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Lensmeter using a lateral shearing interferometer

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ABSTRACT

The use of a laser shear interferometer for checking the collimation condition within a lensmeter is proposed. The interferometer consist of a wedged glass plate which produces a shear along the orthogonal direction to the wedge; when the fringes at the center of the pattern are parallel to the shear, the collimation condition is attained. The feasibility of the proposal for measuring the vertex power is experimentally shown and the accuracy of the method is under 5% of the measured value being an improvement to the commercial instruments based on the focusing of a reticule.

1. Introduction

The traditional lensmeter [1,2] is an elegant instrument, efficient, and simple to use. For this instrument the Newton's equation for lenses [3,4] are applied; hence the front and back focal points of the lens are used as reference planes for the measurements of the distances of an object and its image from such focal points.

Fig. 1 shows a scheme of the classical instrument, where the graticule is located at the front focal point, F_r, illuminated with a collimated beam, first without the ophthalmic lens (OL); then lens L_x, is fixed at the back focal point, F_r', and the graticule is focused by eye. When the lens OL is located at the point F_r', the graticule is observed out of focus; but shifting the lens L_r by a distance $\pm x$, depending of the lenses under test, the reticule can be brought to focus by the observer. By means of the Newton's equation:

$$xx' = -f_r^2, \tag{1}$$

from the previous knowledge of f_r and measuring x, the value of the focal length $f_0 = x'$, of the lens OL, can be obtained.

In next sections we propose, that instead of the classical method, where a reticle is used in the lensmeter, an interferometric technique can be applied, keeping the same theory and efficiency in the measurements of the focal distances of the OL.

2. Lateral shearing interferometer

In a review of the methods for measuring long curvature radii of optical surfaces, several techniques are found in the literature. Most of the techniques applied collimated [5–7], and few of them uncollimated beams [8,9]. In particular, in the paper by Xiang [7], a Fizeau interferometer is used combined with same Newton's equation for lenses; where the focal points are used as reference positions for doing measurements. Given the similarity of the Xiang's method with the principles applied in the classical lensmeter, the idea of using an interferometric method instead of the graticule was analyzed. Even some measurements of the focal length of ophthalmic lenses were done by means of Xiang's scheme; the system, however, has several drawbacks in its application.

Given the compact system of the lensmeter, several interferometric techniques were studied [10,12]; trying to find out one that can be used, properly, for measuring the focal distance of ophthalmic lenses, OL. As a result, the use of the lateral shearing interferometer developed by Murty [11] was selected. In Fig. 2 we show the proposed scheme of the experimental set up for measuring the focal length of the ophthalmic lenses. The main components of the arrangement are: a laser light source, producing a point source at F_r'; the reference lens, L_r, and the quasi plane-parallel plate (PPP) for the observation of the shearing interferograms. As in the classical lensmeter, in the interferometric scheme, the laser point source and the ophthalmic lens are positioned at the focal points F_r' and F_r, of the reference collimating lens, L_r.

In order to do the measurements, a reference interferogram, with a collimated beam, is obtained with fringes along the horizontal direction; this interferogram is observed without the ophthalmic lens. Since the lateral shear interferometer, consist of

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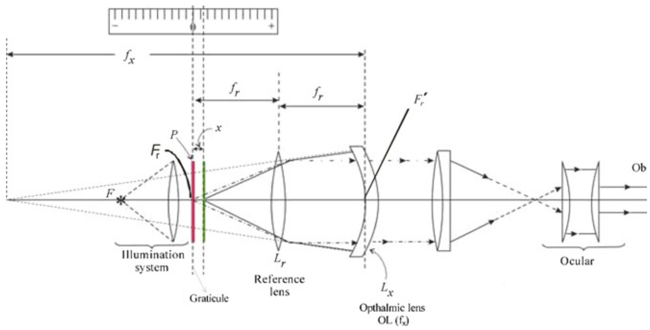


Fig. 1. Scheme of the classical lensmeter instrument.

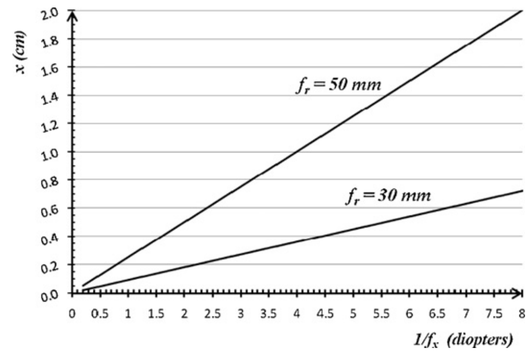


Fig. 3. The shift, x, of reference lens versus the power of the ophthalmic lens, $1/f_x$, for two values of the reference lens Fr, 50 and 30 mm.

a wedge glass plate, the shear is produced along the orthogonal direction of the wedge; hence when the fringes at the center of the pattern are parallel to the wedge, the collimation condition is obtained [13–15]. This condition for the interference fringes is the clue for its use in the proposal of this paper.

