"An improved technique for quantitative measurement of displacements by double exposure holographic interferometry".*

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We describe here a method for measuring displacements, strains and vibrations of diffusely reflecting three dimensional objects by using double exposure or stroboscopic holographic interferometry. Several methods have been proposed so far [1-3] but they are often rather unpractical due to the difficulty in interpreting accurately the interference pattern. To overcome this drawback we developed a simple opto-electronic apparatus.

The method is based on the principle first introduced by Aleksandrov and Bonch-Bruevich [4] which exploits the non-localization of fringes in multiple exposure holograms. If we look therefore at an object point and change continously the line of sight, we can see a number of fringes crossing the point. This number, N_i, is related to the displacement $\underline{d}$ undergone by the point between the exposures by the equation:

$$\underline{d} \circ (\underline{\rho}_0 - \underline{\rho}_i) = \pm N_i \lambda \qquad (1)$$

where $\underline{\rho}_0$ and $\underline{\rho}_i$ are unit vectors in different directions of observation and λ is the light wavelength. The choice of three suitable directions $\underline{\rho}_i$ will allow us to build three independent equations which can be solved with a computer and give the values of the displacement components. The ambiguity in sign is due to the impossibility of distinguishing the order of the exposures; it is therefore necessary to choose a conventional direction for the motion of the fringes in order to obtain consistent results.

The fringes could obviously be counted by looking directly at the virtual image and moving the eyes, but this is rather unpractical.

We construct, therefore a real image by illuminating the hologram with a conjugate reference beam: this image takes exactly the place of the object during the recording. If such a reversed beam crosses only a small region of the hologram, it produces a real image corresponding to the direction of observation defined by the object point and by the light spot on the hologram. Moving the spot is the same as changing the line of sight, and the interference fringes move across the real image: they can thus be counted by placing a suitable detector at the observed point. If we move now the spot along three proper directions we will be able to derive the coefficients of system (1) and to solve it. The scanning of the beam is accomplished by means of a mirror oscillating around an axis which can be oriented in any direction. The laser beam is focused onto the mirror by a lens L_1, so that the mirror acts as a point source. The diverging beam crosses the hologram a first time, and is made convergent by a spherical mirror which has its center of curvature on the oscillating one; the beam comes back through the hologram forming the real image (fig. 1). The counting of the fringes is accomplished by putting the end of an optical fiber in the point under test and observing at the oscilloscope the signal of a photomultiplier connected to the fiber (fig. 2).

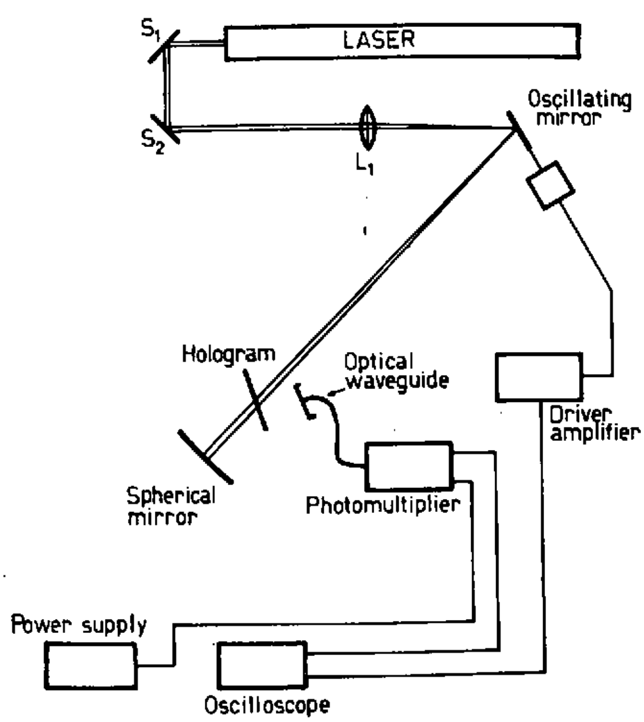

Fig. 1

An alternative setup exploits a converging corrected lens which takes the place of the spherical mirror; the lens needs to be corrected in order to avoid aberrations which cause the real image to move with respect to the detector.

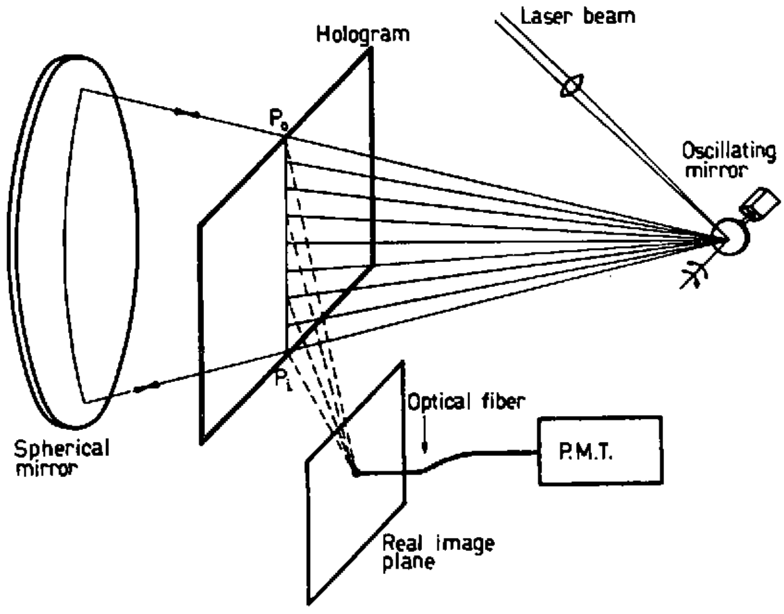

Fig. 2

By properly positioning the object and the plate a good accuracy is achieved for displacement components which are parallel to the hologram plate: in this case an uncertainty of 0.1 ÷ 0.2 fringes gives an absolute error of ± 0.1 ÷ 0.2 μ . The third component can not be determined with the same precision: we have found errors of 0.6 ÷ 0.7 μ typically. These results have been obtained by exploiting more than three scannings, thus overdetermining system (1): this can now be solved by the least square method.

This method applies to any kind of displacement, strain or vibration recorded on a double exposure hologram. When a point exists however which remains steady between the exposures, we can apply an alternative [1] method.

The steady point, in fact, is crossed by a zero order fringe so that we can measure the displacement of the point under examination by counting the number of fringes lying between the point and the zero-order fringe. This gives the component of the displacement $\underline{d}$ along the bisector of the angle formed by the direction of illumination of the object and the line of sight. This component is roughly perpendicular to the hologram plate. As a consequence a suitable combination of both methods seems the most powerful technique for quantitative measurements.

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References

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