Multilayer dielectric narrow band mangin mirror

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Abstract. The design of multilayer stack of dielectric films for narrow band mirror is developed using thin film coating software. The proposed design is materialized by employing thin film coating (PVD) method and reflectance in narrow band spectrum range is achieved. Thickness of high and low refractive index material is taken precisely up to nanometer level. The curved coated substrate is cemented with another K9 matching substrate that forms a Mangin mirror for wavelength 650nm. Narrow band mirrors with reflectivity more than 90% has been produced by properly stacking of 21 layers and advantage of the use of this type of mirror as an interference filter is discussed.

1. Introduction
In mid 60s the use of lasers has been increasing that demand for high quality multilayer dielectric narrow band mirrors [1-3]. Technology evolution for small size diode laser has created further demand of the dielectric narrow band stop filter [4]. New application of narrow band transmission mirrors is now a day that it is a main sophisticated part of the optical sights that is used to reflect the red desired band and transmits the entire visible region. This sight is extensively used in the surveillance, forestry and hunters to target for their desired purposes.

Thin film coating on optical components can be attributed to the following [5]:

• To reduce scattering, absorption and reflection from window/mirrors due to poor polish, strains, wedge and or incorrect mounting angle. Careful cleaning and assembly procedures are necessary.
• Diffraction losses depend upon mirror radius of curvature and geometry. Optical filters or interference filter are devices that selectively transmits or reflects electromagnetic radiation of desired region. These filters are commonly used in optical sights now a day for desired purpose. Dielectric filters are particularly suited for precise scientific work, since their exact colour range can be controlled by the thickness and sequence of coating with different refractive index optical material. They are usually much more expensive and delicate than absorption filter.

In our optical system the minus filter is coated on back surface of the negative Convexo-concave lens that is known as Mangin mirror [6]. This type of mirror was invented in 1876 by French scientist Alphonse Mangin. This mirror reduces spherical aberration affects by refracting the beam twice.

In this report we present the design of narrow band stop filter and PVD method employed to fabricate thin film coating on optical component. The parametric analysis and comparison of design with experimental electromagnetic spectrum is discussed.
2. Multilayer Dielectric Coating
The reflectance $R$ and transmittance $T$ of a stack of non-absorbing, optically homogeneous films deposited upon a transparent substrate of refractive index $n_s$ are a function of the geometrical thickness. A high reflectance can be obtained from a stack of quarter wave dielectric layers of alternate high and low refractive index. The desired wavelength band reflected from all interfaces in the stack of equal phase reach the front surface and combine constructively [7].

The reflection in air or free space is given by:

$$R = \left[ \frac{1 - \left( \frac{n_H}{n_L} \right)^{2m} \left( \frac{n_H^2}{n_S} \right)}{1 + \left( \frac{n_H}{n_L} \right)^{2m} \left( \frac{n_H^2}{n_S} \right)} \right]^2$$

(1)

Where $n_H$ and $n_L$ are the indices of the high and low index respectively and $m$ is the number of layers in the stack. The greater number of layers the greater reflectance. Maximum reflectance for a given odd number of layers is always obtained with the high index layers outmost.

If

$$\left( \frac{n_H}{n_L} \right)^{2m} \left( \frac{n_H^2}{n_S} \right) > 1$$

(2)

Then

$$R \cong 1 - 4 \left( \frac{n_L}{n_H} \right)^{2m} \frac{n_S}{n_H^2}$$

(3)

and

$$T = 1 - R \cong 4 \left( \frac{n_L}{n_H} \right)^{2m} \frac{n_S}{n_H^2}$$

(4)

The materials used are transparent and the absorption in a multilayer stack is very small.

3. Experimental
Thin film coating technique was employed by using optical design software while $n_L$: 1.38 and $n_H$: 1.63 refractive indices were used that correspond to coating materials MgF$_2$ and Al$_2$O$_3$ respectively. The adopted coating scheme was (H 2L)10 0.25H at reference wavelength $\lambda_o$: 868nm.

