RANDOM PARTIAL DIFFUSER AS BEAM SPLITTER IN A NEW, COMMON PATH INTERFEROMETER *,**

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Use of a random partial diffuser is suggested as a beam spitter. An aberration-free reference beam coaxial with the test beam is obtained when the latter converges on the diffuser. Based on this principle, an interferometer has been realised for absolute measurements with a sensitivity equal to that of a Mach–Zehnder interferometer. A large variety of optical components can be tested by this simple and inexpensive interferometer which could replace the already existing ones in optical workshops.

A ground glass diffusing screen transilluminated by a beam of coherent light produces a speckle pattern in a plane behind it. A multitude of coherent diffracted waves with random phases interferes to produce such an effect. The granularity in the speckle pattern is a function of the area of the diffuser from where the waves the waves are emanated. In the case where the light beam is focussed on the diffuser, the speckle consists of a slowly varing intensity distribution. This is, further, limited by the spread function of the focussing system and by the grain size of the diffuser. The intensity variations in the speckle field are less pronounced if the ground glass diffuser is replaced by a random partial diffuser. This can be assumed to be due to the interference of two slightly dephased waves†. The random partial diffuser (RPD) consists of a large number of discrete scattering particles randomly distributed in a plane. It is obtained by recording the fine grain speckle in a suitable geometry on a high-resolution photographic plate. The RPD scatters a part of the incident light and transmits directly the other part; the latter, however, has an attenuated amplitude compared with the incident wave.

* The author was with the Institut d'Optique Paris when this work was done.

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† This phenomenon was observed during the course of an extensive study using random partial diffuser as modulator [1].

In fig. 1, L_1 is an aberration free lens illuminated by a plane wave originating from a monochromatic point source at infinity and P is the plane of observation. The RPD is located in the back focal plane of L_1 which is the image plane of the point source. A typical interferogram is shown in fig. 2 and is supposed to be caused by the interference of a diffracted wave and the directly transmitted wave. The path difference between the two interfering waves is of the order of λ.

We assume the RPD to consist of a large number of diffracting elements, each of which diffracts a part of the indicent amplitude into a spherical wave. Such a behaviour can be expected from a pin-hole aperture or a point obstacle. The diffracting element under consideration may contain more than one point obstacle which are so close to one another that the mutual phase difference of the diffracted waves is practically zero. Therefore, at the exit there is one spherical wave with an amplitude equal to the sum of all the in-phase diffracted waves. This condition is almost fulfilled when a point source is imaged on the RPD so as to illuminate a restricted area. The diffracted spherical wave is used as reference wave in the interferometer.

For an unaberrated incident wave, absence of fringes in the field characterises the zero setting (fig. 2). However, in certain cases circular fringes caused by defocussing may appear. Large defocussing errors introduce undesired random interference effects overshadowing the useful results. In the presence of aberrations the

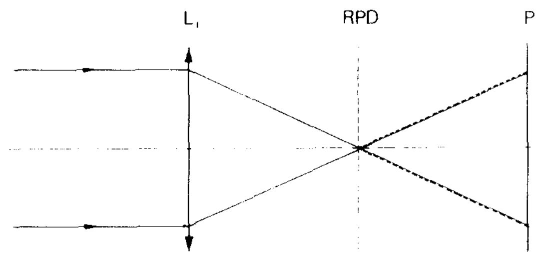

Fig. 1. Random partial diffuser as beam splitter.

point image gets broadened due to its convolution with the Fourier transform of the aberration function. Consequently random interfererence can be anticipated. But, if part of the incident wave is not intercepted by the test sample, it can provide, as before, a perfectly spherical reference wave after diffraction at a point. The directly transmitted wave coming from within the test sample acts as the test beam.

The interferogram of fig. 3 shows the equal-thickness fringes of a microscope slide which consists of a simple wedge with refracting edge parallel to the shorter side. The interferogram has been made in the image plane of the test sample by adding lens L_2 to form the required image (fig. 4). The complex amplitude, in the object plane, can be written as

$$O(x,y) = 1 \quad \text{outside test sample,}$$
$$= W(x,y) \quad \text{inside test sample.}$$

$W(x,y)$ is the aberration function. In the plane of the RPD, the Fourier transform of $O(x,y)$ is given by

$$\widetilde{O}(u,v) \approx \delta(u,v) + \widetilde{W}(u,v).$$

Finally, incorporating the RPD in the u,v plane, the complex amplitude in the image plane becomes

$$O(-x,-y) = 1 + W(x,y) + W(x,y) \otimes \exp\left(\sum_j \mathrm{i}\theta_j\right), \quad (1)$$

where θ_j are the phases of the diffracted waves and $\otimes$ represents convolution. The amplitude of the plane wave given by the first term in eq. (1), has deliberately been assumed to be unity. The third term is an ensemble of several randomly oriented waves arising due to the diffraction of the aberrated wave. This term is responsible for the background noise in the interferogram of fig. 3. The directly transmitted aberrated wave given by the second term interferes with the first term to produce the interferogram of the test object. If $W(x,y) = \exp[\mathrm{i}\phi(x,y)]$, the intensity in the fringe pattern is proportional to $\cos^2 \frac{1}{2}\phi(x,y)$.

