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Letters to the Editor

Reversed path Ronchi test

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The Ronchi grating interferometer [1] plays a very important role in testing of optical elements. It uses grating line projections by a point source placed in the object space of an optical system under test or the projections from the image of a point source given by this system. Since it employs a single beam splitting (shearing) element the Ronchi interferometer is very simple to align and stable against mechanical vibrations. If, however, optical systems with long focal length (for example, concave astronomical mirrors with very long radii of curvature) are tested, then in case of any nonstability between the mirror under test and interferometer head, the interference fringes move in the observation field.

In this note the idea of Shoemaker and Murty of stabilizing the Burch scatter interferometer [2] is applied to the Ronchi test in order to obtain the test configuration extremely insensitive to vibrations. The optical systems of the classical and modified Ronchi tests are shown schematically in Figs. 1 and 2. In the first case [3, 4] the point or extended light source illuminates the grating G_s placed slightly off-axis in the plane of the centre of curvature of the concave

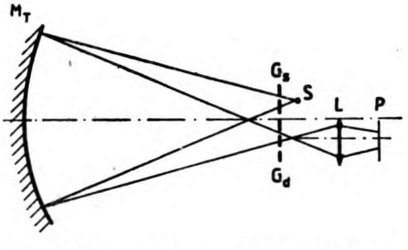

Fig. 1. Schematic representation of the classical Ronchi test arrangement for testing concave mirrors. S – light source (point or extended), G_s – source grating, G_d – detection grating, M_T – mirror under test, L – imaging lens, P – observation plane

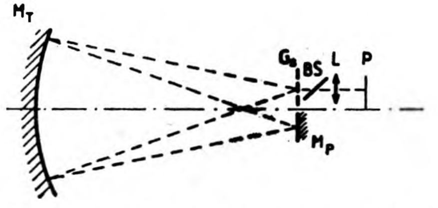

Fig. 2. Schematic diagram of the reversed double path Ronchi test configuration. G_s – diffraction grating illuminated coherently or incoherently through the beam splitter BS, M_P – path reversing plane mirror. Other symbols mean the same as in Fig. 1

mirror under test. The observation is performed through the other half of the same grating or another detection grating G_d, placed symmetrically with respect to the optical axis. Since the lateral magnification of this system is -1, it is sensitive to vibrations and mutual displacements between the mirror and diffraction gratings. In order to stabilize the setup the first (source) grating G_s must be imaged on itself (point to point) with the magnification $+1$. This is obtained by using plane mirror M_p located at the position of the detection grating (Fig. 2). The form of the aberration function (doubling of even order aberrations and disappearance of the asymmetric ones) obtained in this way and its analysis being given in [2], will not be repeated here. In the quoted reference the application of this path reversing principle to the Burch scatter reference beam interferometer has been described. In this paper this principle has been applied to the lateral shear interferometer; the Ronchi setup obtained appeared to be very stable with respect to mechanical vibrations.

In order to verify the performance of the system proposed several experiments have been performed. In these experiments the poor quality spherical mirror of the radius of about 4.5 m was the element tested using coherent and incoherent illumination. The interference fringes obtained in the usual Ronchi arrangement and under point source illumination are shown in Figs. 3 and 1, respectively. Fringes in Fig. 3a correspond to the case when only the detection grating G_d was used, Fig. 3b shows the image plane of the first (source) grating G_s given by the mirror (without the detection grating G_d), the interference field when both the source and detection gratings are used is given in Fig. 3c. Fringes in Figs. 3a and 3c were very unstable since the mirror M_T and the diffraction gratings were placed on separate tables. The configuration of two identical gratings G_s and G_d and the spatially incoherent illumination gave the same fringes as in Fig. 3a. They, however, being of poor contrast are not shown here. The explanation of the contrast decrease is given below.

