Evalution and Design of Omnidirectional Reflecional at 0.6328µm From single -Dimensional Photonic Crystal Structure Using ZEMAX software

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Abstract:

A theoretical investigation to design, analysis of the integral "omnidirectional Bragg reflector" Quarter wave optical thickness multilayerare described ,There Transfer matrix method (TMM) technique was used to investigate the structure's uniquely direction ,spectral performance in the visible zone (0.45 µm – 0.85 µm) . TiO_2andSiO_2 are high , low refractive index dielectric materials put on BK7 glass were chosen. It was demonstrated that using ZEMAX software, the evaluation and design of a wideband Bragg reflector from a 1D PC can be done quickly .

Keywords: (calculation, reflective design, multi-directional).

حساب وتصميم عاكس متعدد الاتجاهات عند طول موجي ٠.٦٣٢٨ مايكرومتر باستخدام بلورات فوتونية ذات بعد واحد وباستعمال برمجة الزيماكس

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الملخص:

تم اجراء دراسة نظرية لتصميم وتحليل عاكس متعدد الاتجاه "عاكس براك" ذات سمك ربع طول موجي .حيث أعتمدت على طريقة المصفوفة المنتقلة أو الانتقالية (TMM) لدراسة اداء هيكلية المنطقة الطيفية التي هي المنطقة المرئية حيث يمتد طولها حوالي (0.45 – 0.85)µm .تم اختيار مادتي تيتانيوم اوكسايد TiO_2 وسيلكون اوكسايد SiO_2 كمادتين عازلتين ذات معامل أنكسار عال والاخر واطئ على التوالي رسبت على مادة الزجاج BK7 كأساس . حيث بينت النتائج تصميم وحساب عرض حزمة عاكس متعدد الاتجاه من خلال بلوة فوتونية ذات بعد واحد بسهولة من خلال استخدام برنامج الزيماكس.

الكلمات المفتاحية: (حساب، تصميم عاكس، متعدد الاتجاهات).

Introduction

Lord Rayleigh, an English physicist, experimented with periodic multilayer dielectric stacks in 1887, demonstrating that they contained a photonic bandgap in one dimension[1]. The model calculation in Fig(1) shows how the optical response of a DBR changes as the number of building components increases. As the refractive index contrast or the number of layers increases, the reflection and transmission properties become more finely defined and frequency-dependent [2]

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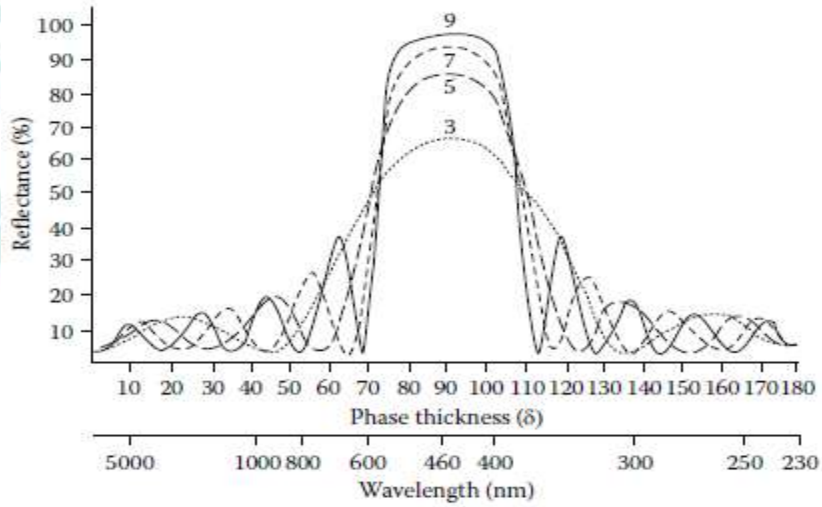

Fig.(1)Reflectance(R) for vertical incidence of every other λ/4 layers for H-index (n_H=2.3) and L - index (n_L=1.38) insulator substratum materials (n_{Sub}=1.52). On the curves, the number of layers is displayed as a parameter. [2].

The every other series of high , low refractive index layer forms dielectric grid, which can be viewed as a single-dimensional (1-D) photonic crystal. Photonic crystals are a novel family of optical materials with more than one dimension. The periodical adjustment of the dielectric provides potential landscapes that controls the diffusion paths a function of frequency of photons within the substance similar to electron propagation in atomic crystals [5]. These materials work by interacting with an optical domain and materials with periodic on the wavelength scale, which influences photon mobility in the selfsame way that ionic grid impact electrons in solid. The major property of PCs is that they can prevent electromagnetic waves from propagating within a specific frequency zone, known the photonic band gap (PBG) [5]

This idea was first introduced by Yablonovitch [3] and John [4] and has become a very active field of research ever since [5, 6-8].

Photonic crystals (P Cs) can be fabricated for 1, 2, or 3 dimensions ,as shown in Fig.(2) [5].

