length is changed, the light never again is completely coupled to the bar state at the yield and rather has some bit of its energy coupled into the cross state. For a viable switch, the adjustment in coupling length brings about the majority of the power being coupled to either the bar or the cross state at the yield of the directional coupler. With a specific end goal to depict the operation of an optical switch, it should first appear for the system numerically. Symmetric coupled waveguides interchange optical power in a sinusoidal manner. Whether power is info onto stand out arm of the directional coupler, the optical power by every waveguide can be appeared for as follows [1]:

$$P_{bar} = P_O cos^2\left(\frac{\pi}{L_C} Z\right) \qquad (1)$$

$$P_{cross} = P_O cos^2\left(\frac{\pi}{L_C} Z\right) \qquad (2)$$

where P_{bar} is the power conveyed in the bar waveguide, P_{cross} is the power conveyed in the cross waveguide, P_o is the power contribution to the directional coupler, Lc is the coupling length of the directional coupler and (Z), is the separation along the directional coupler. From this definition, it can likewise express the power conveyed in every waveguide after the coupling length has been changed as portrayed already. Optical switching can be performed either passively or actively. Optical switching can be performed either inactively or effectively. Optical switching is an operation in passing or blocking light (ON/OFF), or changing the yield port of propagating light. It is extremely valuable in sending data of various wavelengths from focal office to the subscriber in the optical system of fiber-to-the-home. Optical switching can be performed either passively [5]. An inactive switch can be made of number of directional couplers as appeared in Fig. 2 [5].

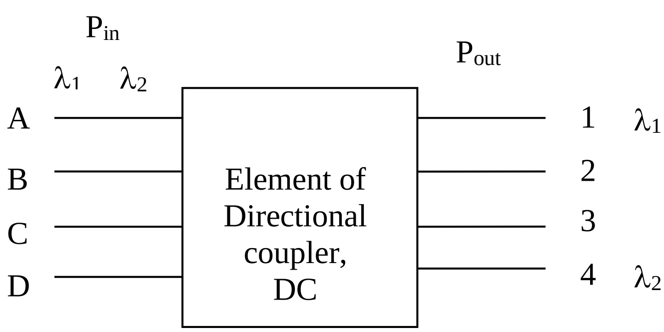


Fig.(2) :4×4 passive optical switch

As coupler is the essential segment in doing optical switch. In the figure appeared over, the info wavelengths λ1 and λ2 can be exchanged into two distinctive yield channels which is and , this configuration is named as inactive switch since the information wavelengths are de-multiplexed into altered yield channel. The user can't change the yield into whatever other yield channel. P1out P2out, this design is named as inactive switch since the info wavelengths are de-multiplexed into settled yield channel. The user can't change the yield into some other yield channel [5]. An effectively utilizing same design, the architect can de-multiplex or switch input wavelength λ2 favored yield channel. This should be possible by applying electro-optical impact to every component of the coupler. The design appeared in Fig. 3, is called dynamic switch[5].

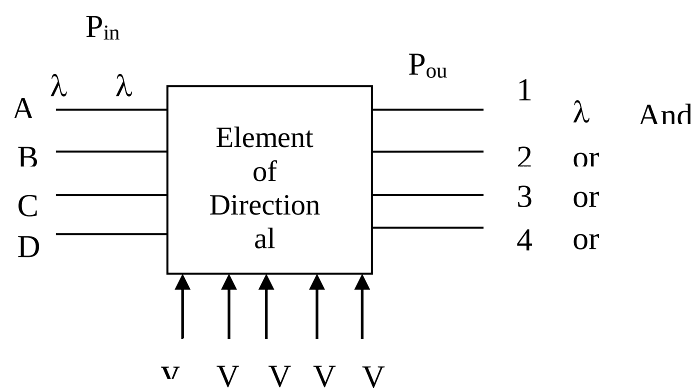


Fig.(3) : 4×4 Electro optic Active switch

By applying electro-optical impact to the coupler, changes will happen in the refractive index of the coupler. This will bring about the progressions in moving optical power into output 1 or 2 of the coupler. This will prompt full coupling or no coupling conditions of light source. The light source from information A, B, C or D can be occupied into yield 1,2,3,or 4. This should be possible by changing the voltage state in V_1, V_2, V_3 and V_4[5] .

