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Design and improvement high pass filters for microwave region

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ABSTRACT

In the present work theoretically optimization design of wide and narrow band pass filters have been suggested over the range (8.5-11.5)$\times 10^6$ nm.) within Microwave region to use in modern optical laser system. These design based on quarterwave stack, for the numerical calculation, we used Sio_2 as the substrate, Zinc oxide (Zno) and Silicon Si) as low and high refractive index respectively. For the normal incidence at the wavelength design 10$\times 10^6$ nm, the results shows that the transmittance for the suggested design, $(A/(HL)^Z HH(LH)^Z/Sio_2)$, was (99.99 %). Also the number of order and the effect of incidence angle were investigated. The results shows that the transmittance maximum value at Z=2 and the full width at half maximum decreases in the normal incident .while when the angle of incidence increase the transmittance of Electric polarization(TE) will decreases and the transmittance of Magntic polarization(TM) increase with shifting of wavelength design toward shorter wavelengths of electromagnetic spectrum.

Introduction

A filter which possesses a region of transmission bounded on either side by regions of rejection is known as a bandpass filter. Band-pass filters can be very roughly divided into broadband-pass filters and narrowband-pass filters.

There is no definite boundary between the two types and the description of one particular filter usually depends on the application and the filters with which it is being compared [1]. The most complete information on the performance of a filter is provided by spectral transmittance (T), reflectance (R), absorbance (A), and optical density [2]. By a careful choice of the exact composition, thickness, and the number of coating layers, it is possible to extend the reflectance and transmittance of the coating to produce almost any desired characteristic [3].

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Single cavity band pass filters have a triangular shape with high transmission at the center wavelength of the spacer. The bandwidth of the filter is determined by the relative indices of the materials, the material chosen for the spacer layer and the number of layers, or periods, in the mirror structures [4]. Multilayer coatings are necessary to produce antireflection (AR) systems, several thin film deposition techniques such as thermal oxide growth, vacuum sputtering, can be used to produce the multilayer stacks. Most of these methods allow the production of high quality interference filters but the production costs are relatively high [5]. Band pass filters (BPF) are key devices in communication systems [6]. Band pass filters serve a variety of functions incommunication, radar and instrumentation subsystems. Of the available techniques for the design of band pass filters, those techniques based upon the low pass elements of a prototype filter have yielded successful results in a wide range of applications [3]. The aim of this work is to Design and improvement high pass

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filters for microwave region suggestion designs using computer program (mat lab 7) .

2. THEORETICAL BASIS

Suppose that a plane electromagnetic wave with wavevector **k** and electric field amplitude $\mathbf{E}_0$ is incident on a plane surface separating isotropic media with refractive indices n_1 and n_2.At normal incidence, the reflection and transmission coefficients are given by[7,8]:

$$r = \frac{n_1 - n_2}{n_1 + n_2} \qquad (1)$$

The reflectance given by:

$$R = rr^* = |r|^2 \qquad (2)$$

$$R = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)\left(\frac{n_1 - n_2}{n_1 + n_2}\right)^* \qquad (3)$$

The reflectance of an assembly of thin films is calculated through the concept of optical admittance we replace the multilayer by a single surface which presents an
admittance Y, which is the ratio of the total tangential magnetic and electric fields and is given by:

$$Y = {}^{C}/_{B} \qquad (4)$$

Where

$$\begin{bmatrix} B \\ C \end{bmatrix} = \left\{ \prod_{r=1}^{q} \begin{bmatrix} \cos\delta_r & (i\sin\delta_r)/\eta_r \\ i\eta_r \sin\delta_r & \cos\delta_r \end{bmatrix} \right\} \begin{bmatrix} 1 \\ \eta_m \end{bmatrix} \qquad (5)$$

$\delta_r = 2\pi N d\cos\vartheta/\lambda$ and η_m = *substrate admittance*.Where η_r tilted optical admittancewhich is given by:

$$\eta_r = \frac{N\gamma}{\cos\vartheta} \text{ for p-waves }, \eta_r = N\gamma\cos\vartheta \text{ for s-waves}$$

is the optical admittance of free space ,N is therefractive index. The order of multiplication is important. If q is the layer next to the substrate then the order is

$$\begin{bmatrix} B \\ C \end{bmatrix} = [M_1][M_2]\ldots[M_q]\begin{bmatrix} 1 \\ \eta_m \end{bmatrix} \qquad (6)$$

M_1Indicates the matrix associated with layer 1, as in the case of a single surface, must be real for reflectance and transmittance to have a valid meaning. With that proviso, then [1]

