DOUBLE GRATING INTERFEROMETER WITH VARIABLE LATERAL SHEAR

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A modified Ronchi interferometer using two identical gratings is described. This instrument is very suitable for the measurement of small, zonal aberrations, since the shear can be changed continuously by rotating one grating with respect to the other, while the direction and magnitude of the tilt between the sheared wavefronts can be varied by adjusting the distances of the two gratings from the centre of the gaussian sphere.

1. Introduction

A modification of the Ronchi interferometer [l] using a double-frequency grating [2] has been shown to have major advantages. Since the two interfering beams have the same intensity, the visibility of the fringes is close to unity. In addition, by a suitable choice of grating frequencies, it is possible to work at a small shear without undesirable overlap of the diffracted images from different orders.

A disadvantage which this instrument shares with the Ronchi interferometer is that the shear can be changed only in discrete steps by substituting gratings with different frequencies. In addition, it is often desirable to introduce a tilt between the sheared wavefronts to facilitate the measurement of small departures from the gaussian reference sphere, and in both these instruments this can be done in only one plane. The present letter describes an improved Ronchi interferometer using two identical gratings [3], which retains all the advantages of the double-frequency grating interferometer and in which these problems are overcome.

2. Optical system

The optical system of the instrument is shown schematically in fig. 1. Two identical diffraction gratings are located near the focus of the converging wavefront which is under study. The grating frequency is chosen so that the angle of diffraction ϕ is large enough to avoid overlap of the first order diffracted cones and the directly transmitted beam. With the gratings in contact and with their rulings vertical, the two first order diffracted cones on the same side overlap exactly, and a lens placed behind the grating forms a single image of the exit pupil of the system under test. If, however, the two gratings are rotated in their own plane in opposite directions through equal angles so that their rulings make angles $\pm\frac{1}{2}\theta$ with respect to the vertical, the principal rays of the two diffracted wavefronts lie in planes inclined at angles off $\pm\frac{1}{2}\theta$ to the horizontal and the lens produces two laterally displaced images of the exit pupil, as shown in fig. 2. A shearing interferogram of the wavefront in the plane of the exit pupil will be seen in the region of overlap [4].

The lateral shear between the two wavefronts in the

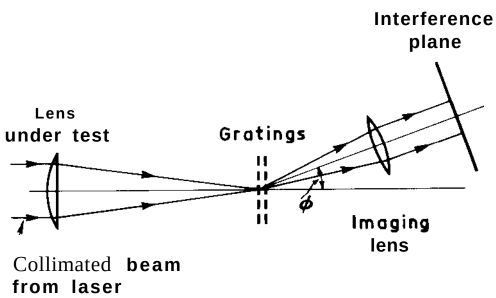

Fig. 1. Schematic diagram of the optical system of the double-grating interferometer.

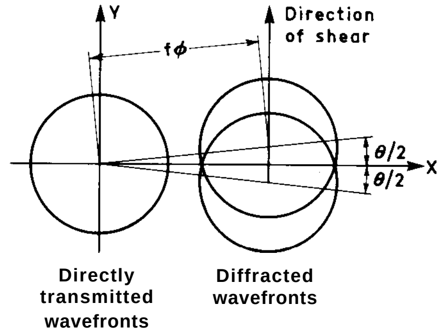

Fig. 2. Sheared images of the pupil formed in the interference plane.

plane of the exit pupil of the lens under test is $2\phi f \times \sin(\frac{1}{2}\theta)$ and this can be varied conveniently, without changing the direction of shear, by rotating the two gratings through equal angles in opposite directions, so as to vary the angle θ between the grating rulings.

With the double-frequency grating, as well as with the Ronchi interferometer, the effect of moving the grating along the axis through the focus is to introduce a tilt between the interfering wavefronts in a plane parallel to the direction of shear. With an aberration-free system this gives straight fringes across the field running perpendicular to the direction of shear. This restriction can be annoying, since it would be very helpful to be able to vary the orientation of the reference fringes, particularly in visual studies of small aberrations.

