Field enhancement of Optical Nanoantenna for 0.55µm Wavelength by Using OptiFDTD Simulation

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Abstract

In this research we choose the design of Dipole nanoantenna with the adoption of finite difference time domain method. The design result of 0.55µm optical antenna and its performance are presented. The optimal parameters are: [Gap=(10, 15, 20, 25, 30)nm & Length=(200, 240, 280, 320, 360)nm]. The influence of the geometrical parameters (gap dimension , nanoantenna length) on the antenna field enhancement and spectral response is discussed. We found the field enhancement be bigger when the gap be very small at dipole nanoantenna, where in the Gap=10nm the field enhancement more than in the Gaps (15, 20, 25, 30)nm.

Key words: Dipole nanoantenna , finite difference time domain method , geometrical parameters

الخلاصة

في هذا البحث سوف نختار التصميم للنانو هوائي ثنائي القطب مع اعتماد طريقة الفرق المحدود للمجال الزمني . وتعرض نتيجة التصميم للهوائي البصري عند 550 nm وأدائها . المعلمات الأمثل هي : الفجوات(10، 15 ،20، 25، 30) نانومتر والأطوال(200، 240، 280، 320، 360) نانومتر. إنَّ لتأثير البارامترات الهندسية { بعد الفجوة، طول الهوائي }على تحسين مجال الهوائي والاستجابة الطيفية قد تم مناقشتها ، ووجدنا أنَّ تحسين المجال يكون أكبر عندما تكون الفجوة للهوائي صغيرة جداً بالنسبة لهوائي ثنائي القطب (Dipole) ، حيث يكون تحسين المجال عند الفجوة=10نانومترهي أكبر بكثير من تحسين المجال عند الفجوات(15، 20، 25، 30) نانومتر.

الكلمات المفتاحية: الهوائي ثنائي القطب ، الفرق المحدود للمجال الزمني ، البارامترات الهندسية

1. Introduction

The antenna is a transducer designed to transmit or receive electromagnetic waves. Antennas have played an essential role since the beginning, and one of the simplest and first designs, the dipole antenna, is being used nowadays because of its easy implementation and characteristics. In telecom applications the need for larger and larger bandwidths has demanded the use of higher and higher frequencies of the supporting electromagnetic waves. At the same time, the antenna design developed more sophisticated layouts that have been successfully applied. From our point of view, an important leap was done with the design of planar antennas structures. They can be fabricated with imprinting and thin-film technologies on an appropriate substrate. Fortunately, the available fabrication techniques and the good radiation-metal interaction have allowed the realization and demonstration of the devices at shorter wavelength and shorter improve the performance of these detectors, and the positive results obtained from these efforts, have deprived the need to look back toward the antenna designs and make them work also in the optical band. At the same time, but working in a very distant field of application, researchers dealing with time standards and astronomy were developing new solutions based in antenna-like detectors. One of the results of these efforts is a new class of optical detectors that we named as optical antennas. They are derived from the whisker diodes [1, 2] first used for frequency-conversion and frequency-multiplication chains [3]. The uniqueness of this application has hidden the potential of the design for some other broader uses that were anticipated by several research groups [4, 5, 6]. A step forward was made when the concept of an antenna for the infrared radiation was totally included in the analysis and design of such devices, specially when taking into account the specific properties of the interaction of light and metals at optical frequencies[7, 8].

2. Field enhancement for Dipole Nanoantenna at(Gap=10nm&Length=200nm)

Displays the refractive index distribution at a single slice within the simulation volume. We can select any axis-aligned slice from the entire volume (see Figure 1from a-e).

The refractive index distribution profile for the structure is shown in Figure 1(a).