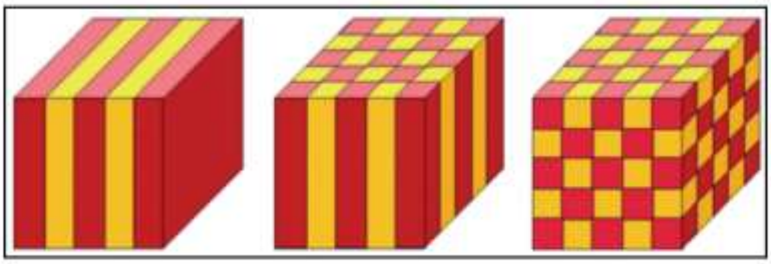

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Fig.(2) Simplified exemplification of 1-, 2- and 3-dimensional crystal [10]

Photonic crystals (PCs) may be considered as a new class of optical materials [5,12]. These materials work by interacting with an optical domin and material with periodic on the wavelength scale, which influences photon mobility in the selfsame path that ionic grids impact electrons in solid. The major merit of PC is that they can prevent electromagnetic waves from propagating within a specific frequency zone, known the photonic band gap (PBG) ,as shown in Fig.(3) , thus , controlling and manipulating light flow[5, 8]

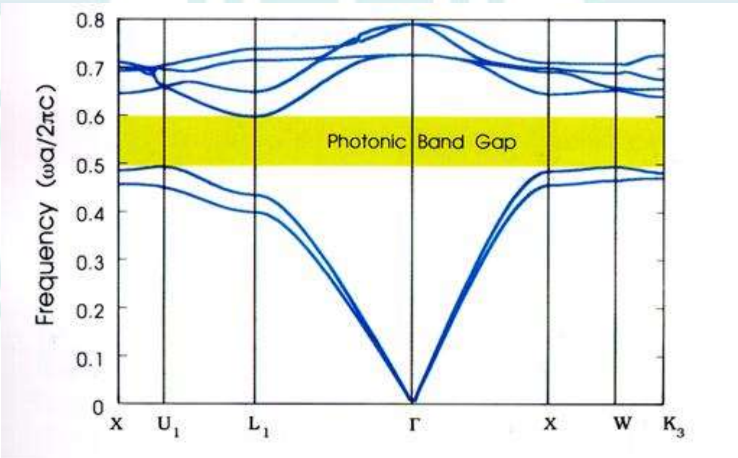


Fig (3) shows an example PBG. (On photonic band graph, the yellow shaded region depicts a photonic band gap.) The multiple directions of the crystal lattice are represented by the letters along the x axis [10]

A insulation mirrors, as well known a Braggreflector, is form of mirror coating made of two materials, one of which has a rising index and the other of which has a low index. The coats have a thickness a quarter wavelength at normal incidence. Can One create ultra- rising mirrors with reflective values of "99.990" percent or more throughout a restricted zone of wavelengths called bandstop [9] by carefully selecting the kind and thickness of the dielectric layers, as shown in Fig (4) The intervention of illumination reflected from the multiple layers of the insulation stack is how dielectric mirrors work [2]. Lasercavity end mirrors, cold and hot mirrors, thinfilm beamsplitters [2], and the coating on current mirrors shade [10,11] are examples of their usage .

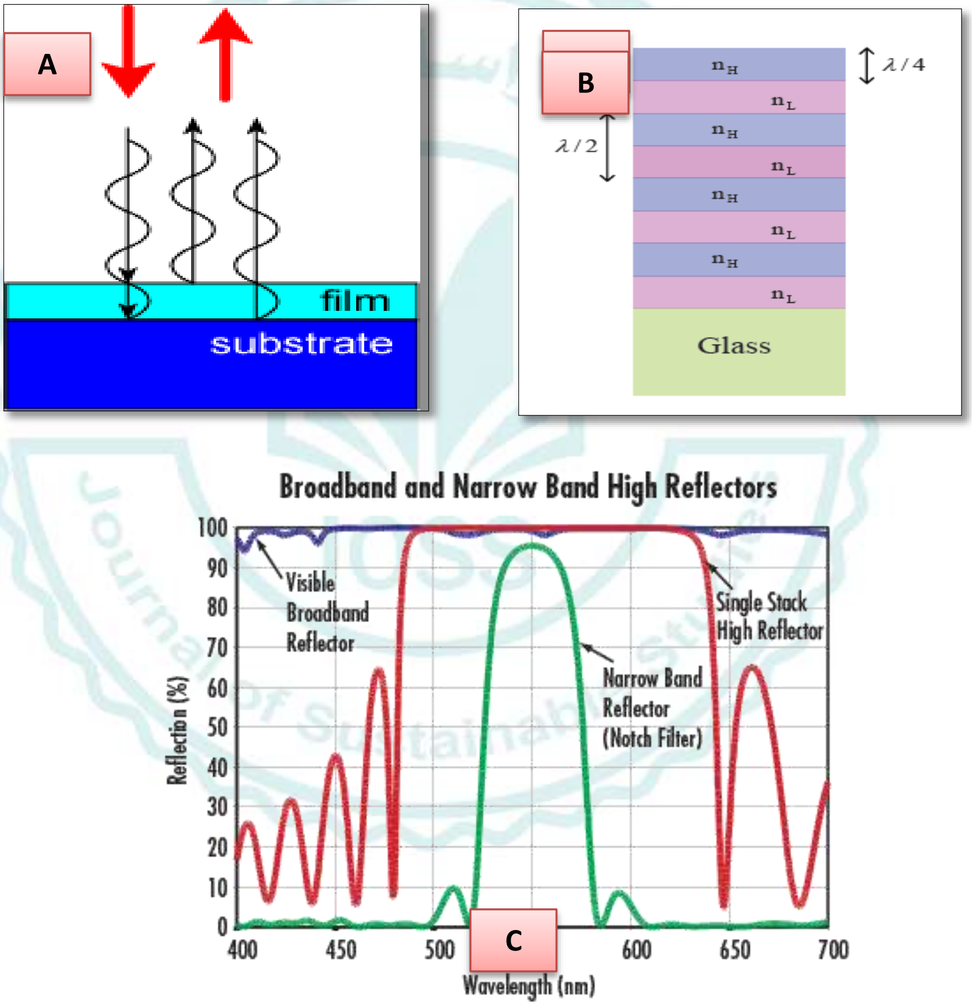


Fig. (4)Illustrations of dielectric mirror design concepts: (A) constructive interference between light reflected from close layers; (B) a quarter-wave stack [2]; and (C). High Reflectors for Broadband and Narrow Band[1].