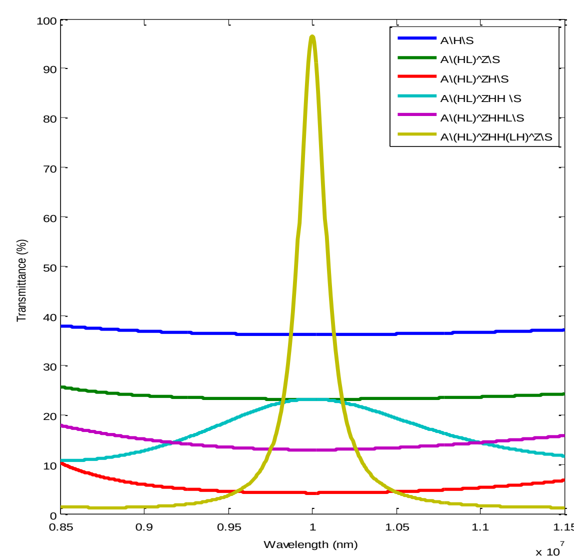
$$R = \left(\frac{\eta_0 B - C}{\eta_0 B + C}\right)\left(\frac{\eta_0 B - C}{\eta_0 B + C}\right)^* \qquad (7)$$

This concept is used to calculate the reflectance of an assembly of thin films and the transmittance and derived through the relationship of (T=1-R), the expression for transmittance and phase changes on reflection are given respectively as follow [1]:

$$T = \frac{4\eta_0 \,\mathrm{Re}(\eta_m)}{(\eta_0 B + C)(\eta_0 B + C)^*} \qquad (8)$$

3. RESULTS AND DISCUSSION

Figure (1) shows Transmittance as a function of wavelength of normal incident for the suggestion designs. This suggestion design Implemented on MATLAB program, this program depends on refractive index of materials (coating) and number of layers, where H and L are materials with high and low refractive index. For the numerical calculation, , the coating consist from SiO_2 with refractive index (n=1.45) as the substrate, we used Silicon(Si) as the high refractive index (n=3.6) and Zinc Oxide(Zno) as low refractive index (n=2).



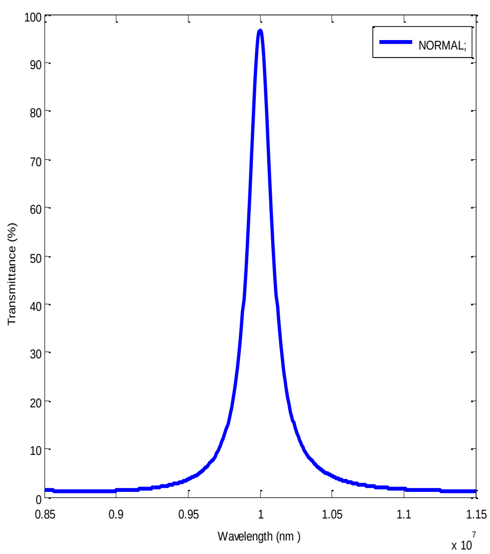
Figure(1) Transmittance as a function of wavelength for suggestion designs

Transmittance T% at $\theta = 0^{\circ}$	The Design	Number of design
36.2	A/H/Sio_2	1
23.14	A/$(HL)^Z$/Sio_2	2
4.174	A/$(HL)^Z$H/Sio_2	3
23.14	A/$(HL)^Z$HH/Sio_2	4
12.91	A/$(HL)^Z$HHL/Sio_2	5
96.63	A/$(HL)^Z$HH$(LH)^Z$/Sio_2	6

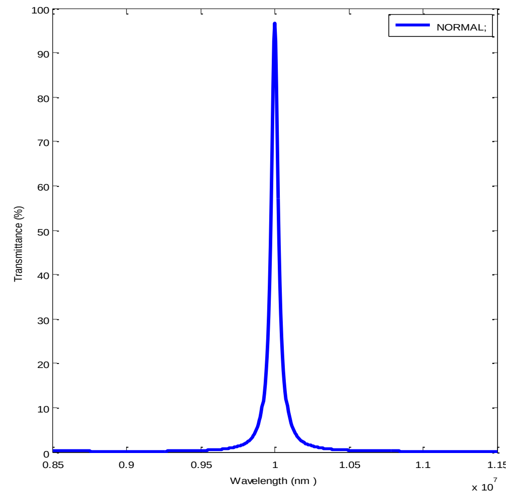
Now we take the suggestion design (A/$(HL)^Z$HH$(LH)^Z$/Sio_2) and change the number of layers order (Z) to know the effect on the transmittance and Bandwidth.

From figure 2 we find the transmittance Increase when the number of layers Increase and the Bandwidth decrease when the number of layers Increase.

