Journal University of Kerbala, Vol. 14 No.4 Scientific . 2016

Study of optical properties for photonic crystals by using OptiFDTD simulation

دراسة الخصائص البصرية للبلورات الضوئية باستخدام محاكاة (OptiFDTD)

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Abstract:

In this research, a high transmission Y-junction and T-junction in (1×2) splitters based of two dimensional waveguides of photonic crystal with lattice consisting of air holes was designed. The results of optical properties obtained by using a simulation program(OptiFDTD) at a wavelength (λ=1900nm) which was used to calculate the electric and magnetic fields as well as the poynting vector-z. The comparison of results for the (Y and T) junctions shows that the T-junction improved the electric and magnetic fields better than Y-junction.

Key words: FDTD(finite difference time domain),waveguides, poynting vector-z.

الخلاصة:

في هذا البحث تم تصميم وصلة- Y و وصلة-T ذات انتقال عالي في شقوق (2×1) على أساس دليل موجي ثنائي البعد لبلورة ضوئية ذات شبيكة مؤلفة من فجوات هوائية. نتائج الخواص البصرية تم الحصول عليها باستخدام برنامج المحاكاة (OptiFDTD) عند طول موجي 1900 نانومتر والتي استخدمت لحساب المجالين الكهربائي والمغناطيسي بالإضافة الى حساب متجه بوينتنك-z. ان مقارنة نتائج الوصلتين (T و Y) أظهرت أن وصلة T تحسن المجالين الكهربائي و المغناطيسي بشكل افضل من وصلة Y.

الكلمات المفتاحية :الفرق المحدود للمجال الزمني، الدليل الموجي ، متجه بوينتنك-z

Introduction:

The photonic crystal has the possibility to supply ultra-compact photonic ingredients that miniaturize of the optical circuits and revolutionized transform to integrated optic. mostly the photonic band gap of operation for such devices lies in the periodical dielectric build that gives compact retention of light to predetermine path ways orderly to transmit it over the circuits[1].

Many of theoretical studies performed go so far include investigated layout of insulation rod at air. The pattern of this system has advantage the wave-guide formed by eliminate a single row of the rods it singular moded. Traveling light about sharp curvatures with high transportation, then comparatively straight forward and T-junction and Y-junction have previously suggest [2].

The tablet of wave-guide building consists from the air cavities digging in insulation medium like a GaAs-AlGaAs hetero structure [3] or a semi-conductor thin film [4 – 5]. The treatment of this dilemma and let the wave-guide without acceptable damages to be achieved. This problems facing the cavities in insulation path is that the one defect photonic crystal wave-guide be multimoded , that makes (PhC) have intractable light to travel efficiently about the loop because of it easily to excite the higher order modes at discontinuities[5–6]. Many groups studied straight and bends waveguides, the problem wich be very important to junction, that is substantial to the process of most compound loop has only newly received notice [7–9].

The more straight forward Y- splitter designing contain from three (one-defect) 'W1' wave-guide connected jointly at (120◦) which produces active reflection and narrow band width process [8]. Another designing based of a triple line defect wave-guide [9], enhances achievement safely because that wave-guides which using be inherently mono-mode. Here; it had been presented first proof of effective light publishing through the Y- junction based on the more usually is using (W1) wave-guide design. From the known as that the model Y- junction frame has low transport without any frame setting at curvature and input ports and output. As well as of that execution of the

Y- junction been enhanced by setting and unsettle these holes at (120°) junction, or by curvature the output ports nevertheless, the difficulties are remain which can not be easy treatment to actual application. This difficulty appear due to the mode mismatch at (120°) junction and these curvature loses the output of the ports. A number of the researcher's studies are obvious that the Y- junction based on potential splitter it self correspond with several of problems of its design. The propose of a singular design is which will not have any disorder as (120°) junction and losing of curvature. The multiple-line disorder wave-guide of (2-D) Photonic crystals based on the potential splitter is that suggested design that be able of treatment the problem of the Y- junction based on the potential splitter as reminded before. Photonic crystals that the multiple-line disorder wave-guides potential splitter reduce the multi-mode of mode issue appear in the exist design. Thus, the suggested design transport the most potential as compare to the exist design. Therefore, Photonic crystals multiple-line disorder wave-guides based on the potential splitter should be disorder [10]

Methodology

It has been taken PBG_atomat refractive index (Re:): 3.1 with waveguide has dimension of width- 1µm, Profile: Profile_PBG, 2D-wafer properties material: air, wafer dimensions length: 21(µm), width: 15(µm), Gaussian modulate continual wave like the input signal with wavelength: 1.9 (µm), Gaussian modulate cw- Time Offset: 5.5e-14(sec) and Half Width: 1.1e-14(sec).

The input signal used in the simulation expressed as [11].

$$E_y^{inc}\ (\text{x}, Z_{inc}) = \text{A T(t)F(x, } Z_{inc}) \sin\ (\ \omega\ t + \theta i\ ) \ldots\ldots\ldots (1)$$

Where, F(x, Z_{inc}) is the transverse field location at the incident field location *zinc* and (A) is the field amplitude, the initial offset (θi) is the phase difference between points at the happening plane. this offset can modify to de- fine the trend of the incident field [11].