A distributed Bragg mirror is another name for a Bragg mirror (DBR). Has a high reflective at a specific wavelength, which is known as the wavelength design. The photonic stopband[5] is the zone of wavelengths are reflected. Light is "forbidden" to propagate in the construction within this wavelength range. It possesses a full TE- band gap, but only a faux TM- band gap, according to DBR. Verticalcavity ,surfaceemitting lasers (VCSELs) and other, forms narrow-linewidth laser diodes[4,7], such as (DFB) ,and distributed Bragg reflector (DBR) lasers, rely heavily on distributed Bragg reflectors. They're also utilized in the fiber lasers and, free electron lasers to make the optical cavity [8]. In this paper investigate ZEMAX ability to design and evaluate the reflectance profile of distributed Bragg reflector based on one dimensional photonic crystal.Investigate "graphical method" to evaluate the photonic bandgab.

Theoretical Analysis

To date, electromagnetic waves have been propagated across a periodic layered media made up of every other layers of material with differing refractive index, Transfer matrix method (TMM) has been adopted to calculate the bandgap and reflectance of some 1D photonic crystal structures.

The transfer matrix method (TMM) based on the Maxwell equation and the boundary condition , the TMM has been widely using to evalution the light path amplitude, and phase spectral of the light wave propagate in a 1D photonic material , which is called a periodic multilayered structure. The sign + (i.e., positive - going) denotes the direction of incident waves, while the sign - (i.e., negative - going) denotes the inverse direction, as illustrated in Figure (5).

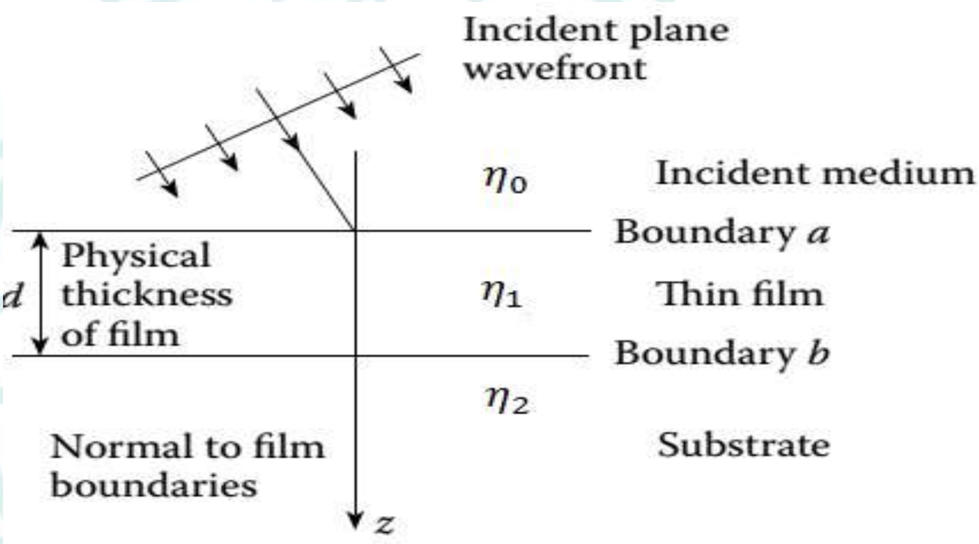


Fig (5) Plane wave fall on a thin film [2]

At film substrate interface (debitedby the symbol b) , Fig(2-1), The substrate has no negative-going waves, and the waves in film could be added together to provide once result pluse (+)-going wave and once result minus (-) -going wave. It is convenient to use special symbols for the tangent components of E and H, i.e. E and H, respectively[2], at this interface

$$E_b = E_{1b}^{\ +} + E_{1b}^{\ -} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$H_b = \eta_1 \times E_{1b}^{\ +} - \eta_1 \times E_{1b}^{\ -} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$H_{1b}^{\ -} = -\eta_1 \times E_{1b}^{\ -} = \frac{1}{2} \times (H_b - \eta_1 E_b) \ \ldots\ldots\ldots \quad (3)$$

$$E_{1b}^{\ +} = \frac{1}{2} \times \left(\frac{H_b}{\eta_1} + E_b\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots \ \ldots\ldots\ldots\ldots\ldots(4)$$

$$E_{1b}^{\ -} = \frac{1}{2} \times \left(\frac{-H_b}{\eta_1} + E_b\right) \quad \ldots\ldots\ldots\ldots\ldots \ \ldots\ldots\ldots\ldots\ldots(5)$$

$$H_{1b}^{\ +} = \eta_1 \times E_{1b}^{\ +} = \frac{1}{2} \times (H_b + \eta_1 E_b)$$

By changing the wave phase factors to account for change in the z- coordinate of zero into - d, the fields at the other interface at the same moment and at a place with similar x- coordinate and y- coordinate can be computed. The pluse-going wave's phase factor will be multiplied by exp(i δ) [2], where

$$\delta = 2\pi\left(\frac{n_1 d \cos\theta_1}{\lambda}\right) \quad . \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

–δ the "phase thickness", d is the layer's geometrical thickness, and θ_1 is the Snell Law's angle of propagation in the second medium .

$$n_0 \sin\theta_0 = n_1 \sin\theta_1$$

because of the tangent componentof "E" and "H" are continued across limit and that is however a pluse - going wave in thesubstrate, there relation connect the tangent component of "E", and "H" at the fall interface with tangent component of "E", and" H " are transmit through the last interface.

