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Original research article

The transmitted wavefront of spherical lens measured by rotation-shift method

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ABSTRACT

The precision of traditional interference testing technology is limited by the precision of reference wavefront. In the measurement of transmitted wavefront of spherical lens, the reference wavefront include the front sphere and the rear mirror. To overcome the limitation, a novel absolute method is proposed. The absolute wavefront of the tested lens was obtained by rotating once and shifting twice. The simulation was completed. In simulation, the order of magnitude of the residual was 10^{-13} and the error caused by rotation error was analyzed. The experimental result was given and compared with the result obtained by other method. The results of simulation and experiment demonstrate that rotation-shifting method can effectively reduce the influence of the front sphere and rear mirror.

1. Introduction

The transmitted wavefront of spherical lens is commonly measured by Fizeau interferometer. The finally interferogram contains the information of the tested spherical lens wavefront and reference wavefront. The measurement precision is limited by the precision of reference elements [1,2]. Therefore, to achieve higher precision, all kinds of absolute testing technology have been developed. Many absolute measurement methods are used to test reflective wavefront of spherical mirror, such as three position method, ball-averaging method, the FPDI, the multi-angle averaging method and so on. These methods are working to remove the influence of the front standard sphere.

Compared with testing reflective wavefront of spherical mirror, the reference elements of spherical lens not only include the front standard sphere but also the rear mirror. It makes harder to get the real transmitted wavefront of the tested spherical lens. For the multi-angle averaging method [3–5], a wavefront consists of rotationally asymmetric symmetrical part. To obtain the rotationally asymmetric part, the tested spherical mirror is measured at N equally spaced angular position rotating with respect to the optical axis. By shifting the tested spherical mirror in the case of keeping the confocal, the rotationally symmetrical part can be fitted based on Zernike polynomial. However, Because of exist of the rear mirror, the confocal shifting cannot be completed, so as to the unavailable of the rotationally symmetrical part. The advantage of ball-averaging method [6,7] and the FPDI [8] is the nearly ideal reference spherical wavefront, but still cannot get rid of wavefront error of the rear flat.

Three position method [9,10] have been proved as an effective absolute testing method for testing reflective wavefront of spherical mirror. Based on the three position method, a new absolute testing method applied for the transmitted wavefront

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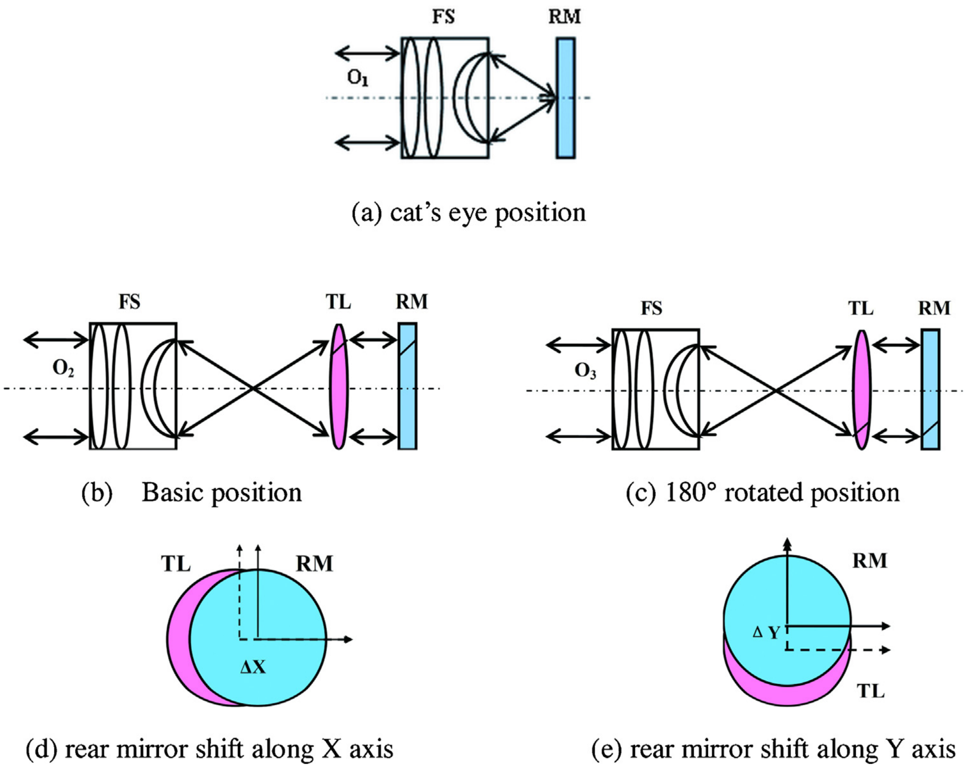

Fig. 1. Schematic diagram of the rotation-shift method.

testing of a spherical lens is proposed in this paper. We first describe the theory of this method. Then the simulation and experimental results are provided.

2. Theory of rotation-shift method

The transmitted wavefront of spherical lens obtained by Fizeau interferometer can be expressed as,

$$O(r,\theta) = W(r,\theta) + R_1(r,\theta) + R_2(r,\theta) \tag{1}$$

where $W(r,\theta)$ the real wavefront of the tested spherical lens, $R_1(r,\theta)$ the wavefront of the front standard spherical lens, $R_2(r,\theta)$ the wavefront of the rear mirror.

Fig. 1 shows the overall measurement process, including three position and two translations. In Fig. 1, the "FS", "TL", "RM" is stand for "the front sphere","the tested lens" and "the rear mirror".

As illustrated in Fig. 1(a), if the tested lens and the rear flat are seen as whole, a spherical wavefront will reflected by it, just like a spherical mirror.

$$W_0(r,\theta) = W(r,\theta) + R_2(r,\theta) \tag{2}$$

where $W_0(r,\theta)$ the wavefront of this special spherical, and that is the sum wavefront of the tested lens and the rear flat.

When the wavefront of this special spherical mirror and the rear mirror have been known, the real wavefront of the tested spherical lens will be the difference of their wavefront.

The first measuring position is done with both spheres in confocal alignment. After the tested spherical lens and the rear flat rotating by 180°, the second measurement is taken. The measurement of third position takes place with the focus of the front sphere; this is also called the "cat's eye" measurement. These three results are respectively expressed as $O_1(r,\theta)$, $O_2(r,\theta)$ and $O_3(r,\theta)$. The sum wavefront of the tested lens and the rear mirror can be solved by using

$$W_0(x,y) = \frac{1}{4}\{[O_2(r,\theta) + O_3(r,\theta+180^\circ)] - [O_1(r,\theta) + O_1(r,\theta+180^\circ)]\} \tag{3}$$

Keep the position of the front sphere and the tested lens in the fourth and final measurement. Translated the rear mirror a distance in X direction, and then we can carry on the fourth measurement. The fifth measurement result is obtained by translating the rear mirror a distance in Y direction. We can get two shear wavefront of the rear mirror though

$$\Delta R_{2x}(x,y) = O_4(x,y) - O_3(x,y) = R_2(x+\Delta x,y) - R_2(x,y) \tag{4}$$