Figure 1. Schematic diagram of thin film coating machine
The high quality polished cleaned optical glass substrate (Diameter: 29mm, thickness: 2.6mm and radius of curvature of coated convex surface: 116.6mm) was used and thin film coating was carried out on coating machine as shown in figure 1. This is a back surface of the optical component that forms a Mangin mirror. Coating was performed at 280°C and pressure of chamber was maintained in the range of 10⁻⁶mbar. Before coating, optical components were cleaned in the chamber for half an hour through glow discharge. MgF₂ and Al₂O₃ were evaporated through thermal evaporation and electron beam evaporation techniques respectively. The coated component was cemented in between of other K9 substrates of matching surfaces for protection from environmental effects. These coated components have gone through the environmental test and transmission spectrum of coated sample was recorded on Spectro-Photometer. The results are shown in figure 2.

![Figure 2. Theoretical and experimental transmission spectrum response](image)

### 4. Results and Discussions

The colour of coating on polished optical components was reddish yellow and spectral response of theoretical simulation and experimental is shown in figure 2. The theoretical simulation and experimental spectrum response is quite similar. The whole theoretical spectrum shows transmission in both wing of narrow band dip averaged around 95% and experimental spectrum less than 90%. While the narrow band stop dip at wavelength 650 nm of theoretical simulated spectrum is more than the experimental spectrum by factor of 3 to 4 percent. The band width of transmission dip at λ: 650 nm is slightly larger than the simulated value. It is because of chamber environment pressure, temperature and purity of the coating materials. This difference of transmission in theoretical and experimental is because of the absorption factor of dielectric thin film coating material that is quite natural. The band width of narrow band stop filter of calculated and experimental is very similar and shifting of dip is around 5nm. This mirror is a unique and can be used in optical sights as an aiming device in which the surveillance person aiming the target however aiming spot on the target does not appear.

A sight is a common optical instrument non-magnifying reflector that gives the user an aiming point in the form of illuminated red dot [8]. The typical configuration for red dot sight is a tilted spherical Mangin mirror with a red light emitting diode as shown in figure 3. The advantage of Mangin mirror is the red light refracted from the first surface of the mirror that gives narrow reflection angle from reflecting surface and sends the rays parallel towards the eyes of the aiming person. Thus a red light emitting diode (LED) at the focus of collimating optics generates a dot style illuminated reticule.
The sight attached with the weapon remains aligned regardless of eye position. The mirror has partially multilayer dielectric coating to reflect just the desired red wave band and allowing it to pass through most other visible light. The size of the dot generated by LED is controlled by a tiny aperture hole in metal or coated glass placed in front of it.

5. Conclusion
The simulated and experimental spectra are in quite good agreement (figure 2). The multilayer dielectric coating techniques can be implemented in an optical sight to aim the target in the form of red dot in place of old type of reticule. The reticule patterns such as cross hairs or concentric circles can be used but need more complex aberration free Optics however, in aiming dot sights the narrow band Mangin mirror optical system is an aberration free optics. These minus mirrors can produce in large quantity by employing PVD techniques in one go. They are considered to be fast acquisition and easy to use in gun sights for target shooting, hunting and surveillance purposes.

6. Reference
[1] Perry D L 1965 App. Opt. 4(8) 987
[2] Baryan H C 1978 US Patent 4106855
[3] Slaughter J M, Medower B S, Watts R N, Tarrio C, Lucatorto T B, Falco C M 1994 Opt. Lett. 19 1786
[4] Young L and Cristal E G 1966 App. Opt. 5(1) 77
[5] Lim Y C, Westerwalbesloh T, Aschentrop A, Wehmeyer O, Haindl G, Kleinberg U and Neinzmann U 2001 App. Phys. A72 721
[6] Leite Jr. P R, Silva M, Padi E T 2009 Proc. SPIE 7338 01
[7] H. A. Macleod 1986 Thin Film optical Filter (2nd edition) Adam Hilger Ltd. Bristol, England
[8] Terebicz V Y 2007 Telesc. Opt. 5 322