Coherent image processing using coupled prisms

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The total internal reflection (TIR) phenomenon and the coupling of prisms through evanescent waves have been used in the context of several image processing requirements. Results are reported for the spatial filtering of bleached photographic transparencies. It is possible to obtain a positive-negative pair of images in the transmission and reflection modes, the relative amplitude of which can be varied.

KEYWORDS: optics, prisms, image processing, total internal reflection

Introduction

The total internal reflection (TIR) phenomenon has been studied in detail since the time of Newton[1]. It is well known that light incident on a prism of high refractive index at an angle exceeding its critical angle is totally reflected, and if another prism is placed in close proximity to the first, the light will be coupled to the second prism through evanescent (inhomogeneous) waves. An evanescent plane wave is characterized by a wave whose planes of constant amplitude and constant phase cross each other at a finite angle. The creation of such waves depends on the properties of the medium and the boundary conditions. These waves are formed in rare media when light is totally internally reflected. They are also formed when light undergoes diffraction at objects with ultra-fine structures. Evanescent waves are converted to homogeneous waves when they interact with a detector, thus making their visualization difficult.

The evanescent wave phenomenon has been used for a number of applications, namely surface profile measurements[2], waveguide coupling[3], finger printing[4], high resolution imaging[5] and spectroscopic measurements[6]. The present paper reports the experimental results obtained with evanescent wave coupled prisms when used in the context of image processing requirements.

Experimental

An evanescent wave coupled prism device of high refractive index ($\mu = 1.7$) has been used for spatial filtering of bleached photographic transparencies. The transparency is placed in a collimated laser beam which is incident on the device at an angle close to the critical angle. The coupling is non-absorbing and the power is propagated through the interface without loss. The reflectivity for TIR can be made less than 100% and can be continuously adjusted between zero and 100%. The coherence properties of the transmitted beam are similar to the incident beam. If the incident beam contains a phase structure, the phases of the transmitted and reflected part will be complementary to each other.

The transmitted beam, through the coupled prism device, is allowed to enter a two lens imaging system as shown in Fig. 1. The device filters out one half of the spectrum of the object and produces a negative contrast image. The partially reflected beam is similarly imaged by another lens combination which forms the positive image. As expected, it was observed that near the critical angle, the transmitted intensity was higher if the polarization was parallel rather than perpendicular, whereas for large angles of incidence the opposite was true.

Thus, it is possible to obtain a positive-negative pair of images in the transmission and reflection modes. The

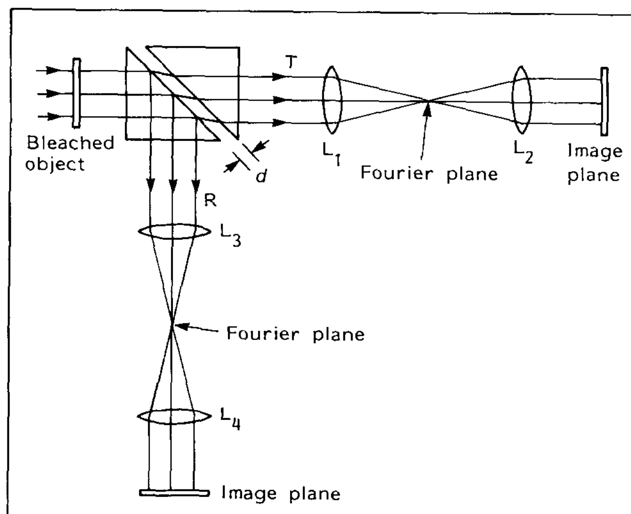

Fig. 1 Schematic diagram for spatial filtering of a bleached photographic transparency by evanescent wave coupled prisms (refractive indices $\mu = 1.7$)

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relative amplitudes of these modes can be balanced by varying the angle of incidence of the beam or changing the coupling strength of the prisms. Fig. 2 shows the results.

When the bleached photographic transparency is placed in contact with the reflecting surface of the prism ($\mu = 1.7$), then at an angle close to the critical angle, the beam will be attenuated according to the surface profile of the transparency. Thus, the reflected beam will show an image of the object. Here, the creation of the amplitude image depends on the variable penetration depth of the evanescent wave field in accordance with the surface relief of the bleached transparency. The amplitude image obtained in the previous case, Fig. 2, is due to spatial filtering of one half of the spectrum of the object transparency like a Schlieren system.

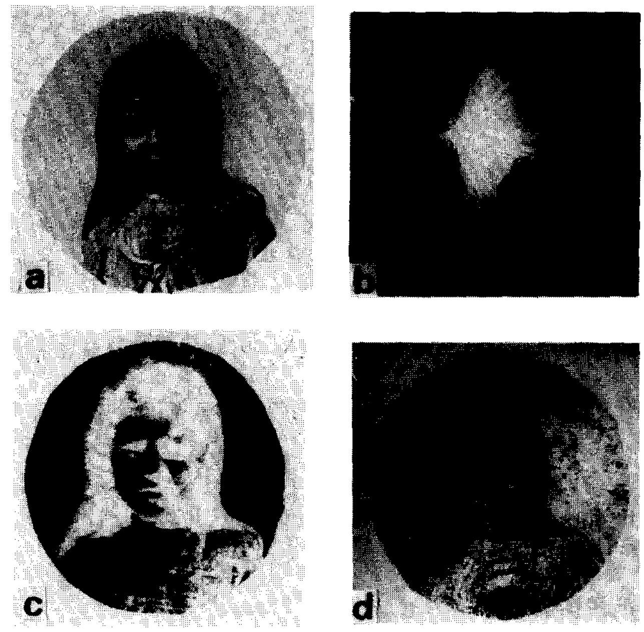

Fig. 2 Experimental results (a) input before bleaching; (b) spectrum; (c) image in transmitted beam; (d) image in reflected beam