By using 2D (FDTD) simulation (finite difference time domain) method, the propagation of the light in the wave-guide used as a principle simulator. FDTD is a time domain numerical method using to modelling the propagation of electromagnetic waves in the optic media, that which is based on make the Maxwell's equations be s in differential form in the free space. Thes methods of time domain have found to have been exactly to simulator the dynamics of propagation the signals in periodical dielectric media [12].

The simulator to TE (Transmission Electric) method, factual mesh used:0.1(µm), delta-X: 0.1 (µm) and delta-Z with number of mesh cells 150 X and 210 Z. The anisotropic perfectly matched layer (APML) Boundary Condition is used. theoretical reflection coefficient : 1.0 e-12, anisotropic (PML) calculation parameters number of Anisotropic (PML) layers :10, real Anisotropic (PML) Tensor Parameters : 5.0 , Power of grading Polynomial : 3.5, and the final result of the simulator it done for 10000 time steps, as show in figure (1) below:

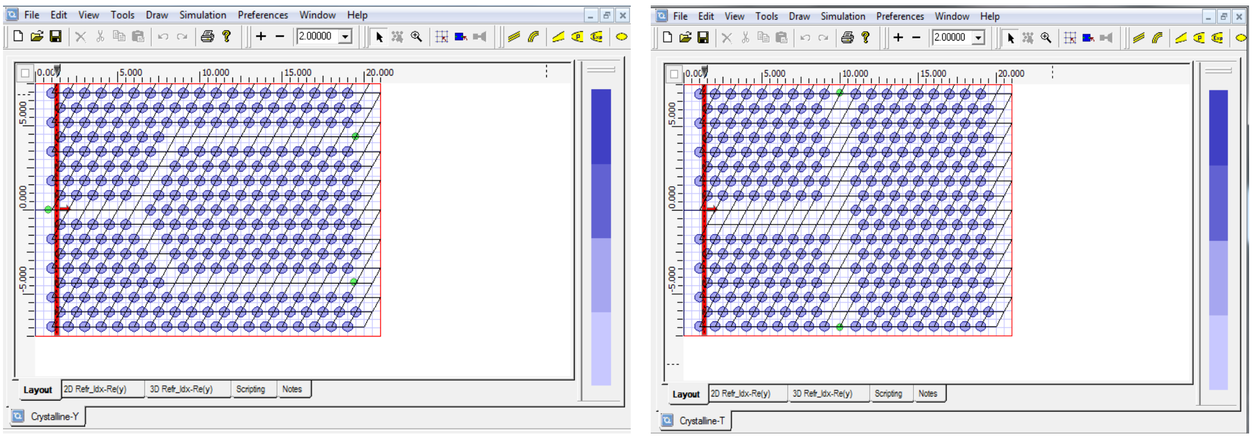
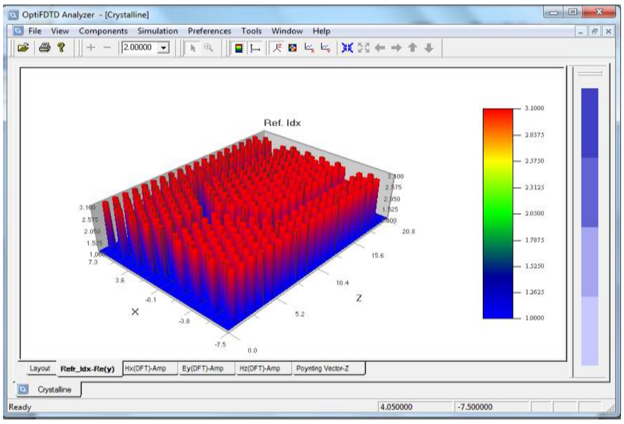


Figure (1)

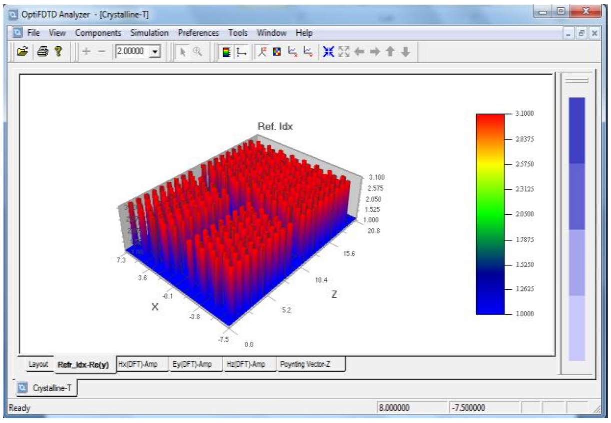
(a) : layout design of (1x2) Y- Junction (b): Layout Design of (1x2) T- Junction

Simulation result

Simulation result of 1x2 (Y-Junction and T-Junction) are display offers distribution of the refractive index in a single chip the size of the simulation. The refractive index distribution for the 1x2 Y-Junction and 1x2 T-Junction (height plot view) and (image map view)are shown in Fig.(2):

