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A METHOD FOR TESTING SURFACE DEFORMS OF LARGE CONVEX MIRRORS

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ABSTRACT

Both ground and space telescopes are being built larger and larger. Accordingly, the secondary mirrors become larger which are convex mostly on the surface form. Testing convex mirrors becomes more difficult and delicate than testing concave mirrors in optics, because additional optical components are needed to make the reflected rays converge. Hindle type tests are frequently used for measuring the surface deforms of convex mirrors, which employs a meniscus lens to reverse the diverted rays from the mirrors. In case of testing large convex mirrors by using Hindle type tests, attention would be needed as larger meniscus lens is required. A method of modified Hindle test has been studied and the characteristics are analyzed. In this paper, current method of testing convex mirrors is presented, and a new method is discussed.

Keywords: optical test, convex mirror, meniscus, metrology, Hindle test, ray tracing

1. INTRODUCTION

As the size of telescope become larger, the secondary mirror is also required to be large. Most of the 8-m class telescopes, Gemini telescopes, Subaru (Kaifu 1993, 1996), ESO's (European Southern Observatory) VLTs (Very Large Telescopes), Keck telescopes (Mast & Nelson 1985, Gillingham 1996), etc., possess convex secondary mirrors to configure Ritchey-Chretien reflector (Osterbrock 1993). Only one exception is the Large Binocular Telescopes (Hill 1996), which contain concave secondary mirrors to configure Gregorian type. Testing the surface form error of convex mirror needs additional optical components, which would make the diverging rays from the convex surface to converge.

Another concern at very large telescopes is high quality of the image, requiring even the diffraction limit of telescope. For example, Gemini telescopes hope to acquire the image quality to be better than 0.1 arcsec (23um in image size) (Gillett & Mountain 1996, Mountain 1996). In order to meet the desired quality, both the primary and secondary mirrors should be fabricated accurately. Testing would play a key role, because without testing accurately the mirrors would not be able to be shaped precisely to the requirements.

In this paper, a testing method of large convex mirrors is suggested and the feasibility of the method has been studied.

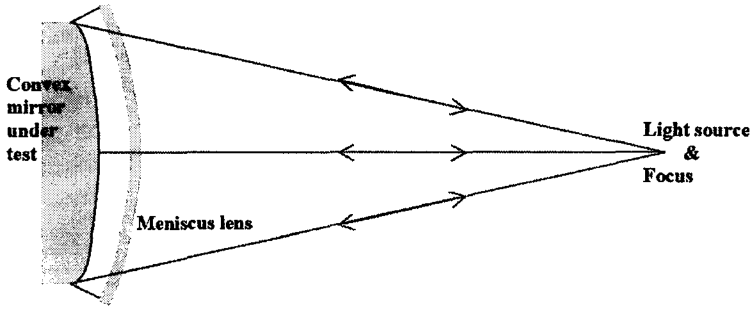

Figure 1. Convex mirror test by using meniscus lens.

Table 1. Tolerances of the arrayed meniscus lenses.

	Tolerances	Remarks
Tilt	±14 nm	Piezoelectric actuator
Displacement	±1.9 um	
Wedge	±0.2 arcsec	
Refractive index	Ignorable	0.2um image size/0.01
Radius of curvature	Little impact	

2. MENISCUS LENS TEST

Applying meniscus lens is one of the frequently used methods for testing convex mirror, like the Hindle type test (Malacara 1978, Walker et al. 1992, Kim 1998). Figure 1 shows how a meniscus lens make the light converge. The emitted light rays from the light source pass through the meniscus lens and reach the convex mirror and reflect to the meniscus lens. At this time, the meniscus lens reflects the rays back to the secondary mirror and again the mirror reflects the rays, which then go through the meniscus lens and converge at the object plane. The converged rays to one point can be tested by using commonly used testing methods.

As is shown in Figure 1, the meniscus lens should be larger than the convex mirror under test. However, there is a problem in testing the secondary convex mirror of the 8-m or larger telescopes, because there is not such a large meniscus lens at present. For example, the diameter of the f/6 secondary mirror of the Gemini telescopes is 2.4m. At present, the biggest meniscus lens in the world is 1.5m in diameter, which is possessed by University College London, England. Making a large meniscus lens which can cover the whole secondary mirror would be a challenging work. Testing can also be degraded because large lens can be distorted by its own weight (Barlow 1975). It may need large amount of money to produce.