[13] Matrix notation, this may be written as

$$\begin{pmatrix} E_a \\ H_a \end{pmatrix} = \begin{pmatrix} \cos\delta & i\sin\delta/\eta_1 \\ i\eta_1\sin\delta & \cos\delta \end{pmatrix} \times \begin{pmatrix} E_b \\ H_b \end{pmatrix} \quad \ldots\ldots\ldots\ldots\ldots(12)$$

With δ and η being the matrix parameters depending on the incident angle of light the optical constant and the layer thickness η also known as the "effective index" optical admit and for layer and surrounding media , and connecting with electric and magnitude fields,

$$\eta = H / E \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

η has different forms for TE and TM polarized light ,i.e $\eta_0$andη_1 are active refractive index "optics admittance" for twice media, there are difference TE,andTM polarizion light where are:

$$\eta_{TE} = n \, . \cos\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(14)$$

$$\eta_{TM} = n/\cos\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

Where n denotes the refractive indcies and θ is an angle at which light strikes the layer or medium.

The produce of various matrix in the right sequence yields the characterize matrix.

$$\begin{bmatrix} B \\ C \end{bmatrix} = \left\{ \prod_{r=1}^{q} \begin{bmatrix} \cos\delta_r & (i\sin\delta_r)/\eta_r \\ i\eta_r \sin\delta_r & \cos\delta_r \end{bmatrix} \right\} \begin{bmatrix} 1 \\ \eta_m \end{bmatrix}$$

……………………….(16)

Under all incidence conditions, the high's transmission and reflection intensity, as well as the electric domin amplitude and phase revision, may be exactly estimated using equation (16) as a function of wavelength [14] and angle, i.e.

$$R = \left(\frac{\eta_{.0} - Y.}{\eta_{\cdot 0} + Y.}\right)\left(\frac{\eta_{.0} - Y.}{\eta_{.0} + Y.}\right)^{*}$$ ……………………………………(17)

For normal incident,the reflectance intensity as given

$$R = \left(\frac{n_0 - Y}{n_0 + Y}\right)\left(\frac{n_0 - Y}{n_0 + Y}\right)^{*}$$ ……………………………………(18)

There reflection (R) of TE while TM polarizat is :

$$R = \left(\frac{\eta_0 - \eta}{\eta_0 + \eta}\right) \times \left(\frac{\eta_0 - \eta}{\eta_0 + \eta}\right)^{*}$$ ………………………...(19)

Where there polarization of TE while TM, that study, ZEMAX software was used to analyze optical performance, which is formerly base on an elegantly method called the (TMM) [15]. An insulation quarterwave stack of alternative H- and L-refractive index material can be used to create a high-reflectance coating. There H-index layers are external on together side if $n_H$and n_L are index of the H- and L-indexlayers, and if stack is order. The transformation matrix for a stack of N quarterwave layers of H- and L- refractive index materials can written as

$[M]=[M_H]\ [M_L]$

Where [M] is characterize matrix of the basis,$[M_H]$the characterize matrix of the basis high refractive index stack and $[M_L]$the characterize matrix of the basis low refractive index stack [2].

$$[M]=\begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix} = \begin{pmatrix} \cos\delta_H & i\sin\delta_H/\eta_H \\ i\eta_H\sin\delta_H & \cos\delta_H \end{pmatrix}\begin{pmatrix} \cos\delta_L & i\sin\delta_L/\eta_L \\ i\eta_L\sin\delta_L & \cos\delta_L \end{pmatrix}$$

At quarter wave length

$$[M] = \begin{pmatrix} 0 & i/\eta_H \\ i\eta_H & 0 \end{pmatrix}\begin{pmatrix} 0 & i/\eta_L \\ i\eta_L & 0 \end{pmatrix}=\begin{pmatrix} -\eta_L/\eta_H & 0 \\ 0 & -\eta_H/\eta_L \end{pmatrix} \quad \ldots\ldots\ldots\ldots..(20)$$

Substituting the double-layer matrix equation (20)

$$[M]=(M)^S=(M_{H1}M_{L1})(M_{H2}M_{L2})\ldots(M_{HS}M_{LS})=(M_HM_L)^S \quad \ldots..(21)$$

Where $(M)^S$characteristic matrix of periodic multilayer is repeated S times.Substituting the equation (20) by (21) as given

$$[M] = \begin{pmatrix} (-\eta_L/\eta_H)^S & 0 \\ 0 & (-\eta_H/\eta_L)^S \end{pmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(22)$$

Then,the maximum reflectance for even layers (2S):

$$R_{\Lambda\,Max} = \left(\frac{(\eta_o/\eta_S)(\eta_L/\eta_H)^{2S} - 1}{(\eta_o/\eta_S)(\eta_L/\eta_H)^{2S} + 1}\right)_{\Lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots (23)$$