Later on, the ophthalmic lens is positioned at the F_r position, and as a consequence the reference interferogram has changed with the fringes rotated with respect to the original direction. For recovering the initial interferogram with the collimated beam illuminating the quasi PPP; the reference lens L_r must be shifted by a distance $\pm x$, depending on whether the lens under measurement is positive or negative. Hence, once the shifted distance x of the reference lens is measured, and the reference interferogram is registered again; the focal length of the ophthalmic lens can be obtained as $x' = f$, from Eq. (1), since the focal length f_r of the reference lens is known in advance.

With the idea of developing a compact and efficient system for the measurement of the focal length of OL, similar to the classical lensmeter; for the interferometric scheme analyzed, an important parameter is the focal length of the reference lens L_r. Therefore, considering a range between 0.5 and 8 diopters for the ophthalmic lenses that means that the focal lengths of the OL are within a range from 2000 to 125 mm. In Fig. 3, are shown the shifts x, for different values of the power of the lens; the inverse of the focal distance $1/f_x$ in diopters; taking the values of f_r as 30 and 50 mm. As a conclusion, the value of f_r must be of few millimeters, in order to have acceptable values for the distance shifts of x.

The plane parallel plate, producing the shearing of the wavefronts for the interferograms, has a small angle between its faces, such that an adequate number of fringes can be observed in the interferogram, and to avoid some reflections. In our experiment we use a plate with thickness of 10 mm, with an angle of 40/arc seconds. The position of the PPP is such that the wedge is oriented perpendicular to the shear of the pupil; therefore the interference fringes are horizontal.

3. Experimental results

In Fig. 4 is shown the laboratory experimental set up. A He–Ne laser was used, with spatial filter to produce the point source located at the front focus of L_r. The lens L_r, with a focal length of 50 mm, was located on a carrier with longitudinal and lateral motions. The interferograms observed, were registered with a CCD camera, connected with a PC, where the reference interferogram is stored.

As can be seen in the experimental interferograms the fringes are different for each lens with different values of its focal length. Even that the lenses can have some aberrations, as are analyzed in the paper by Wyant and Smith [16]; in our proposal we use only the horizontal fringes at the center of the interference pattern as the reference for the collimation of the beam, with the ophthalmic lens in position for the vertex power measurement.

For the experiment, three commercial ophthalmic lenses with values of 0.5, 2.25 and 6.00 diopters were measured. In Fig. 5 are shown ten numerical values measured for each lens, and besides are the interferograms observed for each one of the measurements. The average measurements values for each ophthalmic lens are 0.53, 2.17 and 6.08; and the errors in our measurements are less than 5%, and they decrease for bigger diopter values, see lower row of Fig. 5. The errors for commercial lensmeters [17–19] corresponding to the values of our commercial lenses are 12, 2.5 and 2%, respectively. Therefore, our errors are less for the smaller and bigger values, in diopters, of the ophthalmic lens.

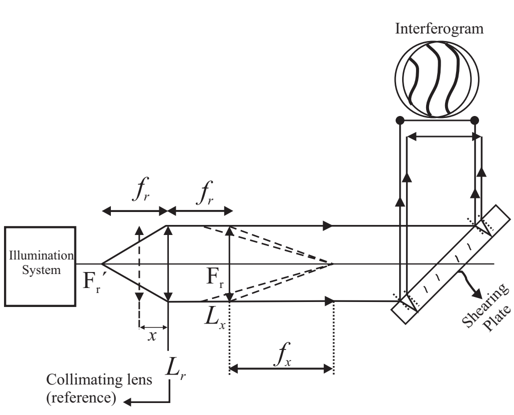


Fig. 2. The proposed scheme of the experimental set up using a lateral shearing interferometer.

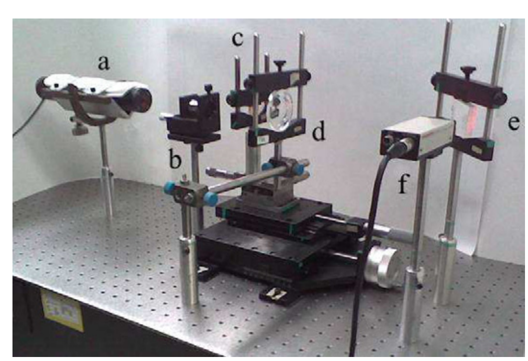


Fig. 4. Laboratory experimental set up: (a) laser, (b) spatial filter, (c) ophthalmic lens, (d) collimating and reference lens, (e) shearing plate, (f) CCD camera.