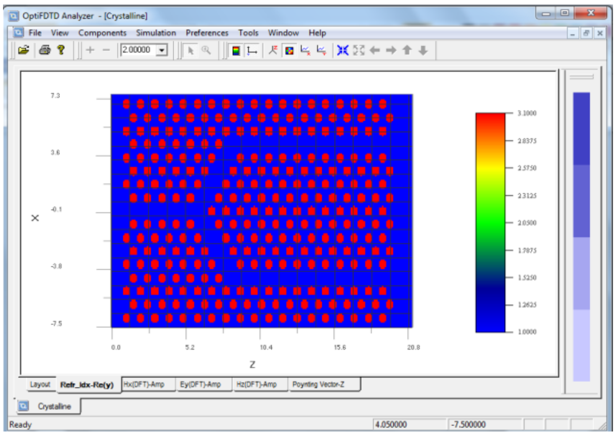


a1

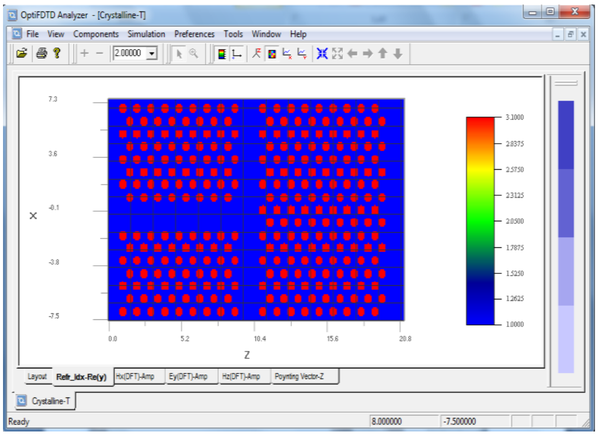


b1

Height Plot view



a2



b2

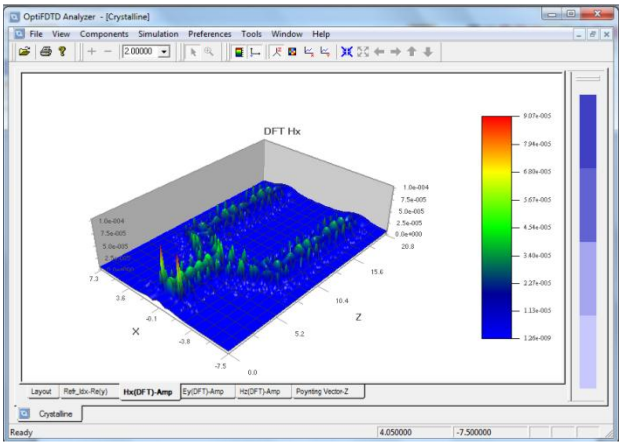
Image map view

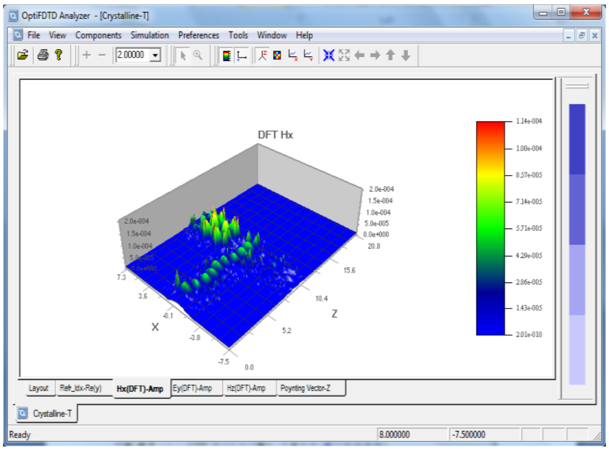
Figure (2)

(a1,a2): Refractive index distribution of design (1x2 Y-Junction).

(b1,b2): Refractive index distribution of design (1x2 T-Junction).

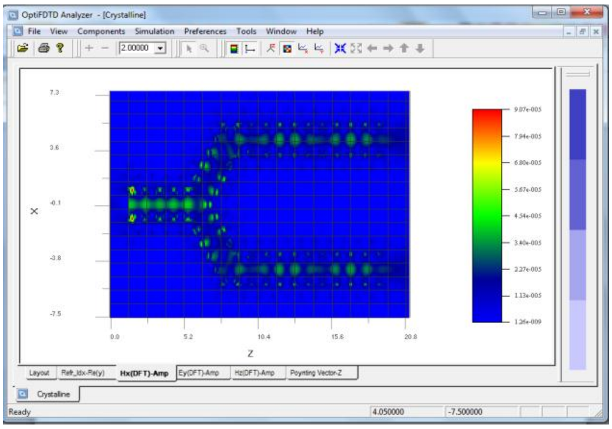
While the difference widening of discrete fourier transform (DFT) product of Components HX, EY, and Poynting vector (height plot view) and (image map view) to the 1x2 Y-Junction and 1x2 T-Junction, its been shown below as in figures (3,4,5):

