Multiple-beam interferometer with two rectangular prisms and near grazing reflections

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ABSTRACT. A simple multiple-beam interferometer using two rectangular prisms working in near grazing condition with respect to their hypotenuse faces is reported. These faces are made closely parallel by bringing them against to each other, so that a thin air layer is formed in between. One of the prisms has a reflecting aluminium deposition on one of its cathetus to reinforce appropriate reflections. When the hypotenuse faces of both prisms are close enough, multiple beams between them are produced. The main advantages of the proposed system is that it is easy to aligne and shows an extraordinary stability.

RESUMEN. Se reporta un interferómetro de haces múltiples empleando un par de prismas rectangulares, entre los cuales pasan ondas pseudo-rasantes en las caras correspondientes a las hipotenusas. Las caras se ajustan paralelamente una frente a otra acercándolas mutuamente, a modo de formar una película de aire entre ellas. Uno de los prismas posee un depósito evaporado de aluminio sobre una de las caras correspondientes a un cateto con el propósito de incrementar las reflexiones luminosas apropiadas. Al estar las caras de los prismas suficientemente cercanas entre sí, se producen reflexiones múltiples. Algunas ventajas mostradas por el sistema descrito son tanto su facilidad de alineación como su gran estabilidad.

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Rectangular glass prisms have found many applications in connection with experimental studies of optical phenomena associated with boundaries between dielectrics, as is the case of generation of near-grazing waves [1] or evanescent waves [2]. The Fresnel coefficients of reflection of near-grazing waves (waves propagating at angles close to $\pi/2$ rads with respect to a surface's normal, *viz.* $[\pi/2 - 0.001]$ rads) can achieve values close to unity and their respective optical phases suffer only small changes along the surface's normal direction within paths ranging up to several wavelengths [3]. These two properties can be of certain advantage for applications in interferometry and do not seem to

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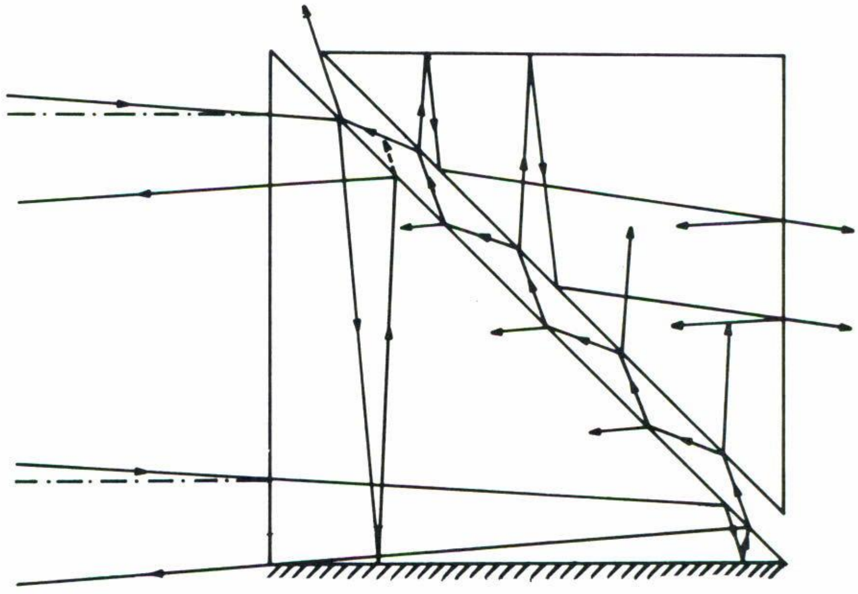

FIGURE 1. Multiple reflections at the air gap between two rectangular prisms. The entrance prism has a reflecting coating.

be fully explored. In this work, we report a simple multiple-beam interferometer constructed by means of two rectangular prisms brought into near grazing condition with respect to their hypotenuse faces. These faces are brought mutually close by pushing one of the prisms against the other, so that a thin air wedge is formed in between. One of the prisms, the entrance prism, has a reflecting aluminium deposition on one of its faces (see Fig. 1). The function of the reflecting face can be better understood by following the path of a ray first entering into a prism without coatings (otherwise equal to the entrance prism), at a certain angle θ as sketched in Fig. 2a. Such a ray leaves the prism at an angle θ_2 across the hypotenuse face after suffering two internal reflections: a total internal reflection at point B and a partial reflection at point C. Thus, the reflective coating in the entrance prism of Fig. 1 reinforces reflection on point C of Fig. 2a.