For normal incident, the maximum reflectance for even layers as given

$$R_{Max} = \left(\frac{(n_o/n_s)(n_L/n_H)^{2s} - 1}{n_o/n_s)(n_L/n_H)^{2s} + 1}\right)^2 \ldots \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

Where there are (2S+1) layers in the stack. Following the same mathematical steps, the reflectance for odd layers is then

$$R_{\Lambda\,Max} = \left(\frac{1 - (\eta_H/\eta_L)^{2S}(\eta_H^2/\eta_o\eta_S)}{1 + (\eta_H/\eta_L)^{2S}(\eta_H^2/\eta_o\eta_S)}\right)_{\Lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots (25)$$

For normal incident, the maximum reflectance for odd layers as given

$$R_{Max} = \left(\frac{1-(n_H/n_L)^{2s}(n_H^2/n_o n_S}{1+(n_H/n_L)^{2s}(n_H^2/n_o n_S}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

The limit condition between the stopandpass bands in H- reflectance coat can expressed by [2], which is well known.

$$\frac{M_{11}+M_{22}}{2} = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (27)$$

From equation (27) the condition can expressed as

$$-1=\cos^2\delta-\frac{1}{2}\left(\frac{\eta_H}{\eta_L}+\frac{\eta_L}{\eta_H}\right)\sin^2\delta_e$$

Because the two layers are of similar thickness, the phase thickness has been calculated without any suffix.

$$\frac{M_{11}+M_{22}}{2}=\cos^2\delta-\frac{1}{2}\left(\frac{\eta_H}{\eta_L}+\frac{\eta_L}{\eta_H}\right)\sin^2\delta$$

Where δ_e- the edge optical thickness , where

$$\Delta g=\frac{2}{\pi}\sin^{-1}\left[\frac{(n_H/n_L)-1}{(n_H/n_L)+1}\right] \quad \text{..................................(28)}$$

The equation (28) the width of the high-reflectance For normal incident, the offer of H- reflectance range , We observed the width of the high-reflectance zone of quarterwave stack depends on the rate (n_H/n_L) and angle of incidence [2],the width reflectance zone for TE-polarization

$$\Delta g_{TE}=\frac{2}{\pi}\sin^{-1}\left[\frac{n_H\cos\theta_H-n_L\cos\theta_L}{n_H\cos\theta_H+n_L\cos\theta_L}\right] \quad \text{.........................(29)}$$

For TM-polarization

$$\Delta g_{TM}=\frac{2}{\pi}\sin^{-1}\left[\frac{n_H\sec\theta_H-n_L\sec\theta_L}{n_H\sec\theta_H+n_L\sec\theta_L}\right] \quad \text{......................(30)}$$

There opticalthickness is oncehalf wavelengths in middle of stopband for best reflection (Braggcondition) from L and H- refractive index layers pair at given angle and polarization. [16]

$\frac{\lambda_c}{2}=n_L d_L + n_H d_H$ …………………………………….. (31)

For (TE-polarization) light was written as

$\lambda_c=[(1-\sin^2\theta_0/n_L{}^2)^{1/2}+(1-\sin^2\theta_0/n_H{}^2)^{1/2}]$ …………….. (32)

For TM-polarization light, λ_c also a decent approach for midle of reflection band [16]. The reflection band's edge λ_E is given by [16].

$\lambda_E = \lambda_c\ [1 \mp \Delta\, g_{?}]$ ……………………………………(33)

Δg can be evaluated for TE and TM polarization light using equation (33).The longer –wavelength edge of the omnidirectional reflection band is determined by the longer wavelengthλ_{Long}TM –reflection edge at 90^oangle of incidence which was called$\lambda_{Long}$and shorter –wavelengthλ_{short} reflection band edge at 0^o , which was called λ_{short}[16] . Thus

$\lambda_{Long} = (\lambda_c)_{90^o}[1 + (\Delta\, g)_{90^o}]$ ……………………… (34)

$\lambda_{Short} = (\lambda_c)_{90^o}[1 - (\Delta\, g)_{90^o}]$ ……………………….. (35)

As a result, the normalized omnidirectional band width $\Delta\lambda_{Omni}$ was defined as [17] with regard to the omnidirectional band's center wavelength λ_c.

$$\frac{\Delta\lambda_{Omni}}{\lambda_c} = 2\,\frac{\lambda_{long}^{TM}(90^o) - \lambda_{short}(0^o)}{\lambda_{long}^{TM}(90^o) + \lambda_{short}(0^o)} \quad \text{........................(36)}$$