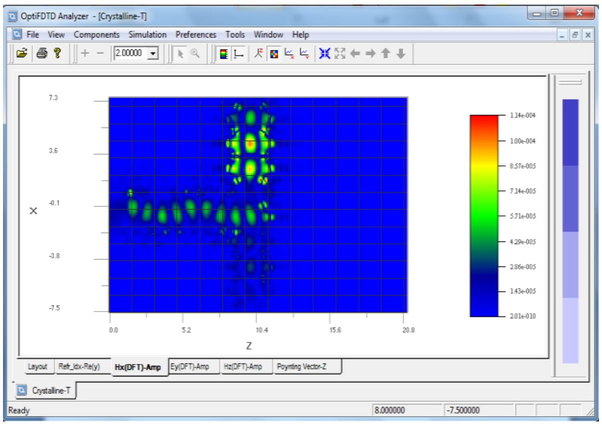




a1 **b1**

height plot view



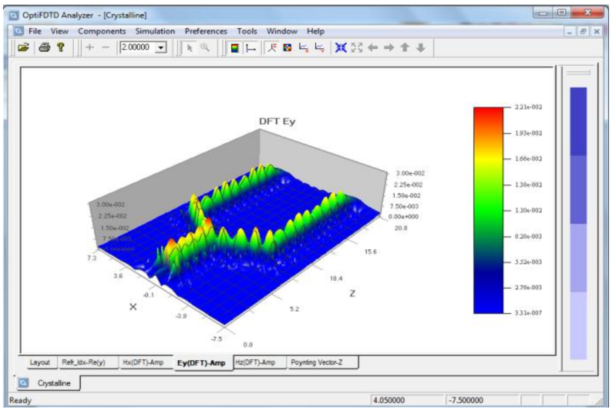


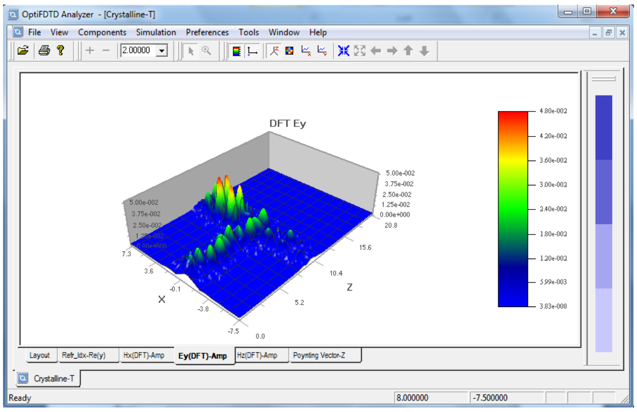
a2 **b2**

image map view

(1x2 Y-Junction) (1x2 T-Junction)

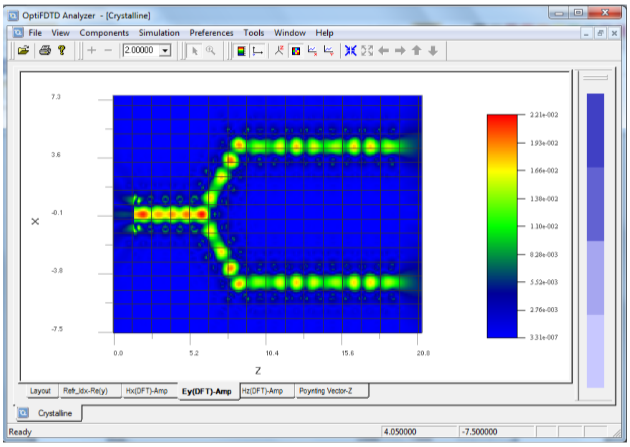
Figure 3: (DFT) Output of amplitude variation of (Hx) along XZ plane.