The value of the angle θ_2 can be found as follows. Fig. 2a shows a ray entering one of the faces of a conventional rectangular prism with an angle θ with respect to its normal at point A. This ray refracts itself at an angle θ' according to Snell's law and impinges the hypotenuse face at an angle $\theta_1' = 45° + \theta'$, suffering internal reflection. The ray reflects itself in the face which contains point C at the same angle θ', and goes back toward the hypotenuse face this time at an angle $\theta_2' = 45° - \theta'$. Then, there must be a particular value of $\theta = \theta_t$ such that its corresponding value of θ_2' equals the value of the critical angle θ_c. For angle θ such that $\theta > \theta_t$, then $\theta_2 < \theta_c$ occurs and the respective rays leave the prism across its hypotenuse face. If a plane surface is located parallel to this face (Fig. 2b), multiple reflections may be produced, in a very similar way as in the case of a Lummer-Gehrke plate. Of course, in such a plate, reflections are of the internal type. As is

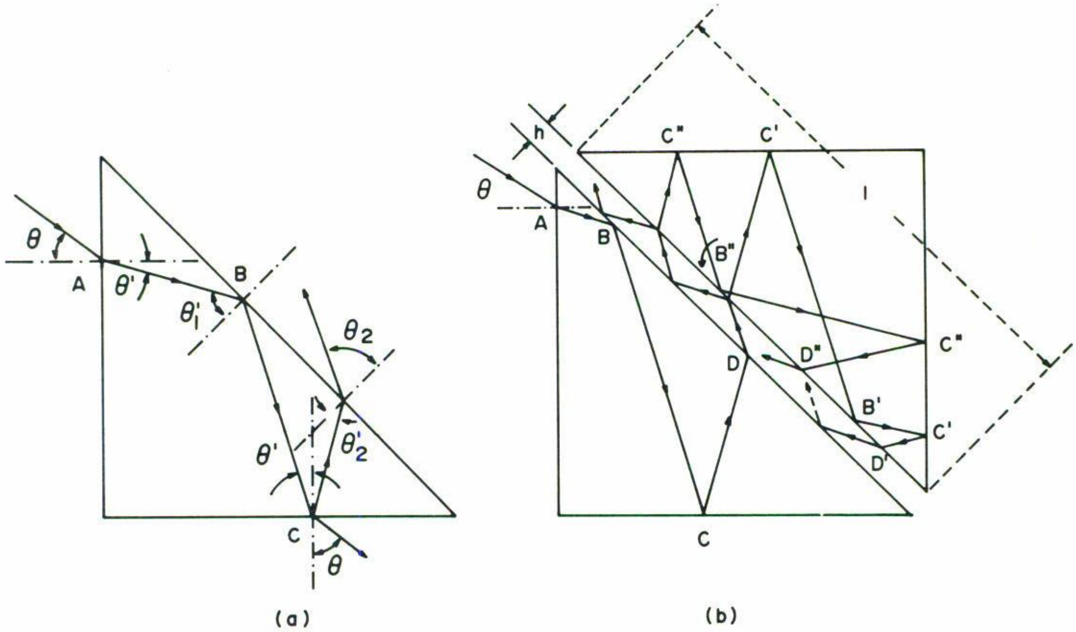

FIGURE 2. a) Tracing of a ray incident at an angle θ with respect to the normal of the entrance face to render a near-grazing ray emerging at an angle θ_2. b) Two rays produced by two reflections at the hypotenuse face of the second prism. Similar reflection points are labeled with the same letters, and equal apostrophe marks a single ray tracing. l: length of hypotenuse faces; h: gap thickness.

well known [4], the number of reflections p that a ray undergoes within a Lummer-Gehrke plate is

$$p \sim \frac{l}{2h} \cot \theta_2, \tag{1}$$

where l is the length of the plate, h its thickness, and θ_2 is the angle of the reflection within the plate. Although in our case θ_2 have to be close to 90 degrees, h can be practically as small as desired, provided tunneling effects are absent. Moreover, if the plane boundary is the hypotenuse face of a second prism as proposed, rays partially transmitted to the second medium suffer internal reflections and reenter the air film in some important way.