The orientation can be changed in the present case by varying the separation of the two gratings. If O, the centre of the gaussian reference sphere for the wavefront under test is at distances z_1 and z_2 from the gratings G_1 and G_2 as shown in fig. 3(a), the magnitudes of the vector displacements Δ_1, Δ_2 of O_1, O_2, the diffracted images of O are given by the relations

$$|\Delta_1| = z_1 \sin\varphi, \qquad |\Delta_2| = z_2 \sin\varphi. \qquad (12)$$

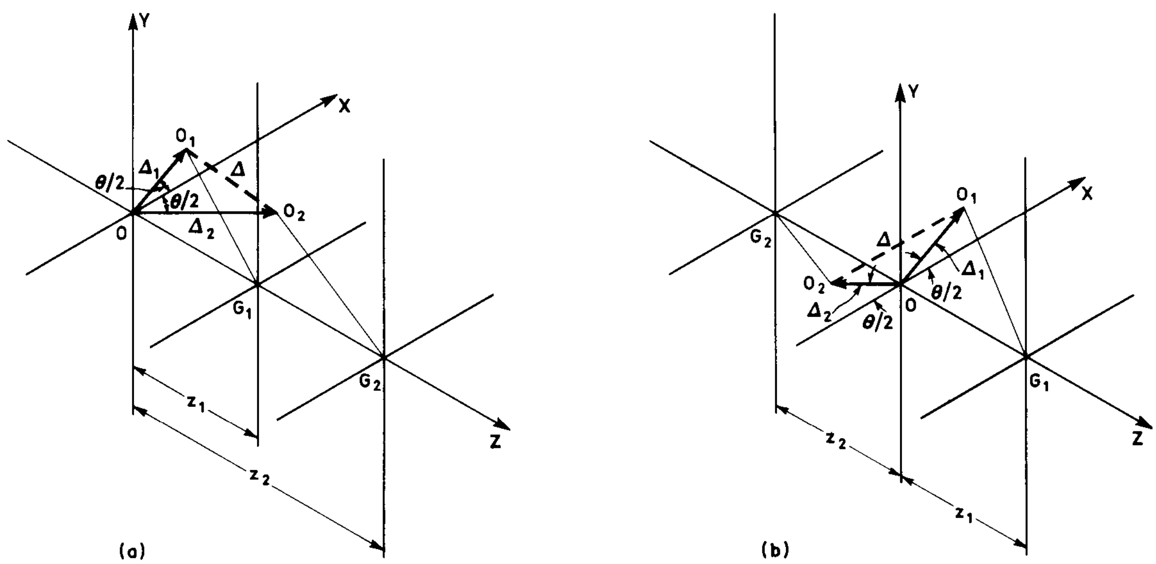

Fig. 3. Introduction of tilt between the sheared wavefronts (a) when the gratings G_1, G_2 are on the same side of the focus, (b) when the gratings are on opposite sides of the focus. The tilt is proportional to A, the difference of the vector displacements Δ_1, Δ_2 of the two diffracted images of O in the XY plane.