Figure 4 displays the Ronchi interference pattern of the same mirror obtained in the reversed (double) pass configuration of Fig. 2 under point source illumination. Figures 4a and 4b (observation in the image plane of the grating) correspond to the cases of Figs. 3a and 3b, respectively. The obtained interference fringes were very stable against mechanical vibrations and similar to the patterns observed in the classical Ronchi test arrangement (Fig. 3). The number of fringes depends in both arrangements on the longitudinal position of diffraction gratings with respect to the centre of curvature of M_T and, in the second (path reversed) arrangement, on the position of plane mirror.

Very similar fringes observed in the reversed path system using incoherent illumination of the diffraction grating were of poor contrast and therefore are not given here. This decrease of contrast can be attributed to the use of Ronchi rulings with opening ratio equal to 0.5 (defined as the ratio of the slit width to grating period) and to doubling of the amount of defocusing in the double pass optical system under consideration. As it has been recently shown [5, 6], the Ronchi test with incoherent grating illumination can be treated as the

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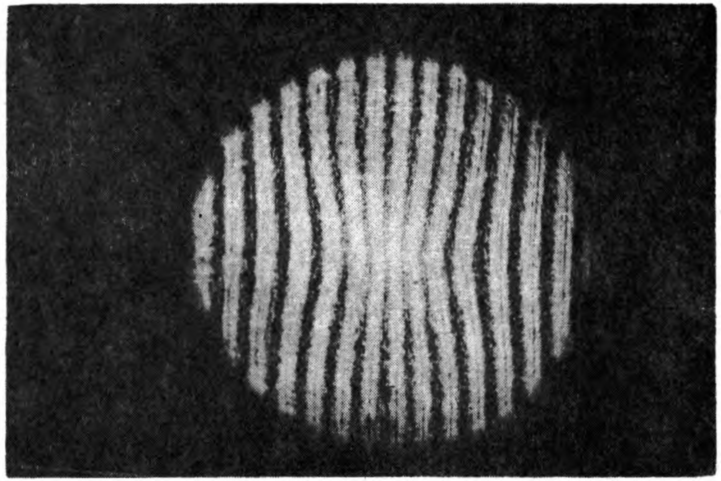

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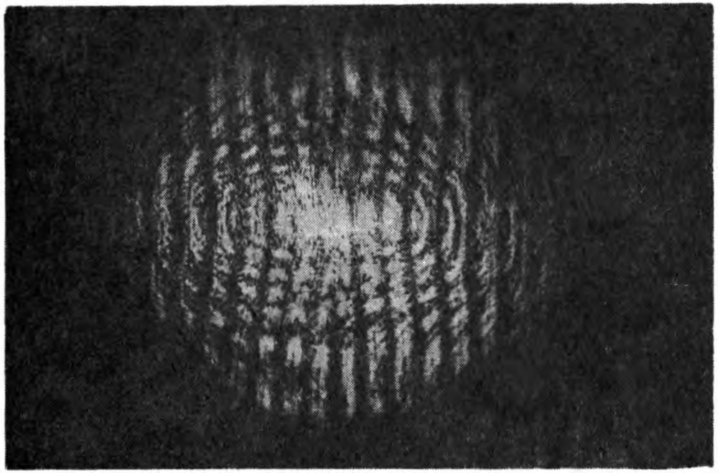
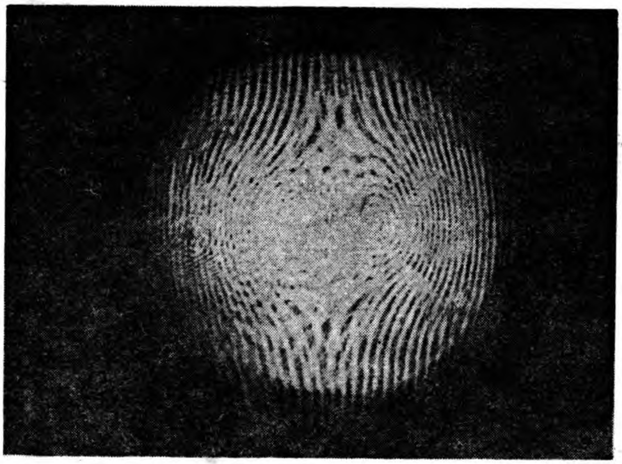


