POLARIZATION PRESERVING REFLECTED BEAM SPLITTER

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ABSTRACT

The design of a polarization preserving reflected beam splitter (PPRBS) is presented. The PPRBS consists of a V-shaped absorbing substrate coated with a single thin film layer. The PPRBS operates in the UV region. The power reflection coefficient ranges from 69%-90% for angles of incidents ranging from 85-89 degrees respectively.

Keywords: *Polarization preserving, Reflected beam splitter, Single-layer coating, absorbing substrate, UV range.*

الملخص

تصميم جها ز للمحافظ على الاستقطاب الضوءي بعد الانعكاس . الجهاز يتالف من مادة ممتص على شكل حرف V و مغطاه بمادة اخرى رقيقة . الجهاز يعمل في المنطقة المافوق البنفسجية . درجة الانعكاس تراوحت بين ٦٥% - ٩٠% لزوايا اسقاط بين ٨٥-٨٩ درجة .

1. INTRODUCTION

Polarization preserving devices are often needed in optical systems to preserve the polarization state of the incoming light after it goes through reflection or transmission. A number of polarization preserving devices are reported in literature. These devices consist of two parallel or orthogonal reflected substrates coated with appropriate thin film layers [Azzam et al, 1992, 1982, 1985]. In these devices, the incoming beam has to reflect off two substrates before it can return back to its original polarization. In this paper we are introducing the polarization preserving reflected beam splitter PPRBS. The PPRBS splits the incoming beam into two beams with two different directions. The state of polarization of the two beams is the same as the incoming beam. The advantage that the PPRBS has over the previous reported devices is that the PPRBS preserves the polarization of the incoming beam without the need to go through a second reflection.

The PPRBS consists of a V-shaped absorbing substrate coated with a single thin film layer. The designed PPRBS operates in the ultra-violate (UV) region. Two different materials are considered as substrate for the PPRBS. The first material is Germanium Ge with a complex reflection index N=2.516-j4.669 at a wavelength λ=4.4 eV or 281.93 nm. The second material is Gallium Antimonide GaSb with a complex reflection index N=2.522-j4.13 at a wavelength λ=4.2 eV or 295.35 nm [Aspens et al, 1983]. The power reflection coefficient of the PPRBS ranges from 69-90% for angle of incident ranging from 85-89 degrees.

2. THEORETICAL BACKGROUND

Consider the structure shown in Fig. 1. The structure need to be positioned symmetrically in the path of the original beam as shown in Fig. 1. The structure consists of a V-shaped absorbing substrate of a complex index of refraction $N_2=n_2-jk_2$. The substrate is placed in a medium of refractive index N_0. In this paper we used $N_0=1$ for air. Both surfaces of the substrate are coated with a single thin film layer of index of refraction N_1. The film has a uniform thickness ***d*** over the total area of both surfaces of the substrate. The subscript 0,1, and 2 denotes the incidence, film, and substrate media, respectively, for both surfaces. These media, are assumed to be linear, homogeneous, isotropic, and are separated by parallel-plane interfaces. Suppose that a linearly polarized monochromatic plane wave is incident on both sides of the structure at an angle ϕ_0. The orientation that the incident wave makes with the p-axis is 45° as shown in Fig. 1. The complex amplitude reflection coefficient of the film-substrate system for any of the two sides of the substrate can be written in general as: [Bron, et al, 1999].

$$R_\upsilon = (r_{01\upsilon} + r_{12\upsilon}X)/(1 + r_{01\upsilon}r_{12\upsilon}X), \tag{1}$$

where υ indicates the *p* or *s* polarizations and *X* is given as:

$$X = e^{-j2\pi\zeta}, \tag{2}$$

In Eq. 2 ζ is the normalized film thickness and is equal to:

$$\zeta = d / D_\phi, \tag{3}$$

where ***d*** is the actual film thickness and D_ϕ is the film thickness period and is given as:

$$D_\phi = \frac{\lambda}{2}\left(N_1^2 - N_0^2 \sin^2\phi\right)^{-1/2}. \tag{4}$$

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In Eq. 4 λ is the wavelength of the incident beam. Looking back at Eq. 1, the *p* and *s* Fresnel reflection coefficients for the 01 interface on both surfaces of the structure are given as:

$$r_{01p} = \frac{\tan(\phi_0 - \phi_1)}{\tan(\phi_0 + \phi_1)} \tag{5}$$

$$r_{01s} = -\frac{\sin(\phi_0 - \phi_1)}{\sin(\phi_0 + \phi_1)} \tag{6}$$

and for the 12 interface they are equal to:

$$r_{12p} = \frac{\tan(\phi_1 - \phi_2)}{\tan(\phi_1 + \phi_2)} \tag{7}$$

$$r_{12s} = -\frac{\sin(\phi_1 - \phi_2)}{\sin(\phi_1 + \phi_2)} \tag{8}$$

In order to preserve the polarization of the incoming light the following equation has to be satisfied:

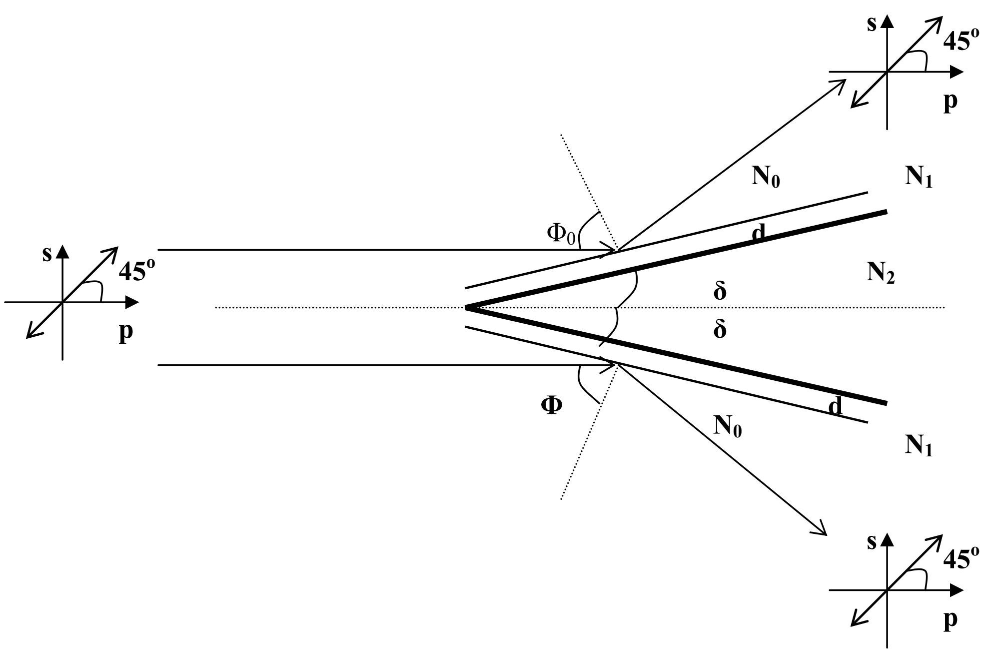

Fig. 1 The PPRBS layout.

$$\rho = \frac{R_p}{R_s} = 1. \tag{9}$$

Rewriting Eq. (9):

$$R_p - R_s = 0 \tag{10}$$

This condition can be written as a function of four parameters:

$$F(\phi_0, \zeta, N_1, N_2) = 0 \tag{11}$$

In this paper we studied the conditions of the said four parameters that satisfy Eq. 11.

3. RESULTS AND ANALYSIS

The summary of results for the designed PPRBS using Ge and GaSb substrates are shown in Tables 1 and 2 respectively. The two Tables show a list of angles of incidence ϕ_0 and their corresponding normalized ζ and actual film thicknesses *d*, the power reflectance $\Re_s \cong \Re_p$ and the magnitude and phase of ρ, $|\rho|$ and $\angle\rho$, respectively. The power reflection coefficient is equal to:

$$\Re_\upsilon = |R_\upsilon|^2 \tag{12}$$

The power reflection listed is for each side of the substrate. Each side of the substrate receives one-half of the intensity of the incoming light. It should be mentioned that due to the absorbing nature of the substrate, the beam will loss some of its power.

The results in Table 1 are for Ge whose index of refraction N_2=2.516-j4.669 at a wavelength λ=4.4eV or 281.93nm. The index of refraction of the thin film on both sides of the Ge substrate N_1= 4.0363. Table 2 shows the results for GaSb. The index of refraction of GaSb N_2=2.522-j4.13 at a wavelength λ=4.2eV or 293.36nm. The index of refraction of the thin film on both sides of the GaSb substrate is N_1= 3.698515. Suitable materials for use as thin films for N_1 are metallic thin films such as (Gold, Silver, or Aluminum).

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Table 1. PPRBS Design table for Ge N_2=2.516-j4.669, N_1=4.0363, and $\lambda = 4.4$ eV or 281.93 nm

ϕ_0 (degrees)	ζ	$d(m)$	$\Re_s \cong \Re_p (\%)$	$\lvert\rho\rvert$	$\angle\rho$ (degrees)
85	.2988008333	1.07685E-08	69	1.008	-103E-10
86	.2988014766	1.07695E-08	74	1.006	-59E-10
87	.2988019804	1.07703E-08	80	1.004	-20E-10
88	.2988023421	1.07708E-08	86	1.003	15E-10
89	.2988025599	1.07712E-08	93	1.002	-1E-10

Table 2. PPRBS Design table for GaSb N_2=2.522-j4.13, N_1=3.698515, and $\lambda = 4.2$ eV or 293.36 nm

ϕ_0 (degrees)	ζ	$d(m)$	$\Re_s \cong \Re_p (\%)$	$\lvert\rho\rvert$	$\angle\rho$ (degrees)
85	.2994088572	1.233E-08	68	.99994	-6E-10
86	.2994104025	1.23314E-08	74	.99995	75E-10
87	.2994116100	1.23325E-08	80	.99996	63E-10
88	.2994124755	1.23332E-08	86	.99997	41E-10
89	.2994129960	1.23337E-08	93	.99998	21E-10

4. CONCLUSION

A polarization preserving reflected beam splitter (PPRBS) is introduced that operates in the UV region. The two materials that are considered as substrate for the PPRBS are Germanium Ge with a complex reflection index N=2.516-j4.669 at a wavelength λ=4.4 eV or 281.93 nm and Gallium Antimonide GaSb with a complex reflection index N=2.522-j4.13 at a wavelength λ=4.2 eV or 295.35 nm.

The PPRBS splits the incoming beam into two beams with equal intensity. The state of polarization of both beams is the same as that of the incoming beam. The power reflection coefficient of the PPRBS ranges from 69%-90% for angles of incidents ranging from 85-89 degrees respectively.

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5. REFERENCES

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