2. TECHNIQUE OF SWITCHING IN MZI-STRUCTURS

The Mach Zehnder interferometer(MZI) switch, as appeared in Fig. 4, cycles between the bar state, where the vast majority of the light shows up in the waveguide on the same side as the information, and the cross state, where

a large portion of the light moves to the waveguide on the opposite side [6].

A normal EO-impact based 2×2 MZI switch comprises of two interferometric arms of equivalent length associated between two 3dB-couplers. These arms are set sufficiently far from

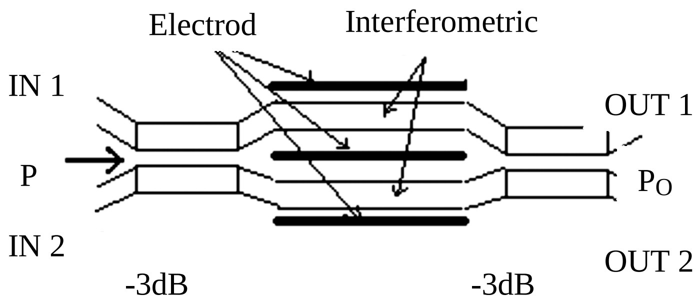


Fig.(4): Electro optic MZI Switch with equal interferometric arm lengths

each other to keep away from evanescent coupling between them. The principal coupler is utilized to part the light uniformly into two beams (I_1, I_2), which when progressed through the interferometric arms experiences a net phase change of $2\Delta\phi$. This phase difference is expected to a push–pull impact brought on by the field connected in opposite direction through the waveguides under the terminals [6]. This makes the light to constructively or destructively interfere at the output depending on the field (phase), connected. The subsequent yield control relies on upon their relative phases $\Delta\phi$. Taking phase-shifts brought on by the MMIs [7], onto account the subsequent light intensities at the bar- and cross-yield ports are given by[7]:

$$I_{Out-CROSS} = \frac{1}{2}\left(I_1 + I_2 + \sqrt{I_1 I_2}\cos\Delta\emptyset\right) \qquad (3)$$

$$I_{Out-bar} = \frac{1}{2}\left(I_1 + I_2 + \sqrt{I_1 I_2}\cos(\Delta\emptyset + \pi)\right) \qquad (4)$$

The phase-shift $\Delta\phi$ is the result of a refractive index change Δn in an arm of the Mach-Zehnder interferometer switch.

3. MATHMATICAL MODEL

The equation (5), shows generally the equation of an optical passive switch as shown in the Fig. 2, when the incident light is split in two parts (I_1 and I_2), which follow independent optical path and are merged again in a combiner where they interfere with each other, provided that the optical path difference is smaller than coherence length of the light and this technique is working without any applied voltage on the electrodes. So, when the laser diode is used Then[8]:

$$\frac{2I_1 - I_2}{I_2} = 2_{E_1}\left[(E_1 - 1) + (1 - E_1)\cos\Delta\emptyset\right] \qquad (5)$$

Where I_1 and I_2 are intensity of light for the arm one and arm two respectively and (E_1), is electric field of the waveguide. So, if the voltage is applying on the electrodes as shown in Fig. 3 and 4, and which presents an electro-optic active switch as shown in equation (2), then[5]:

$$E = \frac{2\,\Delta_n V_\pi L}{\lambda d} \qquad (6)$$

Where (V_π), is switching voltage, (L), is a length of the electrodes and (d), is a distance of the separation between the electrodes and (λ), is an input wavelength. So, Substituting Eq.(2), in to Eq. (1), yields:

$$\frac{2I_1 - I_2}{I_2} = 2\left(\frac{2\Delta_n V_\pi L}{\lambda d}\right)\left[\left(\frac{2\Delta_n V_\pi L}{\lambda d} - 1\right) + \left(1 - \frac{2\Delta_n V_\pi L}{\lambda d}\cos\Delta\phi\right)\right]$$

$$= \left(\frac{4\Delta_n V_\pi L}{\lambda d}\right)\left[\frac{2\,\Delta_n V_\pi L - \lambda d + (\lambda d - 2\,\Delta_n V_\pi L)\cos\Delta\emptyset}{\lambda d}\right]$$

$$= \frac{8\Delta_n^2 V_\pi^2 L^2 - 4\Delta_n V_\pi L\lambda d + \left(4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2\right)\cos\Delta\phi}{\lambda^2 d^2}$$

$$\frac{(2I_1 - I_2)\lambda^2 d^2}{I_2} =$$

$$8\Delta_n^2 V_\pi^2 L^2 - 4\Delta_n V_\pi L\lambda d + (4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2)\cos\Delta\phi$$

$$= 8\Delta_n^2 V_\pi^2 L^2 + 4\Delta_n V_\pi L\lambda d = (4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2)\cos\Delta\phi$$

$$\cos\Delta\phi = \frac{(2I_1 - I_2)(\lambda^2 d^2)}{I_2(4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2)} + \frac{4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2}{4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2}$$

$$\cos\Delta\phi = \frac{(2I_1 - I_2)(\lambda^2 d^2)}{I_2(4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2)} + 1$$

$$\because \Delta\emptyset = \frac{\pi L}{\lambda} n_o^3 r \frac{V}{d}$$

Where n_o is refractive index, r is pocket coefficient and v is DC bias voltage.

$$\therefore \cos\left(\frac{\pi L n_o^3 r V}{\lambda d}\right) = \frac{(2I_1 - I_2)(\lambda^2 d^2)}{I_2(4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2)} + 1$$

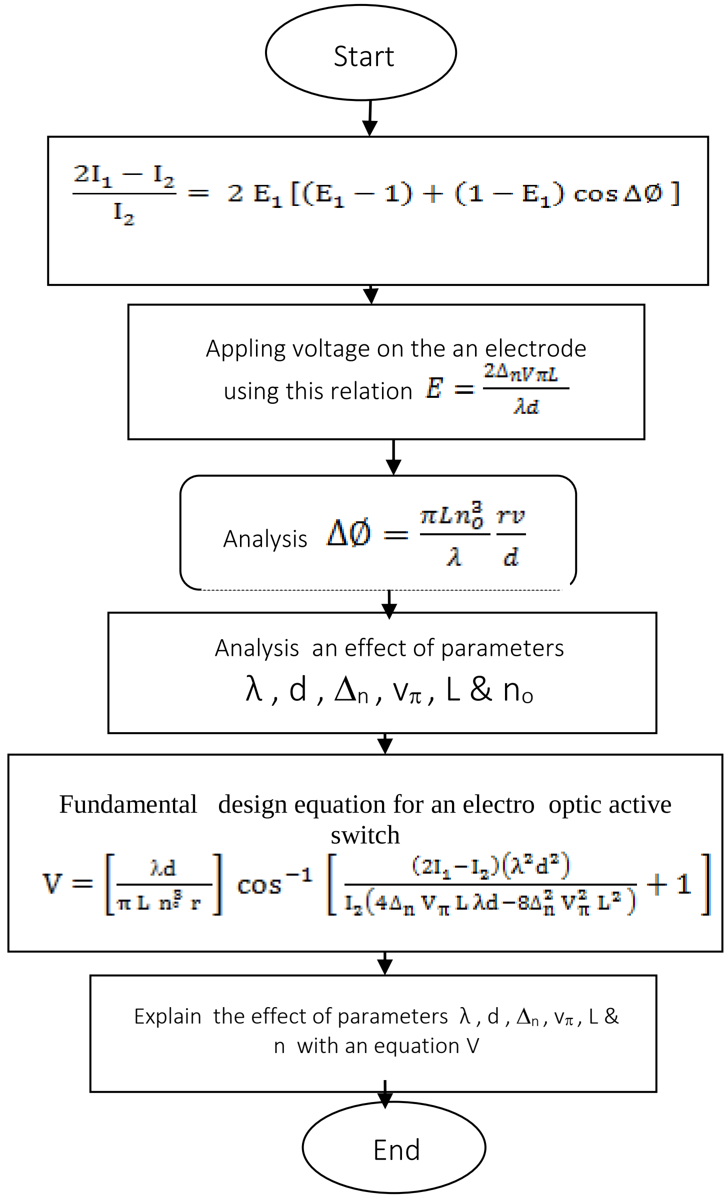
$$\left(\frac{\pi L n_o^3 r V}{\lambda d}\right) = \cos^{-1}\left[\frac{(2I_1 - I_2)\lambda^2 d^2}{I_2(4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2)} + 1\right]$$