b

Fig. 3. Lateral shear interference fringes obtained in the classical Ronchi grating interferometer while testing a poor quality spherical mirror with point source illumination: (a) the case when only the detection grating is employed, (b) image of the source grating given by the mirror under test, (c) the case when both source and detection gratings are used



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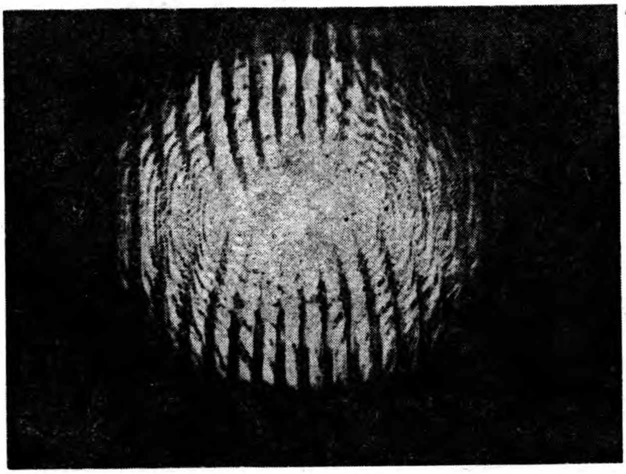

b

Fig. 4. Interference fringes obtained in the modified Ronchi setup of Fig. 2, point source illumination: (a) diffraction grating placed in the image plane of the source (not coinciding with the point source plane), (b) observation in the grating image plane (for comparison see Figs. 3a and 3b)

multiple incoherent superposition of the coherent Ronchi arrangements. It can be called, as well, as the Lau interferometer [6]. The fringe contrast in this configuration is highly dependent on the opening ratio of the gratings (in effect, on their Fresnel images profile) and on the gratings separation distance. While using the interpretation model proposed in [5, 6], poor contrast fringes obtained in our experiments with incoherent illumination can be readily explained. In order to display a reasonable number of fringes in the observation field the grating G_s in Figs. 1 and 2 must be displaced from the plane of the centre of curvature of the mirror under test. In consequence, the grating image (detected by the identical detection grating G_d in Fig. 1 and by the grating G_s itself in Fig. 2) has spatial period different from that of detecting grating. As the result the necessary condition of multiple coincidence of identical in-phase Ronchi patterns [5, 6] is violated. Moreover, in the case of incoherent superposition fringes, Ronchi type rulings produce very low contrast fringes and should be replaced by another type of binary diffraction gratings [3, 4].

An experimental observation concerning some difference in the properties of fringes obtained in the coherent and incoherent arrangements is worthy to be mentioned. As it has been stated before the plane mirror reversed path configuration is characterized by the magnification $+1$. Therefore, when the diffraction grating is laterally displaced, the Ronchi fringes should not move. In fact, this is the case of incoherent illumination only where the optical conjugation principle governs solely the system performance. With coherent illumination, however, the fringes move in the observation field. This is due to shadow (projection) imaging called also the self-imaging. The grating is first projected by a point source on the mirror under test with magnification $+1$. Next, after reflection from it and from the plane mirror M_p the projection is rotated through 180°. Therefore, when the surface of the mirror under test is observed, the moving fringes are seen because of the antiparallel movement of two above mentioned coherent grating projections.

Finally, we would like to add that the configuration proposed, besides its application to testing concave spherical and aspherical mirrors, can be employed in testing of long focal length lens systems. The grating is placed at the double focal length distance in front of the lens, whereas the path reversing plane mirror is symmetrically located on the other side of the lens.

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