Where the omnidirectional bandwidth is given by

$$\Delta\lambda_{Omni} = \lambda_{long}^{TM}(90^o) - \lambda_{short}(0^o) \quad \text{..........................(37)}$$

there middle wavelength of omnidirection band by given

$$\lambda_c = \frac{1}{2}\left[\lambda_{long}^{TM}(90^o) + \lambda_{short}(0^o)\right] \quad \text{.................... (38)}$$

$$B = 2 * \left(\frac{\frac{1}{2}\left[\frac{(n_H^2-1)^{\frac{1}{2}}}{n_H}+\frac{(n_L^2-1)^{\frac{1}{2}}}{n_L}\right]\left[1+\frac{2}{\pi}\sin^{-1}\left(\frac{n_H^2(n_L^2-1)^{\frac{1}{2}}-n_L^2(n_H^2-1)^{1/2}}{n_H^2(n_L^2-1)^{\frac{1}{2}}+n_L^2(n_H^2-1)^{1/2}}\right)\right]-\lambda_o\left[1-\frac{2}{\pi}\sin^{-1}\left(\frac{n_H-n_L}{n_H+n_L}\right)\right]}{\frac{1}{2}\left[\frac{(n_H^2-1)^{\frac{1}{2}}}{n_H}+\frac{(n_L^2-1)^{\frac{1}{2}}}{n_L}\right]\left[1+\frac{2}{\pi}\sin^{-1}\left(\frac{n_H^2(n_L^2-1)^{\frac{1}{2}}-n_L^2(n_H^2-1)^{1/2}}{n_H^2(n_L^2-1)^{\frac{1}{2}}+n_L^2(n_H^2-1)^{1/2}}\right)\right]+\lambda_o\left[1-\frac{2}{\pi}\sin^{-1}\left(\frac{n_H-n_L}{n_H+n_L}\right)\right]}\right) \quad (39)$$

For maximum omnidirectional bandwidth the low refractive index can be obtained from [17]

$$\frac{\partial}{\partial n_L}\left(\frac{\Delta\lambda_{Omni}}{\lambda_c}\right) = 0 \quad \text{.. (40)}$$

Which was found to be~ 1.5 at a fixed n_H value ($n_H \leq 2.264$).

Results and Discussion

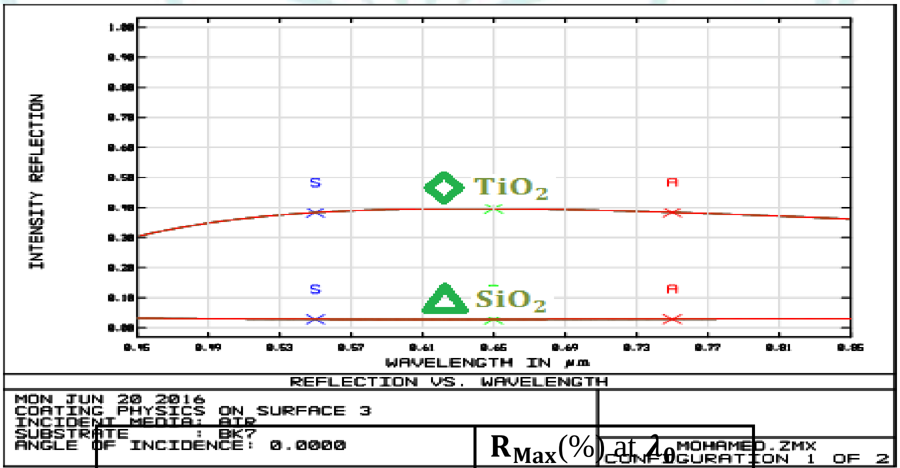
In the present work , ZEMAX software is used to computed the normal reflectance behavior over the visible spectral region, with design wavelength 0.6328µm.Results were compared to that obtained usin the equations (1) –(19) programed with the aid of MATLAB.Layer deposited as follows:

Air | H | glass

Air | L | glass

and the behavior were shown in Fig. (6) and Table (1):

"H" and "L" represent "high" and "Low" index material of QWOT,the optical thickness for each layer , i.e. $n_L d_L = n_H d_H = \frac{\lambda_0}{4}$. TiO_2 and SiO_2 were selected as high and low indices (n_H=2.58, n_L=1.46)at λ_0 =0.6328µm deposited on BK7glass of index (1.52) .The obtained result is considered as a building block for high reflectance mirror.



	R_{Max}(%) at λ_0
Design construction	

Fig (6) Reflectance of a QWOT single TiO_2 and SiO_2 dielectric layers deposited on BK7glass *vs.*wavelength for design wavelength of 0.6328 μm

	0.6328 μm
Air | L | glass	3.0
Air | H | glass	40.0

Table (1)R_{Max} of singleQWOT TiO_2 and SiO_2 dielectric layers deposited on BK7 glass.

The histogram (R-N) 3-D at normal reflectance in Fig. (7), as well as the results described in Table (2), show that there are "distributed Bragg reflectors" (D.B.R) at vertical incidence to span the visiblespectral area. The reflectional of a dielectric material stack was calculated using TiO_2as a H- index (nH=2.58) material and SiO_2as a L- index (nL=1.46) material. At there wavelength design of the laser line "λ_0 =0.6328μm"., the optical thickness of high and low materials was "Quarter wave optical thickness multilayer." rising the number of period for the specified design has the following effect:

$$Air[LH]^N glass \quad and \quad Air[HL]^N glass$$

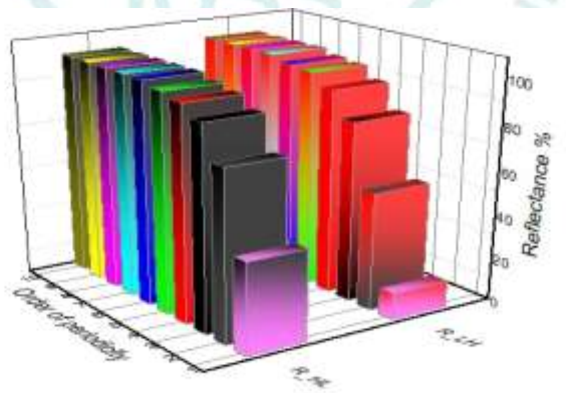


Fig.(7): (R-N) 3- D- histograms of vertical reflection *vs.* number of period for twice design: "Air[HL]^{N}glass and Air[LH]^{N}glass "

Table (2): vertical $R_{Max}$and band- width for design "Air|(HL)^N|Glass and Air|(LH)^N|Glass" at λ_0=0.6328μm .