The partial interception of the cross-section of the

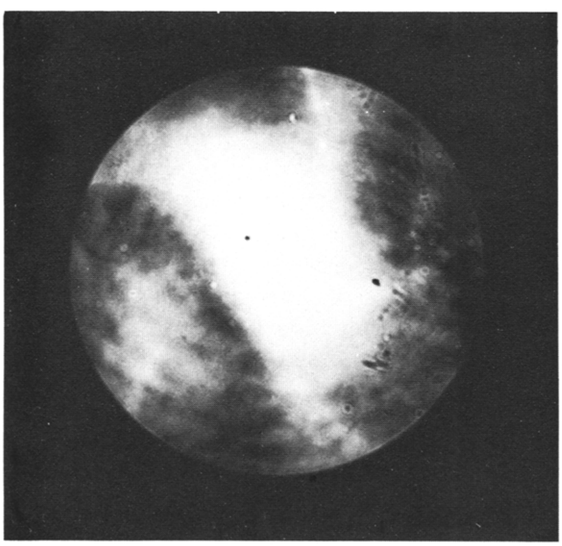

Fig. 2. Interferogram where the incident wave is aberration free. It shows variations of the order of λ.

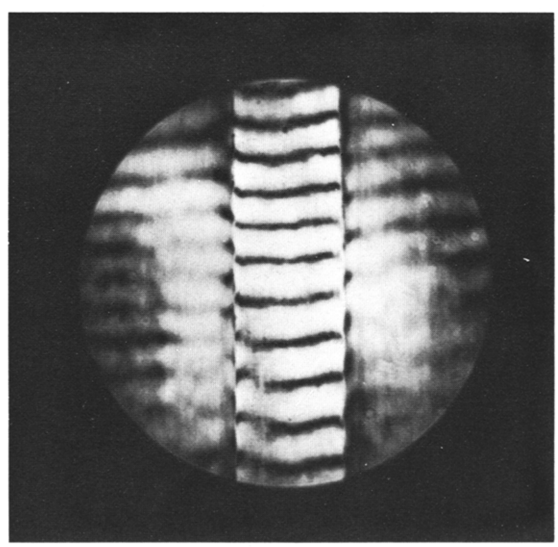

Fig. 3. Interferogram of a wedge shaped microscope slide: the wedge is of the order of 12λ over 40 mm.

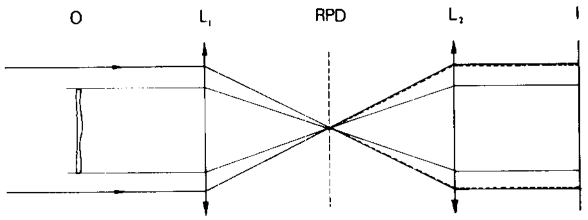

Fig. 4. Interferometer setup to record interferograms in the image plane of the test object.

incident wave by the test sample is indispensable unless the test sample contains zero spatial frequency. For example, no interference fringes will be observed if a purely wedge shaped phase object intercepts the entire cross-section of the incident wave. To compensate for the defocussing, a quadratic phase shift may be introduced by translating lens L_1 longitudinally. In the case of lens testing the reference wave is derived from the paraxial zone. Fig. 5 shows the interferogram of a lens suffering from spherical aberration. The lens to be tested replaces the lens L_1 in fig. 4.

We have presented a qualitative description of a common-path interferometer using a random partial diffuser. The interferometer reveals the constant thickness contours of the samples with a sensitivity equal to that of a Mach–Zehnder interferometer. Apart from examining small plates like phase samples, the interferometer is capable of testing lenses, prisms, beam dividers, plane and curved mirrors, etc. This simple and inexpensive interferometer can be more fascinating to the workers in optical workshops. A detailed version of this paper is in preparation.

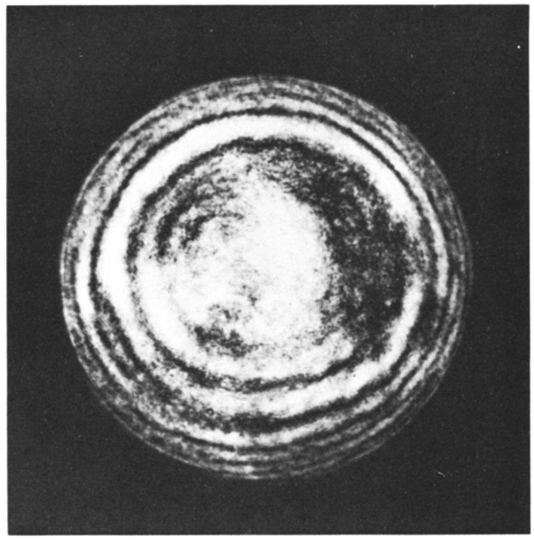

Fig. 5. Interferogram showing the spherical aberration of a lens. The reference wave has been derived from the paraxial zone.

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Reference

[1] C.P. Grover, Thesis "Traitement optique de l'information a l'aide d'une modulation spatiale aleatoire", University of Paris VI (1973).