

## DESIGN HIGH REFLECTION MIRRORS FOR VISIBLE LASER BY USING DIELECTRIC MATERIALS

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### Abstract

Design and manufacture of high reflectance He: Ne laser mirrors have been fulfilled. Dielectric materials such as zinc sulfide and Magnesium fluoride are used as high and low index materials to obtain of low losses laser mirrors. To obtain high reflectance, the sequences are arranged in stacks of quarter-wave of alternative high and low index. The two materials show a large difference in refractive index to obtain high reflectance value with the least number of layers. Any addition of layers does not effect the zone of high reflectance.

### Introduction

Laser normally incorporates a resonator with two mirrors; at least one of them has a finite. Transmitting for laser beam, in most cases thin evaporated films are essential parts of these mirrors and their properties are important for the performance of the laser.

In the early stages of laser development, evaporated metal films have been used as mirror coating [1], and often metal films are not acceptable because of their high absorption and sensitivity to oxidation [2]. Also most metal films are rather softer than hard dielectric films. This is a serious disadvantage especially when periodic cleaning of mirrors is necessary. One solution is periodic recoating. An alternative, which improves the robustness of the coating and also protects them atmosphere corrosion is over coating with additional dielectric layers. Also it is possible to increase the reflectance of a simple metal layer by boosting it with extra dielectric layers [3], due to the inherent absorption of metal films they have been replaced by dielectric mirrors, consisting of stacks of films with alternative high and low refractive indices [1].

These new types of reflecting, the all dielectric multilayer has been developed to meet the performance to be obtained in a multiple- beam systems using the highest quality optical components. The high reflectance can be obtained from a stack of quarter-wave dielectric layers of alternate high and low index, this is because the beams

reflectance from all the interfaces in the assembly are of equal phase when they reach the front surface where they combine constructively[3].

The optical performance of a multilayer depends on the number of constituent, on their thickness and optical constant of the film and on the optical constant of the substrate and the medium [4]. This stack exhibits high reflectance at the center wavelength where the optical thickness is equal to  $\lambda/4$ , and shorter wavelength where the optical thickness is equal to  $3\lambda/4$ ,  $5\lambda/4$ , ... etc.

### Theoretical Design

A design of high reflection mirrors was based on the quarter-wave stack usually consists of the layer sequences [5]:

Incident medium [basic period]<sup>N</sup> substrate

In which the basic period is repeated N times. The design of quarter-wave stack was easily described in a notation in which (H) represents a high index layer of quarter-wave optical thickness (QWOT) and (L) layer of the same optical thickness with low index .i.e.

:

AIR (HL)<sup>N</sup> QUARTZ

To compute the reflectance (R) of such a multilayer [2, 5] the transfer matrix is used. The theoretical analysis based on electromagnetic theory shows that for normal incidence of light, the reflectance (R) and transmission (T), of such a stack is given by the following expression [2,6]:

$$R = \frac{n_0 - Y}{n_0 + Y}$$

And  $T=1-R$ . These expressions are true an absorption free multilayer stack deposited upon transparent substrate of refractive index  $n_0$ .

$Y=C/B$  was known as the optical admittance [2, 6] of the stack (or assembly) and

$$\begin{pmatrix} B \\ C \end{pmatrix} = \begin{pmatrix} M11 & M12 \\ M21 & MM22 \end{pmatrix} \begin{pmatrix} 1 \\ n_s \end{pmatrix} - 1$$

where

$$\begin{pmatrix} M11 & M12 \\ M21 & MM22 \end{pmatrix} = \prod_{r=1}^q \begin{pmatrix} \cos \delta r(\lambda) & i \sin \delta r(\lambda) / n_r \\ i n_r \sin \delta r(\lambda) & \cos \delta r(\lambda) \end{pmatrix} - 2$$

$$i = \sqrt{-1}$$

$\delta r$ : is the phase thickness of the r layer

$\delta r(\lambda) = 2\pi n_r d_r / \lambda$  for normal incidence of light.

### Results and Discussion

The simplest effective analytical method was that first proposed by Turner and Baumeister [5] by a placing a quarter – wave stack for one wavelength on the top of another for another for a different wavelength. In their improvement the reflectance wavelength for each stack was adjusted to make their high reflectance bands either contiguous or overlapping on a wavelength or frequency scale. Turner and Baumeister adopt both characteristic matrix [5, 7] and the equivalent layer theories for the quarter-wave stack (1:1) stack.