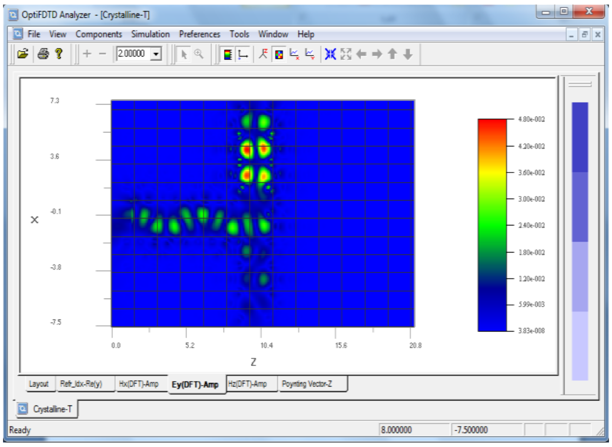




a1 **b1**

height plot view



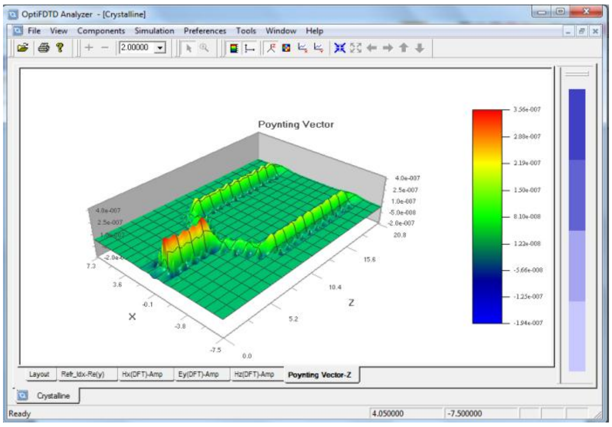


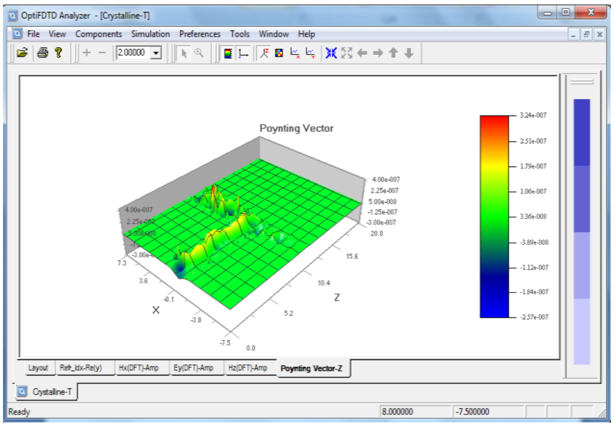
a2 b2

image map view

(1x2 Y-Junction) (1x2 T-Junction)

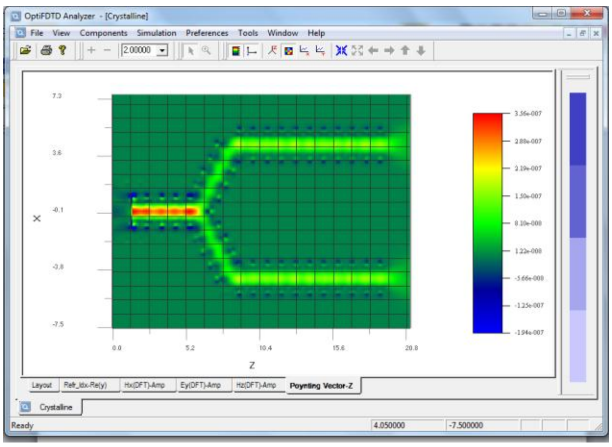
Figure 4: DFT output of Amplitude variation of Ey along XZ plane.

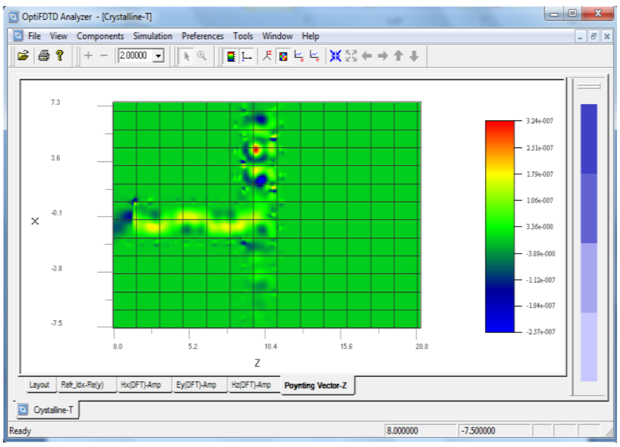




a1 b1

height plot view





a2 b2

image map view

(1x2 Y-Junction)(1x2 T-Junction)

Figure 5: Variation of Poynting Vector along XZ plane.