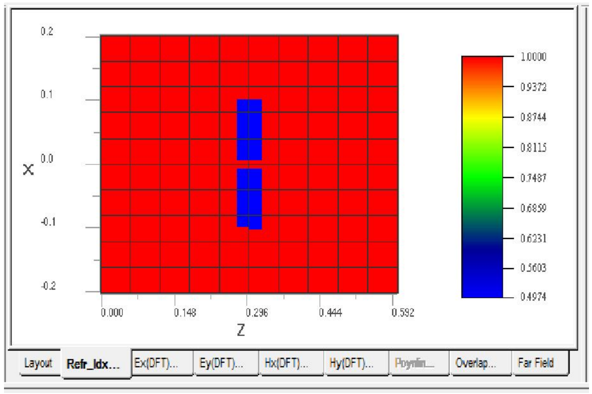
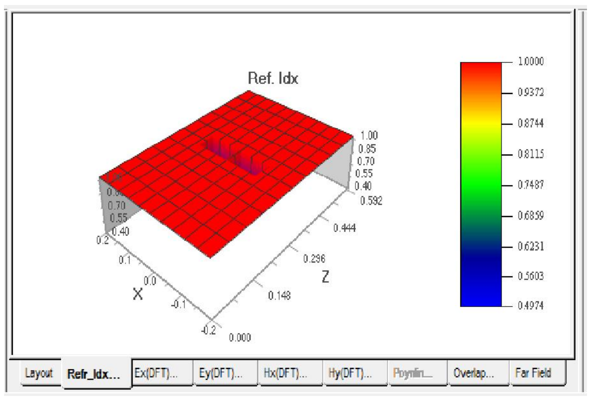


Image Map view



Height Plot view

Figure 1(a): Refractive index distribution profile of designed Dipole Nanoantenna (G=10nm & L=200nm)

The amplitude variation of Discrete Fourier Transform (DFT) output of all the components of tab and the poynting vector, overlap, and far field has been shown below.

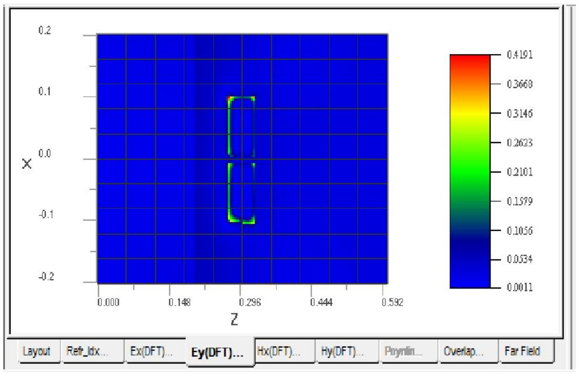
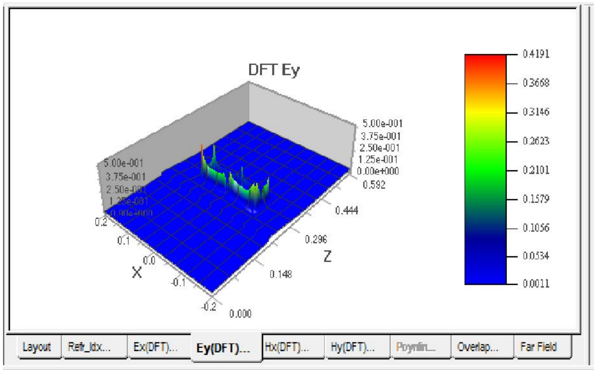


Image Map view



Height Plot view

Figure 1(b): DFT output of Amplitude variation of Ey along xz plane.

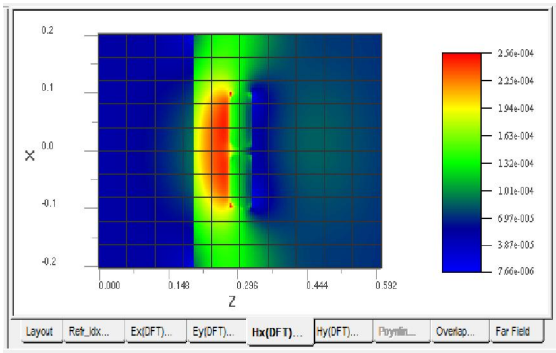
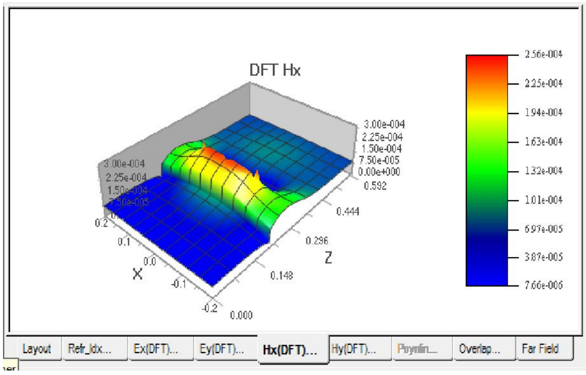


Image Map view



Height Plot view

Figure 1(c): DFT output of Amplitude variation of H_x along xz plane.