Design construction	R_{Max} (%)	bandwidth(n.m)
"Air|(HL)^1|Glass"	73	____
"Air|(LH)^1|Glass"	50	____
"Air|(HL)^3|Glass"	94	322.4
"Air|(LH)^3|Glass"	90	____
"Air|(HL)^5|Glass"	98	286.3
"Air|(LH)^5|Glass"	96	295.8
"Air|(HL)^7|Glass"	100	268.7
"Air|(LH)^7|Glass"	98	271.9
"Air|(HL)^9|Glass"	100	255.4
"Air|(LH)^9|Glass"	100	258.6

Some data indicating these tendencies are given in Table (2). One sees that the reflectance quikly approaches 100% for several double layers and the reflectance approaches a " square –top " shape for a large number of layers. Outside the central bandstop , the reflectance oscillates betweena series of maxima and minima which increased in number when the number of layersincreased ,while the width of high reflectance zone is nearly independent of the number of double layers used but increases when the ratio n_H/n_L increases.

Fig.(8) illustrates the variation of η_{TM} and η_{TE}Versus material index n for three different selected angles of incident in air 0 , 45^o and 89^o. At normal incidence the relation between η and n are linear. At 45^o , n_{min}=1 , and this point has a zero slope on the η_{TM} curve. At high angles two refractive index values give the same η_{TM} results in zero R_{TM}. This is precisely the Brewster's condition that transmits the p-polarized light. This is an important result because it had been thought that Brewster's angle could not be met in a stack from an air interface. The minimum η_{TM} occurs at n_{min}=1.414, this is the source of omnidirectional bandwidth extreme .