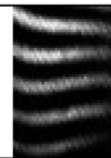
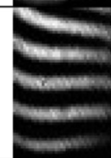
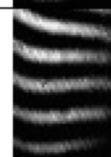
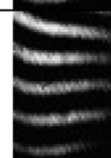
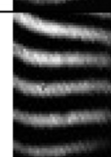
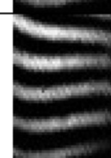
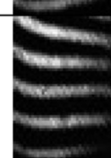
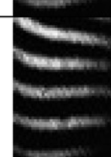
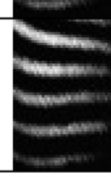
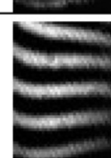
Experimental Results	Interferogram	Experimental Results	Interferogram	Experimental Results	Interferogram
0.52		2.16		6.06	
0.52		2.17		6.07	
0.53		2.16		6.08	
0.52		2.16		6.07	
0.53		2.18		6.07	
0.53		2.16		6.08	
0.54		2.16		6.10	
0.51		2.16		6.07	
0.53		2.19		6.08	
0.54		2.17		6.08	
0.53	0.03	2.17	0.08	6.08	0.08

Fig. 5. Interferograms for 10 measurements for three different ophthalmic lenses with commercial values of 0.5, 2.25, and 6.0 dioptre.

4. Conclusions

Given the results obtained in the experiment using interferograms for measuring the diopters of the ophthalmic lenses; seems to be feasible to use a lateral shearing interferometer, combined with a chosen proper value of the focal length of the reference lens, L_r. Of course, in the case of commercial application, it is necessary to optimize the mechanical mounts, as well as the optical parts of the interferometer. On the other hand, the main characteristics of the classical lensmeter are preserved in a satisfactory way in the experimental scheme presented in the paper.

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References

[1] A.C. Hardy, F.H. Perrin, The Principle of Optics, Mc Graw Hill, 1932.
[2] S. George, D.A. Atchison, The Eye Visual Optical Instruments, Cambridge University Press, 1997.
[3] F. Jenkins, H. White, Fundamental of Optics, Mc Graw Hill, 1976.
[4] M. Born, E. Wolf, Principles of Optics, Cambridge University Press, 1999.
[5] M.V.R.K. Murty, R.P. Shukla, Measurement of long radius of curvature, Opt. Eng. 22 (1983) 231–235.
[6] Z. Mingshan, J. Yaling, L. Gohua, Multi-function spherometer based on self-reference shearing interferometric technique, Proc. SPIE 2536 (1995) 498–505.
[7] Y. Xiang, Focus retrocollimated interferometry for long-radius-of-curvature measurement, Appl. Opt. 40 (2001) 6210–6214.
[8] H.H. Karaow, Interferometric testing in a precision optics shop: a review of testplate testing, Proc. SPIE 192 (1979) 56–64.
[9] Y.W. Lee, H.M. Cho, D.J. Shin, I.W. Lee, Noncollimated bidirectional shearing interferometer for measuring a long radius of curvature, Appl. Opt. 36 (2007) 5317–5320.
[10] D. Sacramento Solano, F.S. Granados Agustín, A.M. Zárate-Rivera, A. Cornejo-Rodríguez, Propuesta para emplear un interferómetro de retrocolimación en un lensómetro, Suplemento del Bol. Soc. Mex. Fis. 20-3, 4MD38 (2006).
[11] M.V.R.K. Murty, The use of a single plane parallel plate as a lateral shearing interferometer with a visible gas laser source, Appl. Opt. 3 (1964) 531–533.
[12] F. Granados Agustín, A. Jaramillo Nuñez, D. Sacramento Solano, A. Cornejo Rodríguez, Lensómetro empleando un interferómetro de desplazamiento lateral, Reunión Iberoamericana de Óptica (RIAO), Universidad de Campiñas Brasil, Octubre, 2007.
[13] D.-Y. Xu, K.J. Rosenbruch, Rotable single wedge plate shearing interference technique for collimation testing, Opt. Eng. 30 (4) (1991) 391–396.
[14] J. Choi, G.M. Perera, M.D. Aggarwal, R.P. Shukla, M.V. Mantravadi, Wedge plate shearing interferometer for collimation testing: use of a moiré technique, Appl. Opt. 34 (19) (1995) 3628–3638.
[15] K. Ung Hii, K. Hiang Kwek, Wavefront reversal technique for self-referencing collimation testing, Appl. Opt. 49 (4) (2010) 668–672.
[16] J.C. Wyant, F.D. Smith, Interferometer for measuring power distribution of ophthalmic lenses, Appl. Opt. 14 (7) (1975) 1607–1612.
[17] Reicher Ophtalmic Instrument, The LM1 lensometer, Reicher Inc., http://www.Reichert.com.
[18] KangJie& Look Products, CCQ-200 Lensmeter, Kangjie Medical, http://www.sz-kj.cn.
[19] Raymond Dennis, FNAO Lensometry Basics, L&T 101, http://www.2020mag.com.