3. ARRAYED MENISCUS LENS TEST

A method of testing large convex mirror has been devised, still keeping the idea of applying meniscus lens. It is, by placing several small meniscus lens rather than a large meniscus lens, as shown in Figure 2. By arranging many small meniscus lenses in a row to cover the whole length of the mirror, the whole profile of the mirror at one direction across the diameter can be known at one

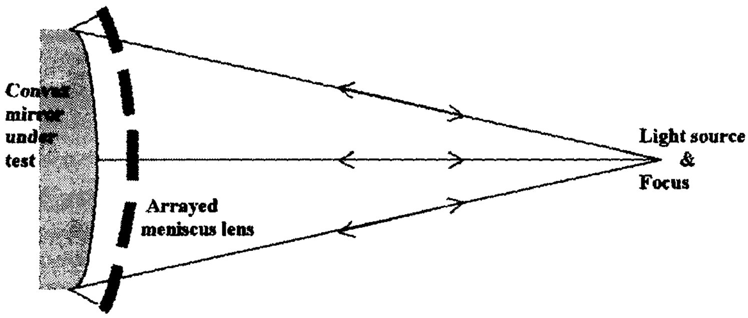

Figure 2. Schematic diagram of arrayed meniscus lens test.

measure.

The diameter of the small meniscus lenses was determined to be 75 mm, which is efficient in imaging and is optimized in making lenses. The radii of curvature of both surfaces of the lenses are made to have co-centre, i.e. the radius of curvature (RoC) of the outer surface equals to the summation of the RoC of the inner surface and the thickness of the lens. According to the ray tracing result by using the Zemax software, the spot diagram of each segmented lens shows the spot smaller than the diffraction limit. When the gap between adjacent lenses is set to be 25 mm, 25 lenses are required to arrange them in a row to cover the whole diameter of the 2.4m secondary mirror. As a preliminary study, several tolerances for the lenses have been calculated. The results are shown in Table 1.

4. DISCUSSIONS

Most of the 8-m class very large telescopes contain convex shaped secondary mirrors. One way of testing the surface form of convex mirror is Hindle type test method. However, large convex mirror is not easy to test, because larger meniscus lens than existing one at present is needed.

A method for testing large convex mirrors, arrayed meniscus lens test, is suggested. The method has been simulated by a ray-tracing tool and tolerances have been assessed. It shows that the tolerance values can be handled within the accuracies of devices. For example, the tilt tolerance is as small as ± 14 nm, but piezoelectric actuators can handle the accuracy. Piezoelectric actuator has the resolution of 2 nm, which is 14 times smaller than the tilt tolerance.

However, there still is a problem: assembling the lenses in a row accurately. If the lenses are not placed accurate enough, the tester itself can generate errors, which leads incorrect test results. High price of piezoelectric actuators can also be an obstacle. Further studies would improve the method of the arrayed meniscus lens test to be practical.

REFERENCES

Barlow, B. V. 1975, The Astronomical Telescope (London: Wykeham Publication LTD)
Gillett, F., & Mountain, M. 1996, The Gemini Newsletter, No.12
Gillingham, P. R. 1996, Proc. SPIE, 2871, 2

Hill, J. M. 1996, Proc. SPIE, 2871, 57
Kaifu, N. 1993, Subaru Newsletter, No.1, 1
Kaifu, N. 1996, Proc. SPIE, 2871, 24
Kim, Y.-S. 1998, PhD thesis, London University
Malacara, D. 1978, Optical Shop Testing (New York: John Wiley and Sons)
Mast, T. S., & Nelson, J. E. 1985, Proc. SPIE, 542, 48
Mountain, M. 1996, Proc. SPIE, 2871, 597
Osterbrock, D. E. 1993, Pauper and Prince: Ritchey, Hale and Big American Telescopes (Tucson: University of Arizona Press)
Walker, D. D., Bingham, R. G., Brooks, D., Diego, F., Humm, B., Jamshidi, H., Kim, S.-W., Kim, Y.-S., Nixon, G., & Rees, D. 1992, ESO Conference and Workshop Proceedings, No.42, 215