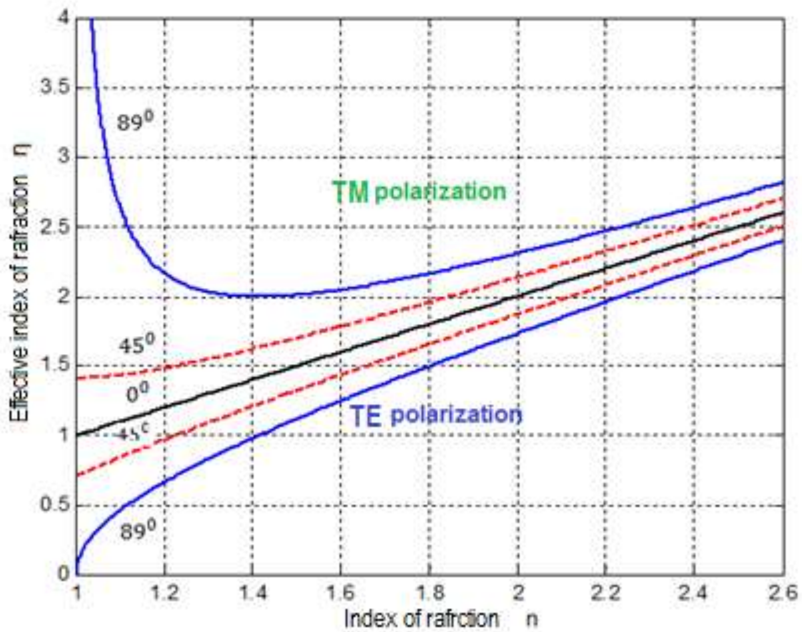


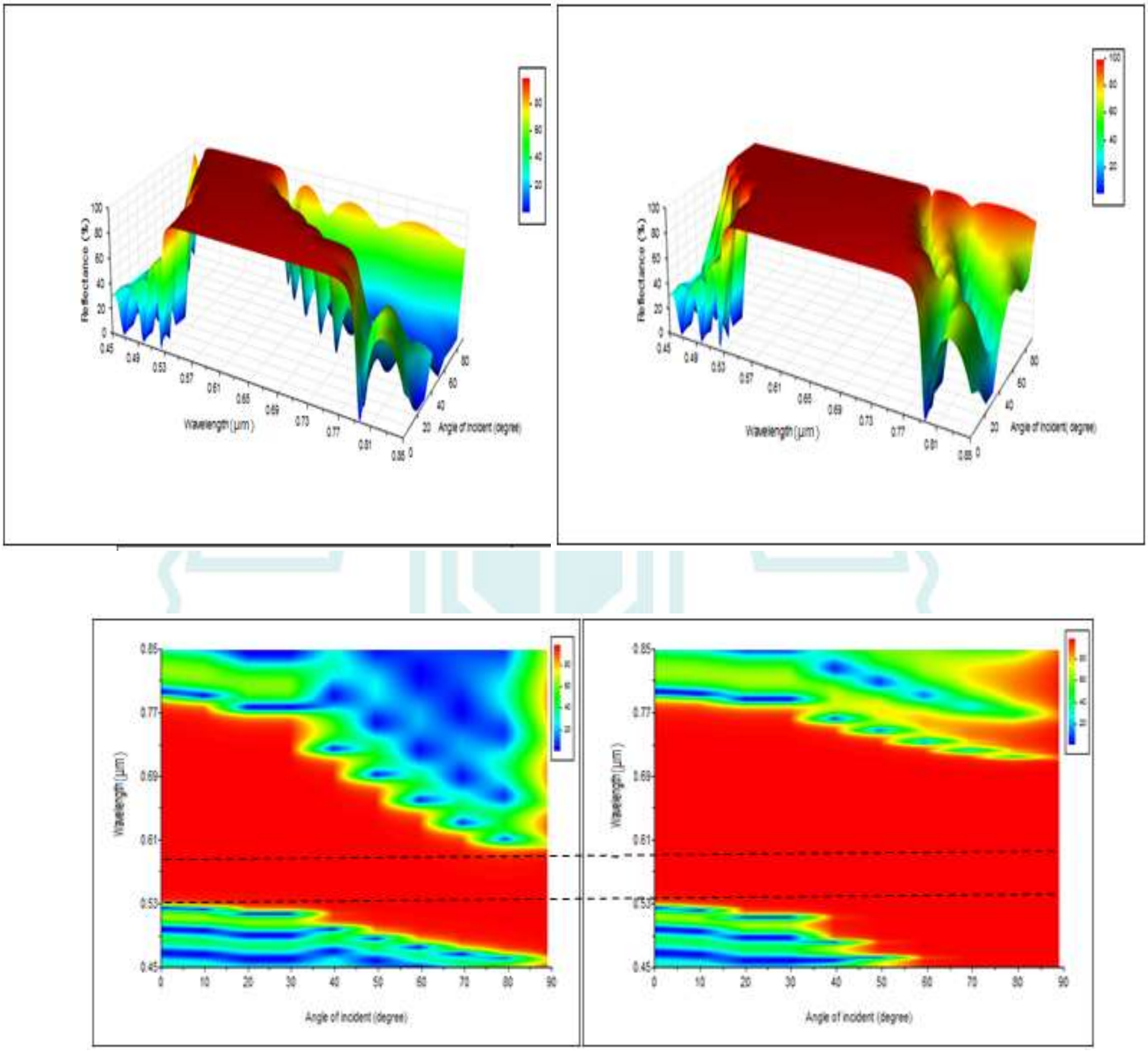
Fig.(8).Effective refractive index η_{TM} and η_{TE}vs. the material refractive indicesfor different angles of incidence in air.

We now,study 1D PC consisting of alternating layers of TiO_2 and $SiO_2$with nine-paired structure as a design $Air[LH]^9glass$ for visible region when design wavelength was 0.6328 .For this one dimensional photonic crystal$\theta_H^{Max} = \sin^{-1}({n_0}/{n_H})$=22.8° and29.5°and$\theta_B = \tan^{-1}({n_L}/{n_H})$=24.1° for 0.6328µm . Since $\theta_B > \theta_H^{Max}$, the effect of Brewster angle can be completely ignored. Fig.(9) the both design designs' ordinary photonicband construction forTE ,andTM polarizations:

$Air[HL]^9glass$ and $Air[LH]^9glass$

at 0.6328 µm, which can be calculated by projecting $R \approx 1$ For incidence angle θ_0 , the spectra are displayed in terms of wavelength. The banned band is represented by the red region, while the permissible band is represented by the other colored sections. The TODR band is the area between the two horizontal lines. Table (3) shows the data for the approximately 100% percent reflectance

Air[LH]^{10}glass at 0.6328μm



Fig(9) : Photonic band gap structure(TODR) of ten pair TiO_2/SiO_2 and SiO_2/TiO_2 for 0.6328 μm.

Table(3) Total reflection region and gap width for Air[LH]^{9}glass 1D PC at λ_0 =0.6328 µm

Incident angle (degree)	**TE polarization**		**TM polarization**	
	Reflection range (µm)	Gap width (nm)	Reflection range (µm)	Gap width (nm)
0	0.5250-0.7968	270.3	0.5250-0.7968	270.3
10	0.5223-0.7937	271.5	0.5223-0.7804	217.5
20	0.5129-0.7856	276.3	0.5180-0.7755	252.3
30	0.4087-0.7755	276.6	0.5103-0.7538	241.5
40	0.4805-0.7612	285.4	0.4971-0.7140	214.3
50	0.4615-0.7489	287.3	0.4864-0.6923	203.5
60	0.4430-0.7345	291.2	0.4752-0.6611	182.7
70	0.4281-0.7222	293.3	0.4675-0.6309	162.2
80	0.4158-0.7140	298.1	0.4611-0.61111	150.3
89	0.4138-0.7120	298.2	0.4612-0.6022	140.9

The omnidirectional reflection for TM polarization is achieved at an angle of incidence of 89^o degrees and has a range of 0.5250µm to 0.6022μm for λ_0 =0.6328 µm. As a result, omnidirectional reflectance both polarization TE and TM of the proposed 1D PC is produced at an angle of incidence of 89^o degrees, covering the wavelength range λ_H = 0.6022µm to λ_L= 0.5250 µm, with a bandwidth of $\Delta\lambda$=(λ_H+ λ_L) =1.1272nm. At a central wavelength of λ_C=560.7nm, the normalized omnidirectional bandwidth is equal to 13.25% percent.

Conclusion

Instead of employing Bloch theorem and based on Transfer matrix approach, ZEMAX poragram followed by graphic approach may now be considered an alternative good approach to directly evaluate photonic bandgap (TMM). These may be easily examined, as can the design and evaluation of a wide band Bragg reflector.

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