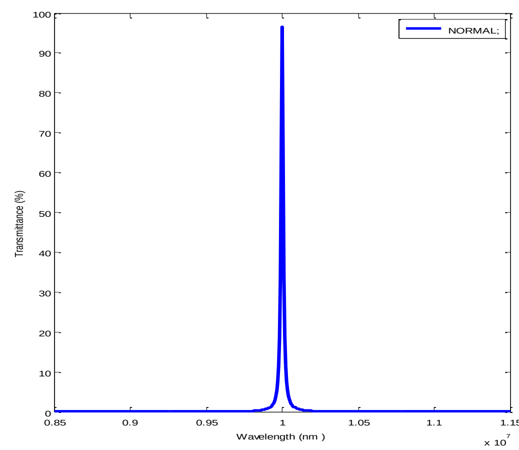
The most common technology for performing such a task uses optical interference filters [1]. Such filters are obtained by optical coating technology, i.e.deposition of a sequence of low and high refractive index materials on top of a substrate. However, in order to achieve complex functions with high efficiencies, it is required to deposit several hundreds of layer resulting in very thick stacks which are very sensitive to errors of depositions [9].



Z=2 a



Z=3 b



Z=4 c

Figure(2)Transmittance as a function of wavelength at Z=2,Z=3,Z=4 At Normal Incident

Now we studying the effect of the change of the incident angle on the Transmittance as a function of wavelength, from figure 3 and we find when the incident angle increases we can discrimination between a typical polarization (magnetic polarization (TM) and electric Polarization (TE)). When the incident angle increase the magnetic polarization (TM) increases and the electric Polarization (TE) decreases depending on the phase thickness as equation ($\delta_r = 2\pi N d \cos\theta/\lambda$) from figure we find also when the incident angle increases bandwidth of TM polarization is wider than that at normal incidence, and that of TE polarization is narrower.

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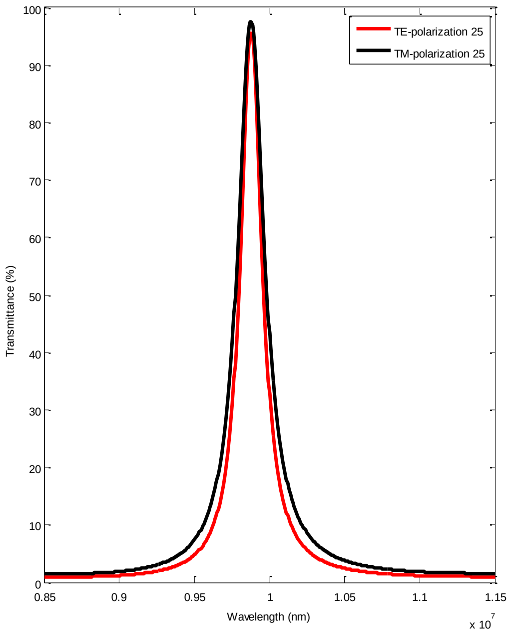

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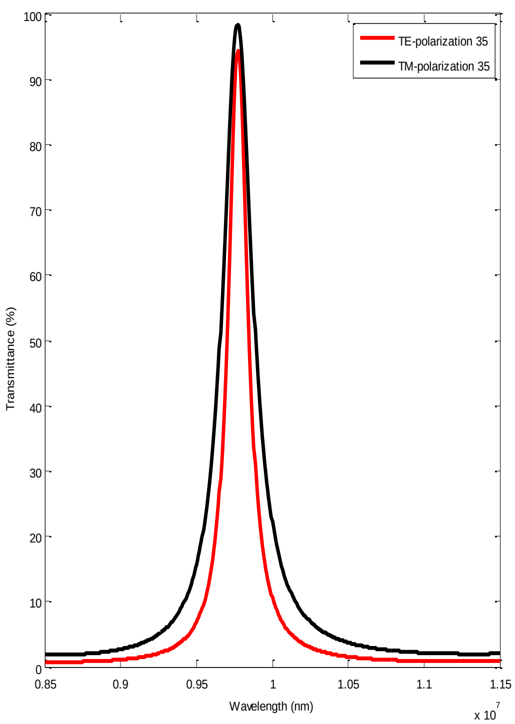

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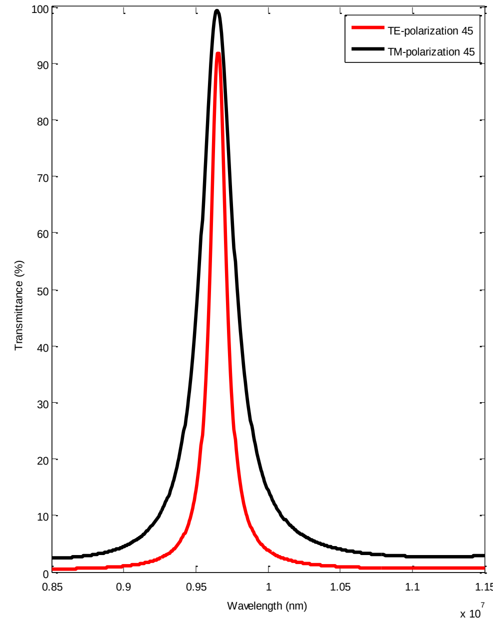