As: Air [HL]<sup>N</sup> Quartz

$N=1$  to  $20$ ,  $n_H(\text{ZnS})=2.35$ ,  $n_L(\text{MgF}_2)=1.35$ ,  $n_S(\text{Quartz})=1.48$ ,  $n_0(\text{air})=1$ , and  $\lambda_0=632\text{nm}$ , in visible region,  $\lambda=400\text{-}1100\text{nm}$

From results will note that

- a- If the outer layer is low refractive index the curve of reflectance will be fall into design wavelength because the change of phase is  $(\pi)$ , as shown in Figs. (1, 3, 5).
- b- If the outer layer is high refractive index the curve of reflectance will be high at design wavelength because no change in phase as shown in Figs. (2, 4, 6) Note Tables (A, B)

**Table (A)**  
**Show the max & min reflectance**

Design	R extreme(%)either min or max at $\lambda_0=632\text{nm}$		No. of Figure
Air[L]Quartz	R min	1.0758	1
Air[HL]Quartz	R max	40.363	2
Air[LHL]Quartz	R min	17.82	1
Air[HL] <sup>2</sup> Quartz	R max	74.45	2
Air L[HL] <sup>2</sup> Quartz	R min	58.28889	3
Air[HL] <sup>3</sup> Quartz	R max	90.7318	4
Air L[HL] <sup>3</sup> Quartz	R min	83.756	3
Air[HL] <sup>4</sup> Quartz	R max	96.68	4
Air L[HL] <sup>4</sup> Quartz	R min	94.3178	3
Air[HL] <sup>5</sup> Quartz	R max	98.945	4
Air L[HL] <sup>5</sup> Quartz	R min	90.089	3
Air [HL] <sup>6</sup> Quartz	R max	99.65	4
Air L[HL] <sup>6</sup> Quartz	R min	99.36	5
Air [HL] <sup>7</sup> Quartz	R max	99.8847	6
Air L[HL] <sup>7</sup> Quartz	R min	99.79	5
Air [HL] <sup>8</sup> Quartz	R max	99.962	6
Air L[HL] <sup>8</sup> Quartz	R min	99.79	5
Air[HL] <sup>9</sup> Quartz	R max	99.987	6
Air L[HL] <sup>9</sup> Quartz	R min	99.977	5
Air [HL] <sup>10</sup> Quartz	R max	99.995	6

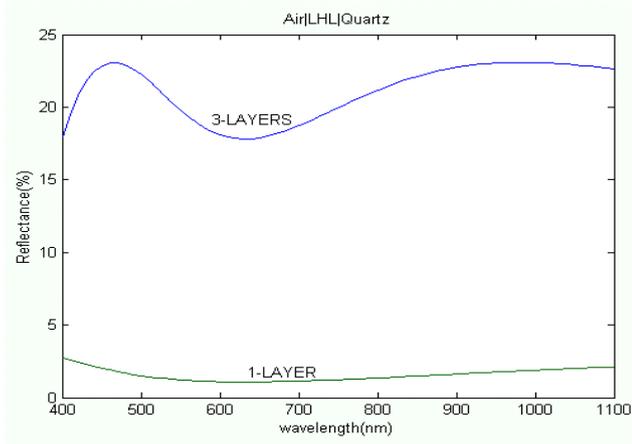


Fig.(1) : Reflectance for 1-3 layers.

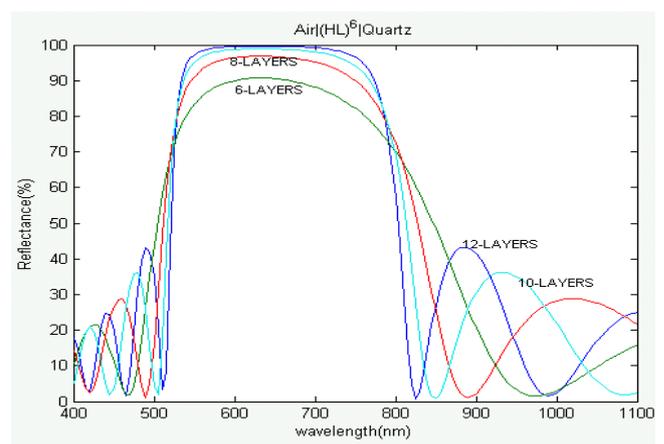


Fig.(4) : Reflectance for 6-8-10-12 layers.

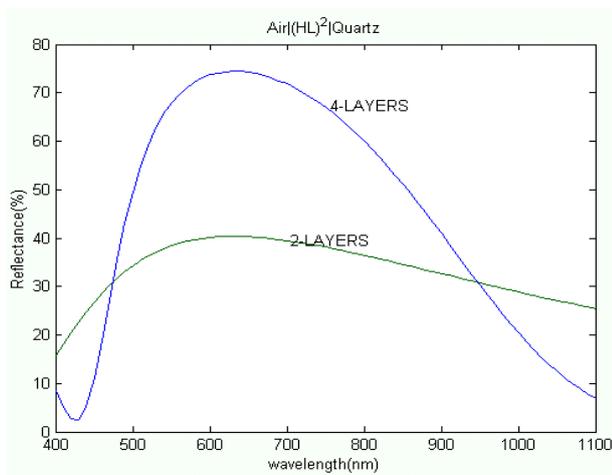


Fig.(2) : Reflectance for 2-4 layers.