$$V = \left[\frac{\lambda d}{\pi L n_o^3 r}\right]\cos^{-1}\left[\frac{(2I_1 - I_2)\lambda^2 d^2}{I_2(4\Delta_n V_\pi L\lambda d - 8\Delta_n^2 V_\pi^2 L^2)} + 1\right] \qquad (7)$$

The equation (7), is the fundamental design equation for electro optic active switch on the optical communication systems. Also, this equation shows the relationship between DC bias voltage (V), and parameters effects such as refractive index (n), switching voltage ($V\pi$), distance separation between electrodes (d), and length of the electrodes (L).

4. RESULTS AND DISCUSSION

The objective of the simulation presents suggestion mathematical model for design an electro optic active switch by analysis the parameters effect such as (λ,d, L, n, and Δn), which they consider important factor to construction of the electro optic active switch. So, the simulation established using a mathematical module by the equation (7). So, equation (7), explains relationship between the DC bias voltage (V), and other parameters such as λ, d, L, n, and Δn . See flow chart of the simulation



4.1 THE EFFECT OF CHANCHING OF THE WAVELENGTH AND DISTANCE OF THE SEPARATION

From Fig. 5, and 6, the wavelength (λ), and separation distance (d), between waveguides are directly proportional to the change of the DC bias voltage (V), while the switching voltage ($V\pi$), is changing. So, when the DC bias voltage is changing then also, coupling efficiency will change and this due to a changing of the distance of the separation between waveguides [5], but the switching voltage ($V\pi$), is changing . So, the distance of separation (d), is directly proportional to the change of the coupling efficiency[5]. while, the coupling efficiency is neglect when the changing of the wavelength is directly proportional to the change of the DC bias voltage[5], but also the switching voltage ($V\pi$), is changing .

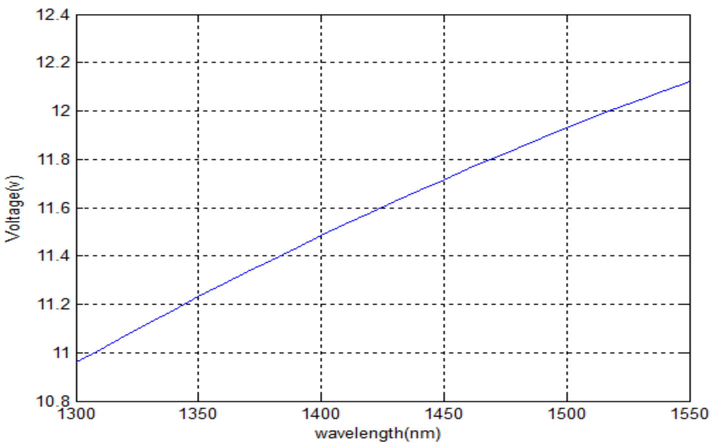
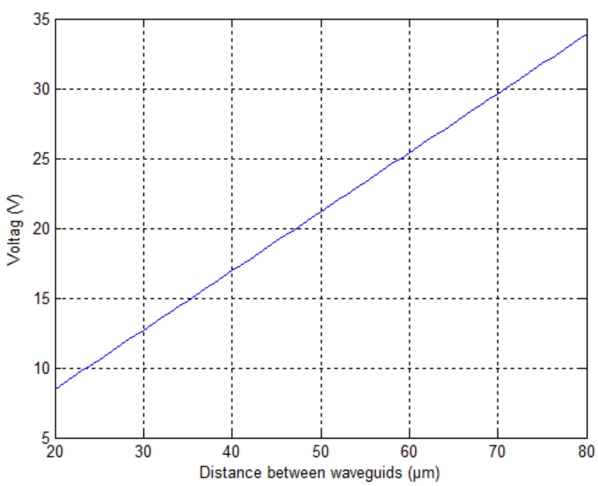