The effect described previously is sketched in Fig. 2.b for two successive reflections (at the second face) of a ray partially trapped within the air film. Each one of the two rays suffers very similar reflections before reenter the film. These reflections are labeled with the same letters when similarity appears, and the apostrophes are in accordance to the ray order. Ray reentering the air film contributes to higher values of irradiance, thus providing interference fringes that can be observed along the normals of the faces of the prism pair with different sign contrast and polarization properties; due to different number of partial/total internal reflections involved. Although interference fringes can be observed with prism pairs with no reflecting coatings, when one of the faces is coated as described in Fig. 1, the irradiance of the maxima are remarkable increased.

Figure 3 shows the set-up of the interferometer described in this letter. A beam from a He-Ne laser is expanded and collimated after passing through a pinhole spatialfilter. A

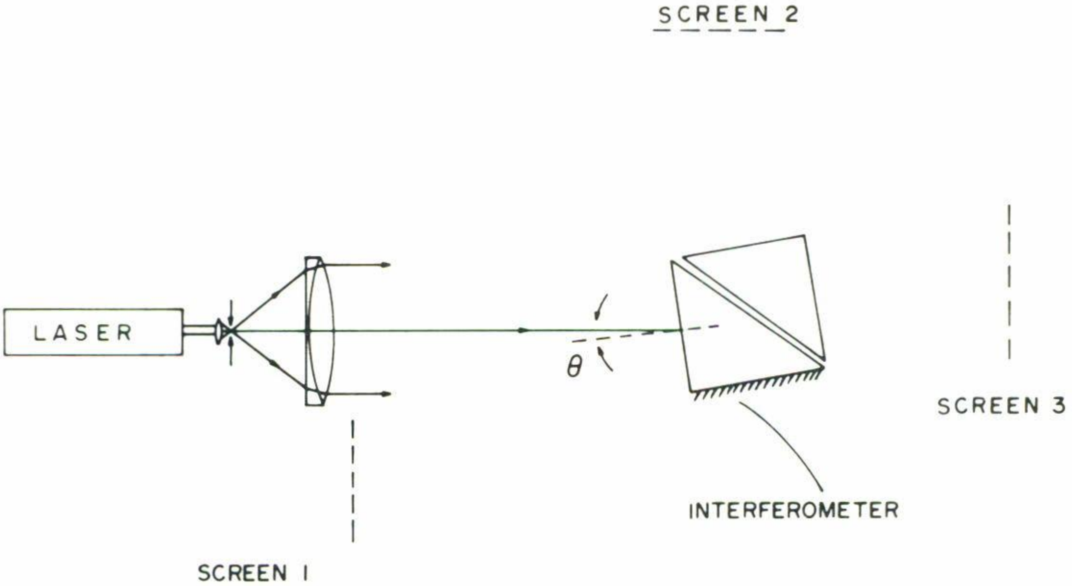

FIGURE 3. Experimental set-up.

pair of similar rectangular prisms are placed in front of the laser beam, at an angle $\theta \geq 4^{\circ}$ as it is shown, and one of the prisms have a reflective coating as have been described above. Interference fringes are observed at screens 1, 2 and 3, when both hypotenuse faces of the prisms are held in close contact to each other; for example this can be done even by hand accommodation of the prism. Both prisms must be put together almost in contact, allowing only a small air gap, which in our case results to be a wedge. Thus, the interference patterns are to be described as multiple-beam Fizeau fringes [5]. However, for this configuration the fringe pattern can be seen only within a narrow range of values of θ. Typical patterns on screens 2 and 3 are shown in Figs. 4.b and 4.c, and they have opposite contrast, each other, and less irradiance with respect to the one observed on screen 1 (Fig. 4a). Note the relative high finesse of the fringes. A maxima irradiance can be further improved by deposition of another reflecting film on one of the faces (side 2 or 3) of the second prism. In order to show potential uses of the system, a MgF_2 thin film was evaporated on the reflecting face of the entrance prism prior to the reflecting coating (Al), so as to produce a thin step. The corresponding interference pattern shows clearly the step as is shown in Fig. 4d.