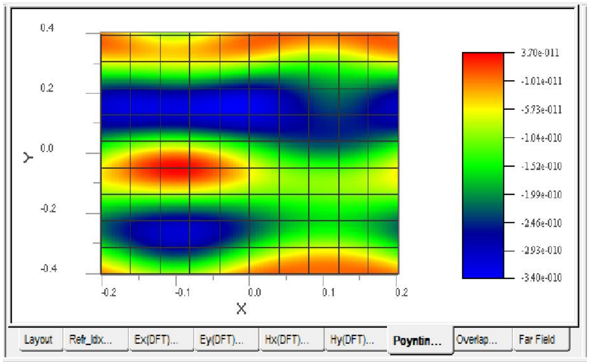
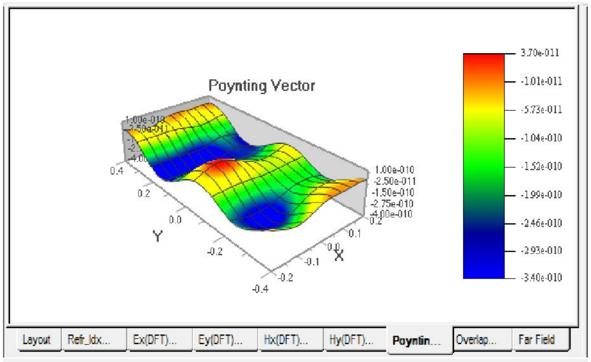


Image Map view



Height Plot view

Figure 1(d): Variation of Poynting Vector along xy plane.

For the z-direction propagation wave. The total power in x-y plan can be divided into two power values: x-direction polarized z-direction propagation power (Pz-x) and y-direction polarized z-direction propagation power (Pz-y).

These Figures above indicate how the field distribution will be varied for the designed of nanoantenna, that is how the electric and magnetic field enhancements in the edge of the dipole nanoantenna , and the Poynting Vector tab is only available if we selected sufficient components in the Simulation Parameters dialog box to compute the Poynting vector.

Displays the output for the Far Field analysis tool as in Figure 1(e).

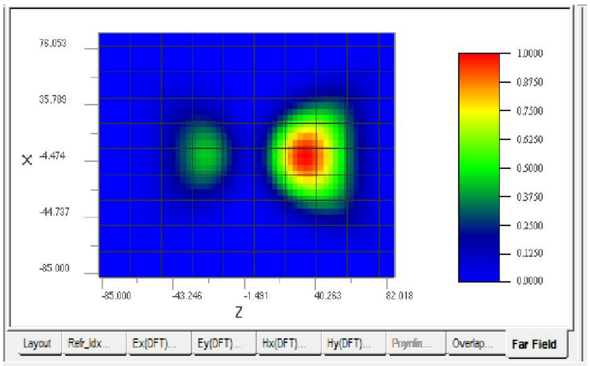
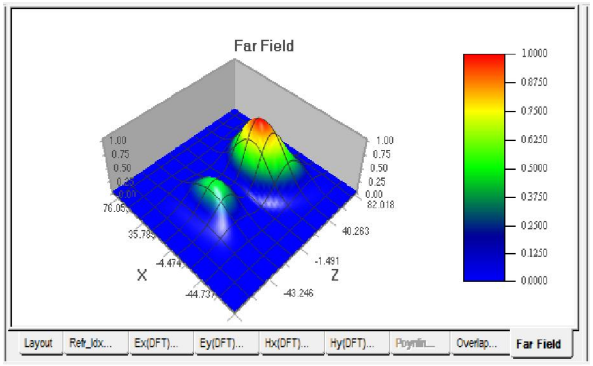


Image Map view



Height Plot view

Figure 1(e): Far field calculation result-Intensity.

The Figure 1(e) shows the far field distribution in the x-z plane . Far-field measurements of the transmission through the central dipole to show the presence of Fano-like interference effects resulting from the interaction of the dipole antenna with the surrounding nanoparticle arrays. (Fano interference is a general phenomenon in systems where energy transfer from an initial state to a final state can occur via two pathways, between the two excitation paths of the bow-tie, through direct illumination and through illumination by the scattered field of the surrounding nanoparticle arrays)[9].

3. Field enhancement for Dipole Nanoantenna at [Gap=(15,20,25,30)nm & Length=(240,280,320,360)nm]respectively.

The following Figure2(a-e) below shows the field enhancement effect for the dipole nanoanten na surface can be observed as we show in Figures of Dipole Nanoantenna at properties (G=10nm & L=200nm) .