Fig.(5): The effect of the changing wavelength (λ) with changing of the DC bias voltage(V)



4.2 THE EFFECT OF THE CHANGING (n_o), (L), AND (Δn)

From Fig. 7 and 8, the refractive index (n), the length of the electrodes (L), are changing and proportional inversely with a changing of the DC bias voltage but also figure (10), shows the switching voltage ($V\pi$), is increasing and proportional directly with changing the DC bias voltage. From Fig. 7, it notes the refractive index (n_o), is increasing until reach to the value (2.2), with decreasing the switching voltage approximately into (3.8 V), so, it explains the main disadvantage for switching voltage is high refractive index because of if the refractive index is high the injection current is also high then that it leads to increasing losses in the form heating losses and this is resulting to low speed of the switching voltage. Addition from figure (9), it notes the relative refractive index (Δn), is changing and proportional directly with changing of the DC bias voltage.

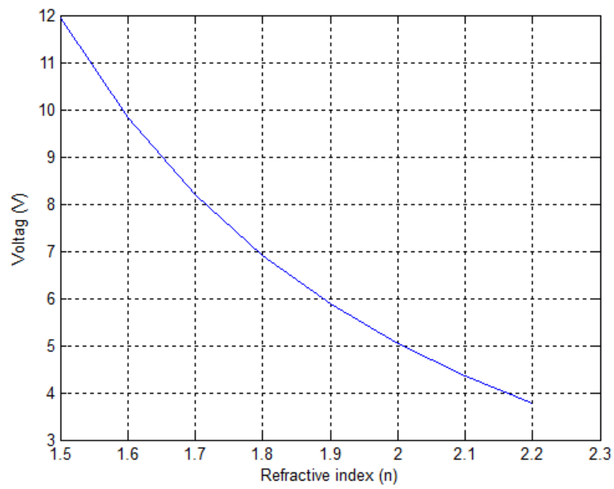


Fig.(7) : The effect of the refractive index(n) with the DC bias voltage (V)

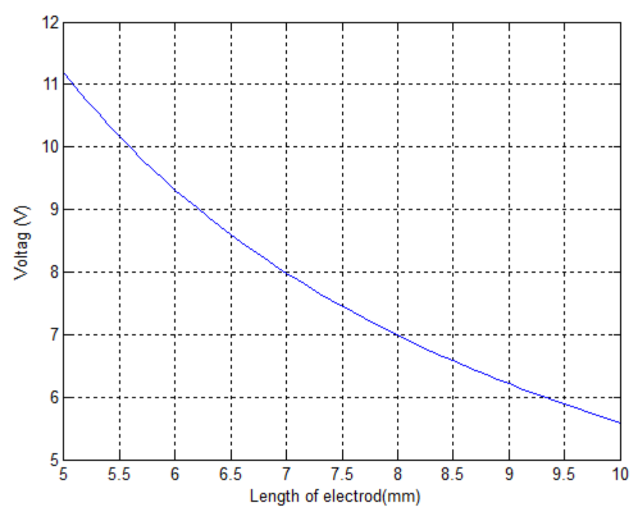


Fig.(8) : The effect of length of the electrodes (L) with DC bias voltage(V)