Other configurations to achieve interference patterns with near-grazing waves and prisms and under different illumination conditions are also possible and they will be reported in detail elsewhere. As advantages of this system, we point out that it is easy to aligned and that it has a great stability. Adjustment to demonstrate fringes can be performed manually with no need of fine mechanics and the set-up shows a remarkable good tolerance to vibrations, so the system has advantages to show interference. Further possible applications of this set-up are the measurements of thin film thickness, prism shop testing, and high resolution spectroscopy.

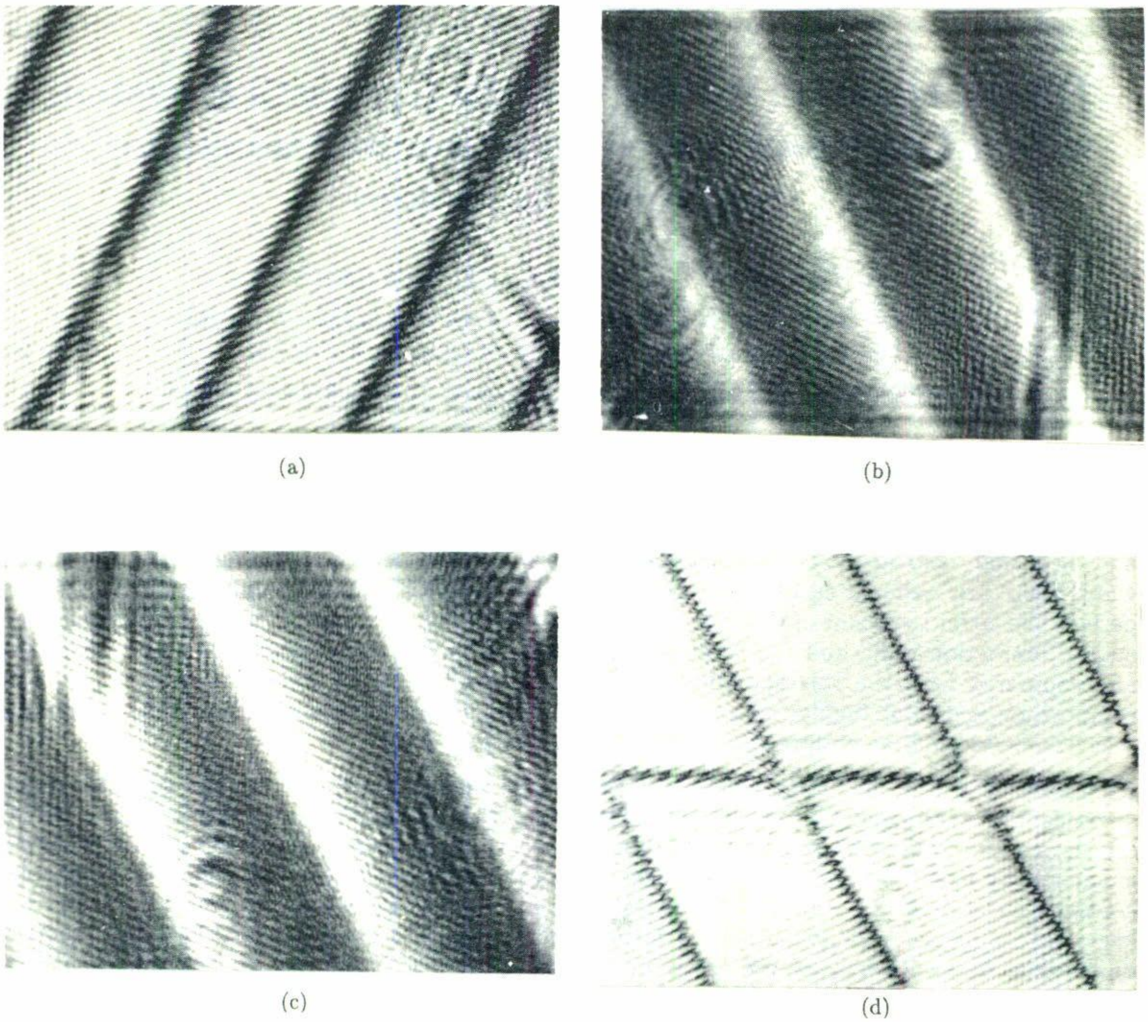

FIGURE 4. Resulting interference patterns. a) screen 1, b) screen 2, c) screen 3, d) screen 1 with a step thin film.

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