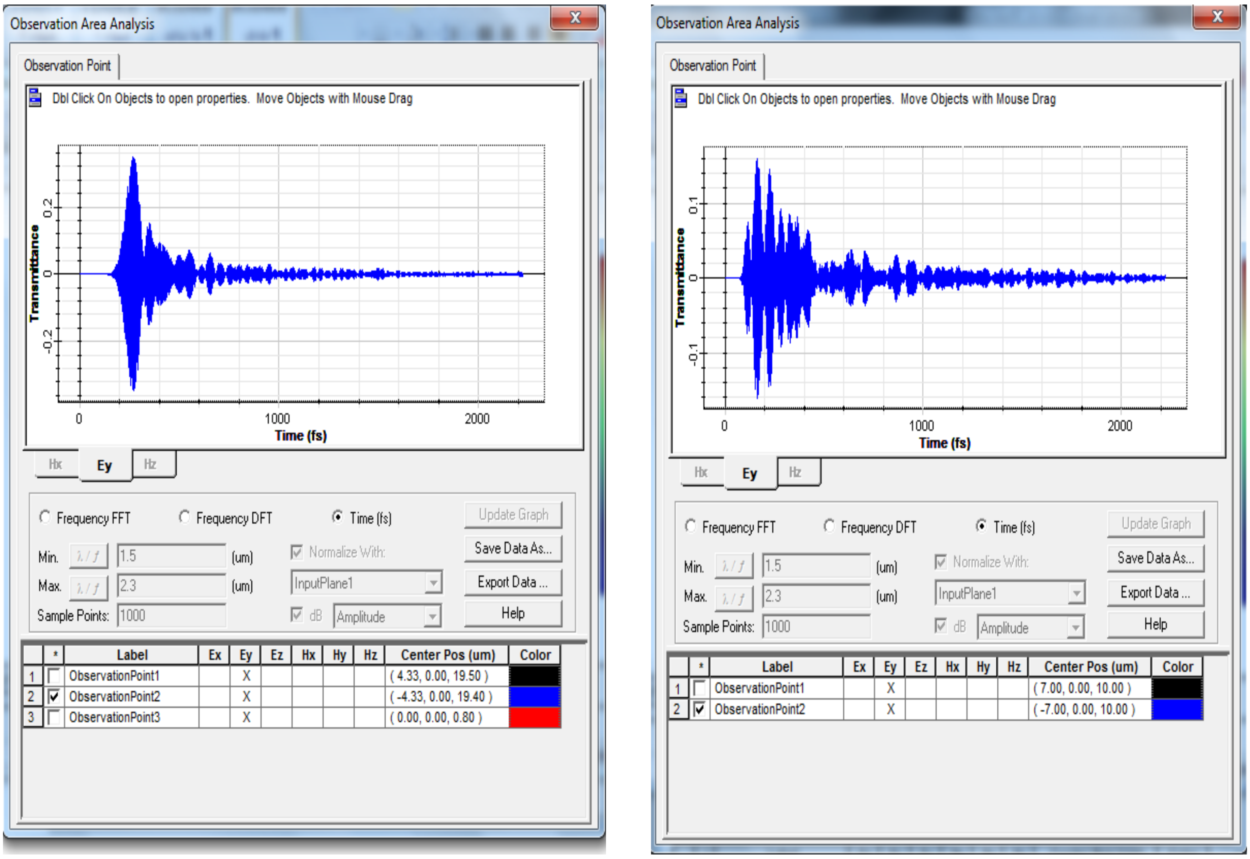
The transmission spectrum for the two output channels is shown in Figures (2,3,4 and 5) above, where that are shows the distribution of electric and magnetic fields in splitters to each of the 1x2 Y-Junction and 1x2 T-Junction, and referring tankers tab, its available if the specified components in sufficient parameters dialog box simulation to calculate the vector of poynting.

Results obtained from the simulation for each of the1x2 Y-Junction&1x2 T-Junction display the distribution of electric and magnetic fields, it was found that the distribution of the fields at the1x2 T-Junction[Ey = 4.80e-002 (V/m) and Hx = 1.14e-004 (A/m)], while the distribution of the fields at the1x2 Y-Junction[Ey = 2.21e-002 (V/m) and Hx = 9.07e-005 (A/m)].

Observation Area Analysis

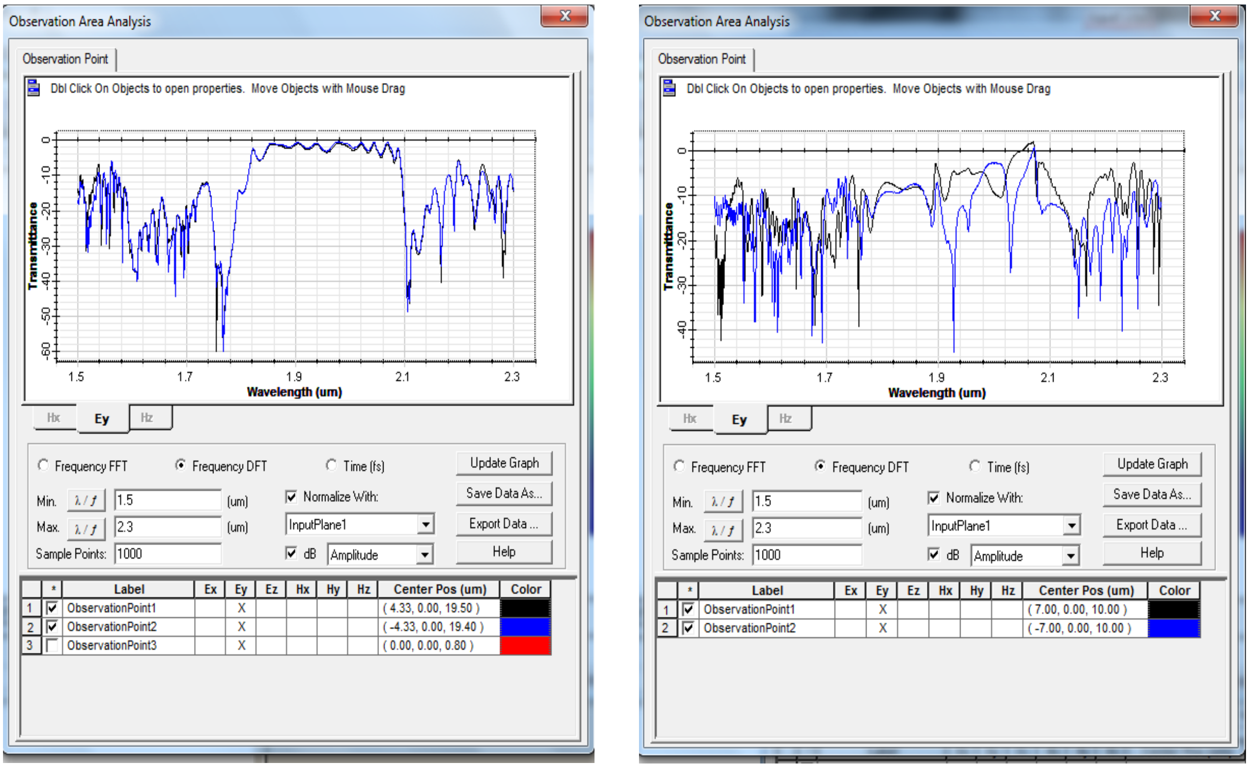
Time domain and frequency domain response observation. It can get a job transfer of observe analysis point if the detector has been developed at the center point of the waveguide in which the peak value.