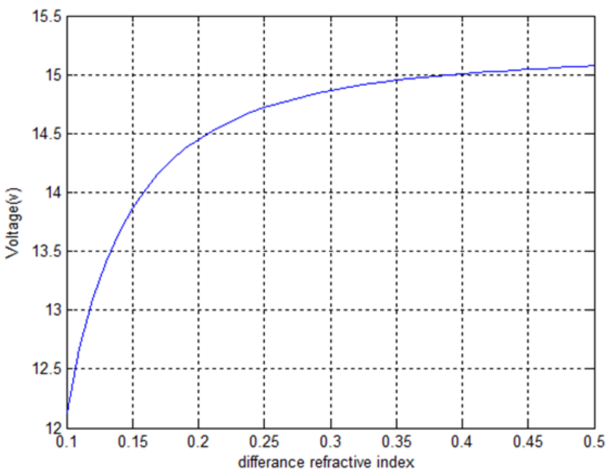


Fig.(9) : The effect of the relative refractive index difference (Δn) with DC bias voltage(V)

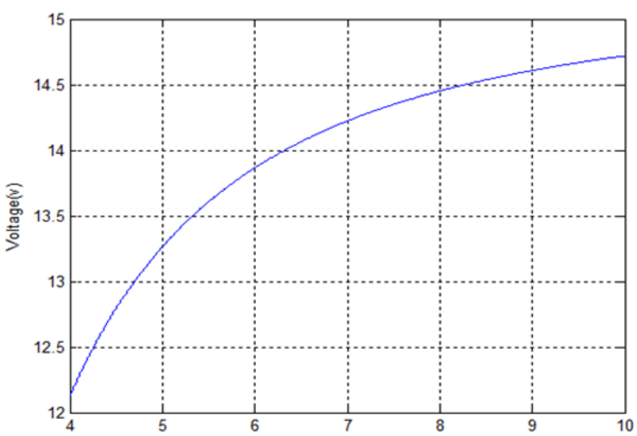


Fig.(10) : The effect of the switching voltage(Vπ) with DC bias voltage(V)

5. CONCLUSIONS

1.In this research it presents analytical model to design electro optic switch and evaluate the effect of parameters such as (λ, d, n, Δn, and Vπ), on the for electro optic switch. Addition, equation (7), suggests for design electro optic switch by analysis an effect of the parameters on the switching voltage. So, this considers other technique to construction electro optic switch.

2. It concluded the wavelength (λ), and distance of the separation between waveguide (d), is gradually increasing until reach into value (1550 nm), and (80 µm), respectively with increasing the value of DC bias voltage approximately into (12.1V), and approximately (34V), for electro optic switch while the coupling efficiency effect with changing the switching voltage so, that when the distance of separation between waveguides (d), changes the coupling efficiency also changes but the applying voltage is changing then, that it leads to controlling on the coupling efficiency and which it considers important factor in the design electro optic switch.

3. It concluded when the refractive index (n), and length of the electrodes (L), gradually increasing the DC bias voltage is decreasing so, it concluded the low speed of switching voltage is resulting from high refractive index due to high injection current so this leads to heating losses and this considers disadvantage it can and this leads to a damage of the electro optic switch and this improve by high fabrication and accuracy when construction of the device.

4. It notes the relative refractive index (Δn), and switching voltage (Vπ), gradually increasing with increasing the DC bias voltage so, when the (Δn), and (Vπ), reach to the maximum value (0.5), and (10 V) respectively , the DC bias voltage (V), reaches into (15.1V), and approximately (14.8 V), so, it concludes the (Δn), and (Vπ), are proportional directly to the changing of the DC bias voltage.

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