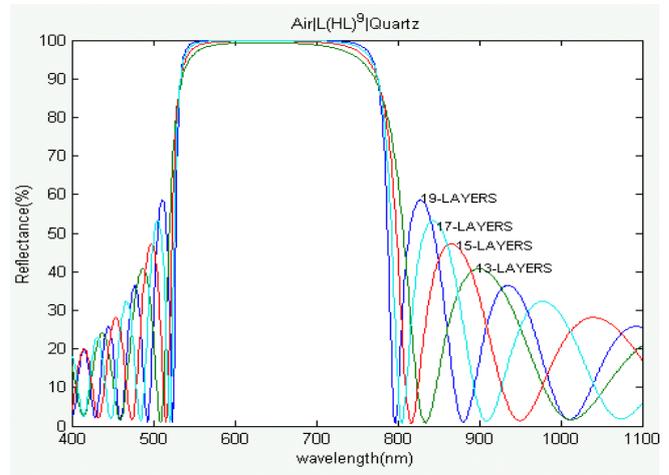


Fig.(5) : Reflectance for 13-15-17-19.

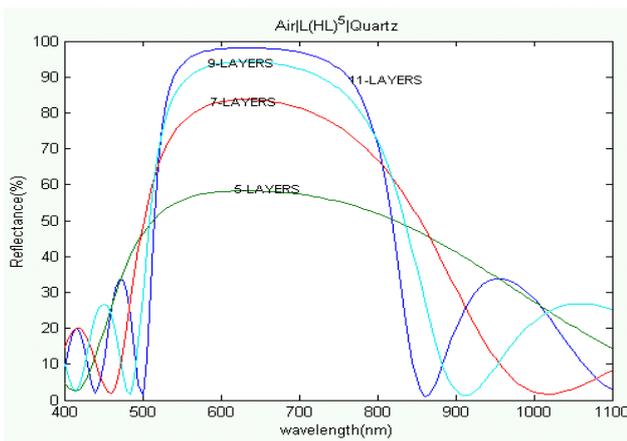


Fig.(3) : Reflectance for 5-7-9 layers.

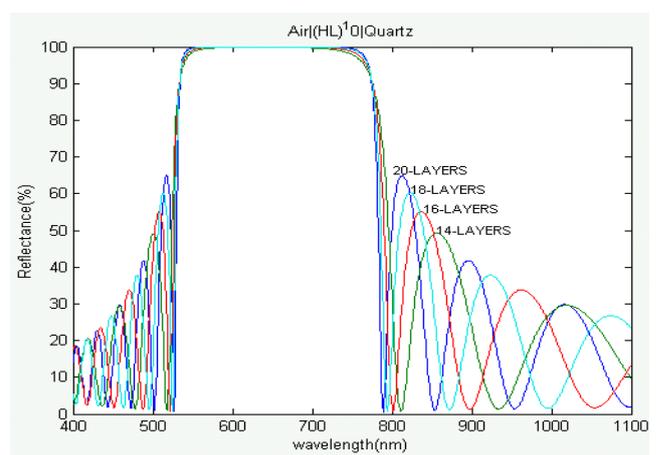


Fig.(6) : Reflectance for 14-16-18-20.

## الخلاصة

## Conclusion

From above results can be concluding the following:

- 1-At the design wavelength ( $\lambda_0$ ), the reflectance has a maximum value, depending on both optical thickness of layers and their refractive indices ratio, in addition to the number of layers.
- 2-The addition of layers does not affect the width of the zone of high reflectance, but increases the reflectance with in it and the number of oscillations outside.
- 3-The width of the zone is a function only of the indices of the two materials used in the construction of the multilayer the higher the ratio is the greater the width of the zone.

## References

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تصميم وصناعة مرايا ذات انعكاس عالي لليزر Ne-He أنجزت. المواد العازلة مثل الخارصين sulfide وفلوريد مغنيسيوم استعملت كمواد دليل عالية ومنخفضة للحصول على مرايا ليزر ذو الخسائر المنخفضة. للحصول على عكس عالي، السلاسل مرتبة في أكوام رُبْع موجة المستوى ذات الترتب العالي و المنخفض. المادتان توضح إختلاف كبير في دليل الانعكاس للحصول على قيمة انعكاس عالية بأقل عدد الطبقات.