Figures (6,7) shows the time domain response and dynamic frequency field and transmittance versus wavelength for the1x2 Y-Junction&1x2 T-Junction.



(1x2 Y-Junction) (1x2 T-Junction)

Figure 6-Dynamic time domain and frequency domain response.



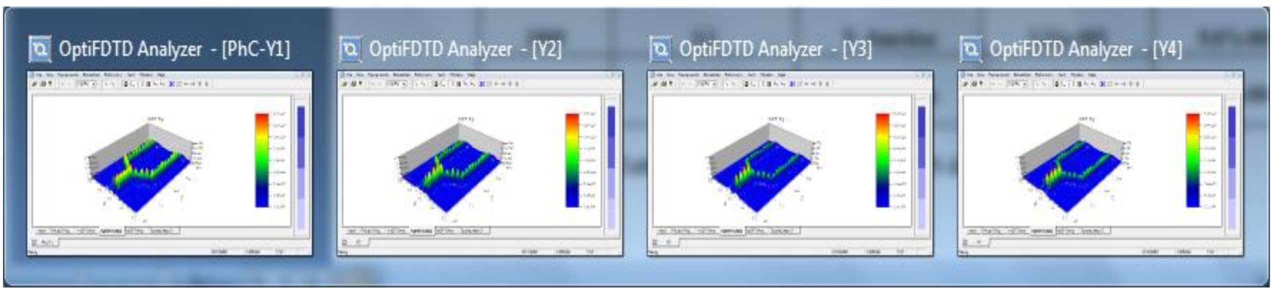
(1x2 Y-Junction) (1x2 T-Junction)

Figure 7- Transmittance versus wavelength.

The injected process of the optic pulses on the wave-guide and every-one of pulse will covering the same wavelength range which is (1.5µm-2.3µm). The components that were actually collected for an observation point are marked with an 'X' under the columns (see fig. 6,7). Each component is displayed in a separate graph, and the values for the frequency domain can be displayed in frequency (THz) or wavelength (µm).

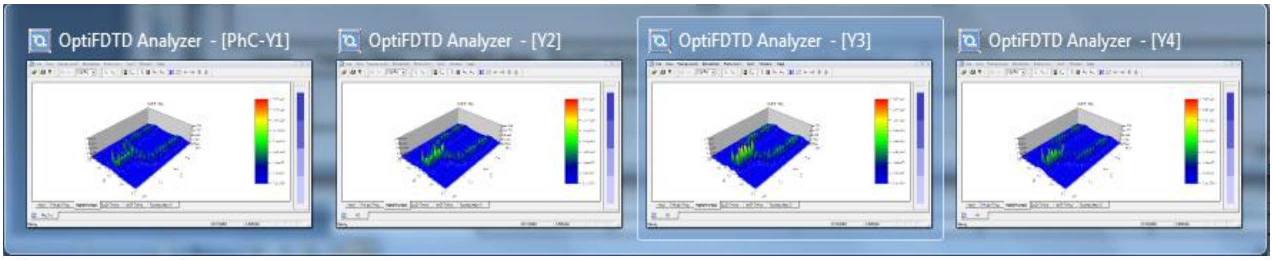
Comparison between the Y- Junction and T- Junction

Several wavelengths selected in addition to wavelength1900 nm for the design of the 1x2 Y-Junction and 1x2 T-Junction, we noticed that the distribution of electric and magnetic fields will be different in each wavelength at both models, and we noticedthat the domain transmission and distribution in the air holes to the1x2 T-Junction be the best of the 1x2 Y-Junction as shown in Figures (8,9,10,11) and the tables (1,2) below:



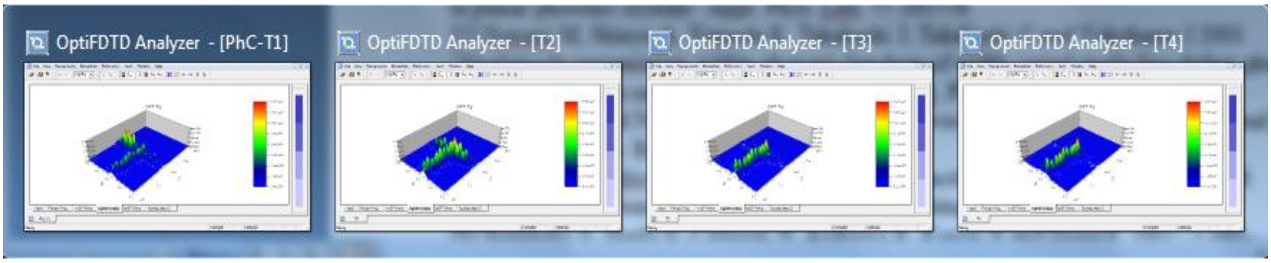
λ= 1900 nm λ= 1890 nm λ= 1880 nm λ= 1870 nm

Figure 8 - Ey (Simulated) -Height Plot view for Y- Junction.



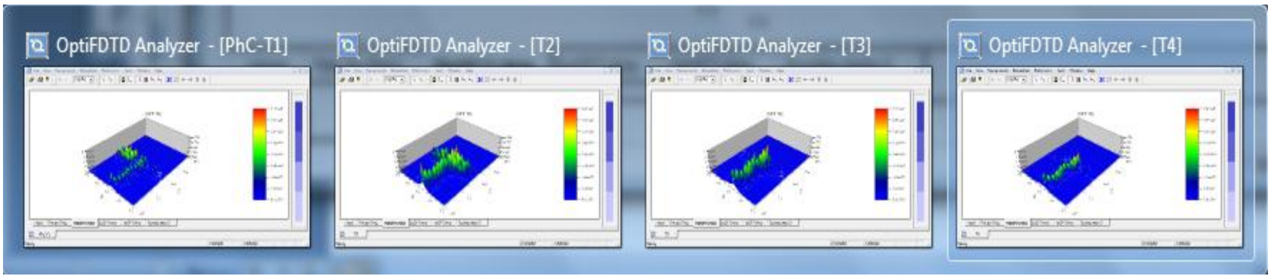
λ= 1900 nm λ= 1890 nm λ= 1880 nm λ= 1870 nm

Figure 9 - Hx (Simulated) -Height Plot view for Y- Junction.



λ= 1900 nm λ= 1890 nm λ= 1880 nm λ= 1870 nm

Figure 10 - Ey (Simulated) -Height Plot view forT- Junction.



λ= 1900 nm λ= 1890 nm λ= 1880 nm λ= 1870 nm

Figure 11 - Hx (Simulated) -Height Plot view forT- Junction.

From figures (8,9,10,11) above note that the distribution of electrical and magnetic values are vary for each of the two models designers above, where we note that the values changes for each wavelength as well be are as electrical and magnetic values for the 1x2 T-Junction better than 1x2 Y-Junction, as shown in tables (1and 2) below:

Table -1- (E&H)-Field value at the1x2 Y- Junction.

Wavelength (nm)	Refractive Index	Ey (DFT) Amp $(^{V}/_{m})$	Hx (DFT) Amp $(^{A}/_{m})$
1900	3.1	2.21e-002	9.07e-005
1890	3.1	2.61e-002	8.01e-005
1880	3.1	3.34e-002	7.98e-005
1870	3.1	3.15e-002	9.89e-005

Table -2- (E&H)-Field value at the1x2 T- Junction.

Wavelength (nm)	Refractive Index	Ey (DFT) Amp $({}^{V}/_{m})$	Hx (DFT) Amp$({}^{A}/_{m})$
1900	3.1	4.80e-002	1.14e-004
1890	3.1	3.79e-002	8.33e-005
1880	3.1	4.03e-002	9.81e-005
1870	3.1	4.28e-002	1.09e-004

From the tables above notes that the values fields electric and magnetic change depending on the wavelength used, was chosen as the wavelengths of from (1900 - 1870) nm for both designs, and the simulation results of the two models that have been used it has shown that change the distribution of spheres electric and magnetic (increase or decrease) at refractive index (3.1), where the electric field values of the 1x2 Y-Junction are between (2.21e-002 - 3.15e-002) V/m and magnetic values between (9.07e-005 - 9.89e-005) A/m, while for the values of the electric field of the 1x2 T-Junction are between (4.80e-002 - 4.28e-002) V/m and values the magnetic field between (1.14e-004 - 1.09e-004) A/m and this values shows that the distribution of the 1x2 T-Junction are better than the 1x2 Y-Junction**.**

Conclusion

It has been designed Y- Junction, T- junction with TE mode, simulation with FDTD method. Characterized by the performance of each structure and compare them with each other by the maximum energy transfer. Different types of division it has shown relatively higher transfer efficiency in contrast with others, where we note that the values changes for each wavelength as well be are as electrical and magnetic values for the 1x2 T-Junction better than 1x2 Y-Junction. Finally, with optimized parameters it has been done in the power output of the differentiation and comparison with a different configuration. Based on these power structures improvements designed incision higher efficiency which can be used in networks, modulate, transmit, switch etc application.

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