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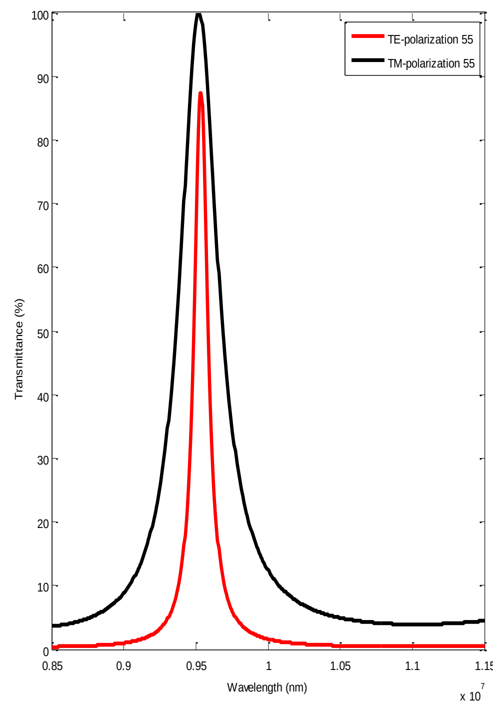

d

Transmittance as a function of wavelength at the Incident of angle ($25°, 35°, 45°, 55°$)

Table (1) Suggestion designs of band pass filter for incident angle (25°, 35°, 45°, 55°)

Coatings	Substrate	Number of layers (Z)	Angle of Incident	Wavelength ($\times 10^6$)nm	Transmittance T%
Si Zno	Sio2	2	0°	10	96.63
Si Zno	Sio2	2	25°	9.88 9.88	TE=95.55 TM=97.44
Si Zno	Sio2	2	35°	9.776 9.772	TE=94.26 TM=98.36
Si Zno	Sio2	2	45°	9.656 9.648	TE=91.96 TM=99.36
Si Zno	Sio2	2	55°	9.536 9.52	TE=87.58 TM=99.99

4. CONCLUSION

Theoretically optimization design of wide and narrow band pass filters have been suggested over the range (8.5-11.5)$\times 10^6$ nm.) within Microwave region to use in modern optical laser system.By using optical material Zinc oxide (Zno) and Silicon (Si) as a low and high refractive index respectively to coated Sio2 as a substrate. The results shows that, the transmittance 99.99 % for the design $A/(HL)^Z HH(LH)^Z/Sio_2$) of angle incidence effect on filter shows shift in reference wavelength to toward the shorter wavelengths of electromagnetic spectrum with an increase of incident angle. Also ,when the incident angle increase the transmittance of P- polarization increase with increase in the full width at half maximum while the transmittance of S- polarization decrease with decrease in the full width at half maximum.

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تصميم وتحسين مرشحات ذات ترددات عالية للموجات الدقيقة

سعاد إبراهيم عواد حمودي العاني أ.د. سعيد نايف تركي الراشد

الخلاصة:

تم في هذه الدراسة النظرية في تصميم وتحسين مرشحات ذات ترددات عالية للموجات الدقيقة واسعة وضيقة النطاق ضمن المدى المقترح بين $(8.5-11.5)10^6$نانومترالتي تستعمل في انظمة الليزرات البصرية الحديثة .ويستند هذا التصميم في حساباته العددية بتكديس عدد من الطبقات بربع طول موجة التصميم حيث استعملنا الاساس Sio_2 والمادتين Zno و Si كطلاءات ذات معامل انكسار واطئ وعالي على التوالي. لحالة السقوط العمودي عند طول موجة التصميم (10×10^6)نانومتر. حيث اظهرت النتائج ان النفاذية للتصميم المقترح $(A/(HL)^Z HH(LH)^Z/Sio_2)$ تساوي (99.99%) مع الاخذ بنظر الأعتبار تأثير زاوية السقوط وعدد الطبقات. النتائج تبين ان قيمة النفاذية تبلغ اعظم قيمة لها عند Z=2يصاحبه نقصان في عرض حزمة المنتصف في حالة السقوط العمودي .وانه عند زيادة زاوية السقوط نلاحظ ان قيم النفاذية الناتجة عن الاستقطاب الكهربائي (TE) تقل بشكل واضح على العكس من قيم النفاذية الناتجة عن الاستقطاب المغناطيسي (TM) التي تزداد تدريجيا مع ملاحظة ان هناك ازاحة جانبية لطيف النفاذية نحو الاطوال الموجية القصيرة من الطيف الكهرومغناطيسي.