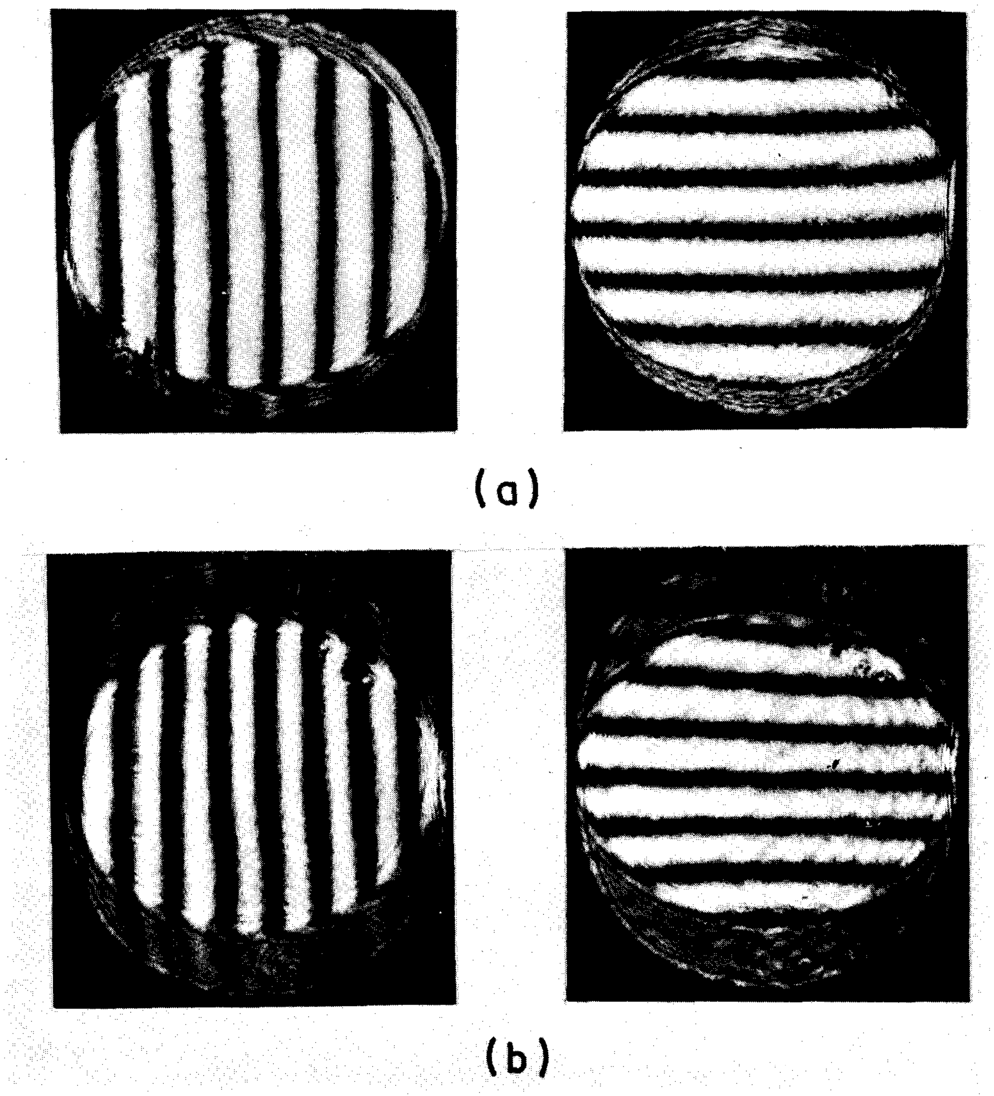

Fig. 4. Interferograms obtained with a telescope objective (relative aperture f/8) for two different shears, showing how horizontal or vertical fringes can be obtained.

These vectors lie in the gaussian plane and make angles of ½ θ and - ½ θ respectively with the horizontal.

The tilt between the two interfering wavefronts is proportional to A, the vector displacement of O_1 relative to O_2) which is

$$\Delta = \Delta_1 - \Delta_2, \tag{3}$$

and it is easily seen that if $z_2 = z_1$ (the two gratings are in contact), straight, horizontal fringes will be obtained with an aberration-free optical system, whereas if $z_2 = - z_1$, as shown in fig. 3(b), the fringes obtained will be vertical.

For two positions of the gratings along the axis,

$z_2 = z_1$ and $z_2 = -z_1$, varying the shear has no effect on the orientation of the fringes. In addition, when $z_2 = -z_1$ (fringes parallel to the direction of shear, which is most convenient for studying small, zonal aberrations), and the shear is small, the number of fringes across the field is practically unaffected by varying the shear.

For the analysis of rotationally non-symmetric wavefronts the direction of shear can be changed as desired by rotating the two gratings together. Alternatively, gratings with two sets of rulings at right angles can be used. This would permit simultaneous recording of two interferograms with the same value of shear in orthogonal directions.

3. Results

Typical interferograms obtained with a telescope objective having a relative aperture of *f/8* and a pair of Bausch and Lomb replica gratings ruled with 200 lines/mm, for two different shears, are presented in figs. 4(a) and 4(b). By varying the separation of the gratings as well as their distance from the focus, the fringes can be made to run in any direction, and their spacing can be varied.

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