An interesting feature of the device is that when using bleached hard-clipped transparencies as the input, the device acts as a spatial filter blocking the information in the horizontal direction for the transmitted beam. This may be attributed to the microsweep which the beam experiences between the two prisms before it enters the second prism. This sweep of the light beam was first demonstrated by Goos and Hänchen[7] who showed that a beam totally internally reflected is displaced upon reflection. The results are shown in Fig. 3 which shows that the spatial filtering action of the device is quite pronounced. The input object transparency may be rotated in its plane to get different filtered images. Fig. 4 shows the results when a binary line structure in the vertical and horizontal direction

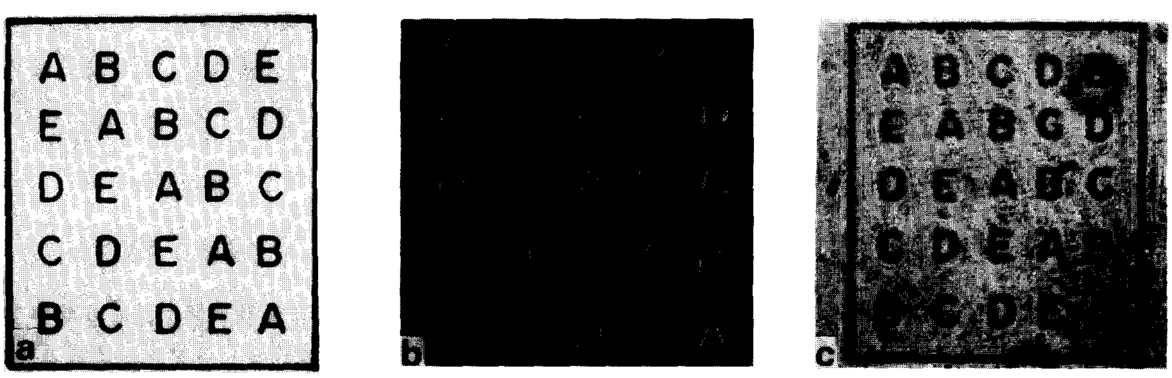

Fig. 3 (a) Negative image of hard-clipped input before bleaching; (b) image in transmitted beam; (c) image in reflected beam

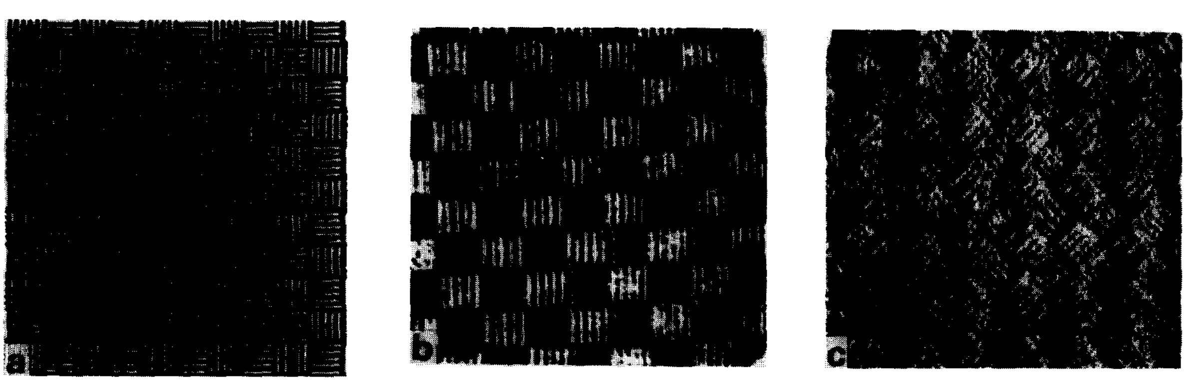

Fig. 4 (a) Input before bleaching; (b) filtering of horizontal frequencies; (c) output when input is rotated in its plane

Fig. 5 (a) Half-tone input before bleaching; (b) and (c) filtered images when input is rotated in its plane

is the input, whereas in Fig. 5 the results with a half-tone transparency are shown.

Conclusions

Applications of evanescent wave coupled prisms for processing of bleached photographic transparencies are reported. It is possible to obtain a positive-negative pair of images in transmitted and reflected parts of the light. Spatial filtering of the horizontal frequency has also been performed. The complete removal of the zero order by the device not only renders the information to be converted into an amplitude image but it also provides the effect of edge enhancement. The method can be extended for pseudo-colouring, multiplexing and density slicing.

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