G=15nm & L=240nm **G=20nm & L=280nm**
G=25nm & L=320nm **G=30nm & L=360nm**

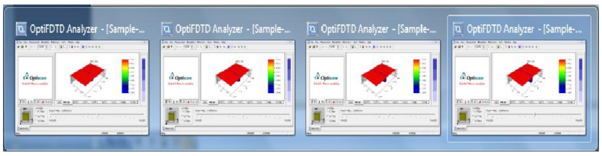


Figure 2 -a-Refractive index in x-z orientation.

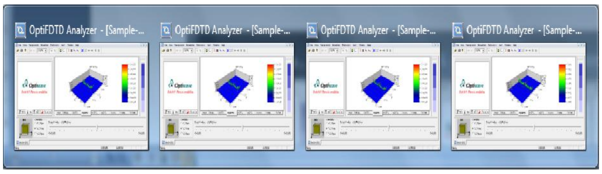


Figure 2 -b- Ey (Simulated) -Height Plot view.

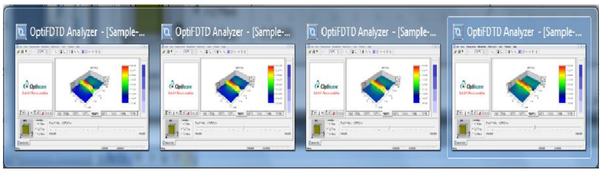


Figure 2-c- Hx (Simulated) -Height Plot view.

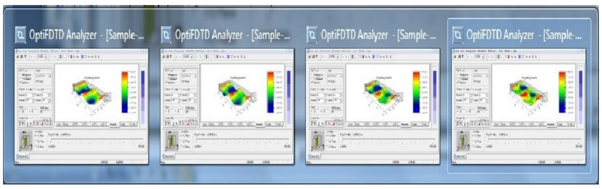


Figure 2 -d- Poynting vector in z-direction.

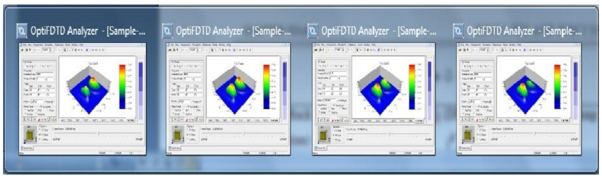


Figure 2 -e- Far field calculation result-Intensity-Height Plot view.

Feedback gap(nm)	Length (nm)	Ey (DFT)Amp (V/m)	Hx (DFT)Amp (A/m)
10nm	200 nm	0.4191	2.56 e-004
15nm	240nm	0.398	2.48 e-004
20nm	280nm	0.369	2.45 e-004
25nm	320nm	0.347	2.43 e-004
30nm	360nm	0.2981	2.43 e-004

Table -1- (E&H)-Field value at the edge of the dipole nanoantenna in different feedback gaps at wavelength= 0.55µm.

From the Figures above and table (1) we observe the electric and magnetic field values at Gap=(10,15,20,25,30)nm, Length=(200,240,280,320,360)nm at wavelength=550 nm are variable, we observe the electric and magnetic field intensity enhancement to dipole nanoantenna at (G=10nm & L=200nm), that when the gap between to rectangles decrease the value of electric and magnetic field intensity will increase.

In this paper, the two components of the dipole nanoantenna are placed close or far apart with different spacing. The gap lengths vary from 10 nm to 30 nm with an increment of 10 nm. As seen from Figures the antenna arrangement with narrower gap tends to exhibit higher light intensity. The intensity at resonance for nanoantenna with the separation gap of 10nm is much higher than those with gaps of 15 nm to 30 nm. This high value gained with the gap of 10 nm is maximum Ey = 0.4191 V/m and maximum Hx = 2.56 e-004 A/m, which is more than of other gaps.

4. Conclusions

This paper discusses various aspects related to the study of optical nano-antennas. We have discuss various aspects of analysis for (Dipole) Nanoantenn , where we found many of conclusions as follow :

1-The geometrical parameters (gap dimension, nanoantenna length nanoantennas) have influence on the antenna field enhancement and spectral response.

2-The simulation results are different to each (state) of design properties.

3-The field enhancement be bigger when the gap be very small at the dipole nanoantenna , where in the Gap=10nm the field enhancement more than of the Gaps (15, 20, 25, 30)nm respectively.

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