Metrological support of aspherical surfaces form parameters deviations measurements in the optical industry

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Abstract:

The problems of metrological support of parameters of aspherical surfaces (AS) of a convex shape up to 250 mm in the optical industry is considered. Methods for measuring AS parameters have been analyzed, a universal method that is not tied to a specific AS has been chosen, the implementation of which will allow the improvement of the Primary National Standard 183-2010.

Aspheric optics is an important component of modern optical instruments and systems. The use of such optics provides a significant reduction in the weight and dimensions of optical instruments, improving the quality of the image, the aperture and the field of view [1]. In systems, such properties are due to the fact that the aspherical surface (AS), in distinct from spherical, has a number of parameters: vertex radius, conic constant and other aspherical coefficients, which makes it possible to reduce or completely compensate for the aberrations of optical systems.

Due to such properties, details and elements of aspherical optics have a wide range of uses: as in microsystems, where the dimensions of parts can be several mm, and large-sized instruments ranging in size from 200 mm to several scores of meters, with the surface form 30-60 nm.

The main measuring instruments of the AS form parameters are interferometers operating according to the Fizeau or Twyman-Green schemes.

An important problem is that today in Russian there is no reference base in the field of aspherical optics form deviations parameters measurements, and the accuracy of the form is provided only technologically in the production process.

The development of metrological support is complicated by the fact, that existing interference devices, intended for the control of aspheric surfaces use special lens, mirror or holographic compensators, which are designed to form the wavefront of comparison [1-3]. Interferometers with such compensators allow one specific aspherical surface to be controlled with certain parameters. A new compensator is manufactured for each new surface. Those, if the interferometer is used as a reference for the standard, it will be necessary to manufacture a plurality of compensators, which is not possible.

Thus, to solve the problem of metrological support, it is necessary:

- develop a set of methods and tools (working standards) for transferring a unit of length from primary standards to working measuring instruments;

- develop a model of a standard, working on the basis of a universal instrument for the control of aspherical surfaces and taking into account the mentioned above features of aspherical surfaces;

- develop a set of normative documents: measuring procedure, verification schemes documenting the procedure for transferring a unit of length in this type of measurements from primary standards to working measuring instruments.

As a result of the modern methods and aspherical surfaces instruments [1, 5-11], it was revealed, that in addition to compensating control methods, the orthogonal ray method [5], the Harman method [6], and the interference control method using the reference sphere with Radius close to the vertex radius AS. The latter method is applicable, if the vertex radius of the AS is equal to the radius of the reference sphere, and the Hartmann method requires the reference surface. Thus, these two methods are not suitable for solving the set tasks, because have limited use.

A feature of the method of orthogonal rays is that it is not tied to a specific AS, and unlike all other methods has a wider application.

To solve the problem, the orthogonal ray method was chosen. Fig. 1 shows the measurement scheme. The investigated surface is illuminated by a beam of parallel rays, propagating perpendicular to the optical axis of the mirror. The interference pattern is formed by the interaction of two wave fronts, one of which (indicated as 2 in Figure 1) is sent to the analysis plane (PA) after reflection from the monitored surface, and the other (indicated as 1), bypassing it.

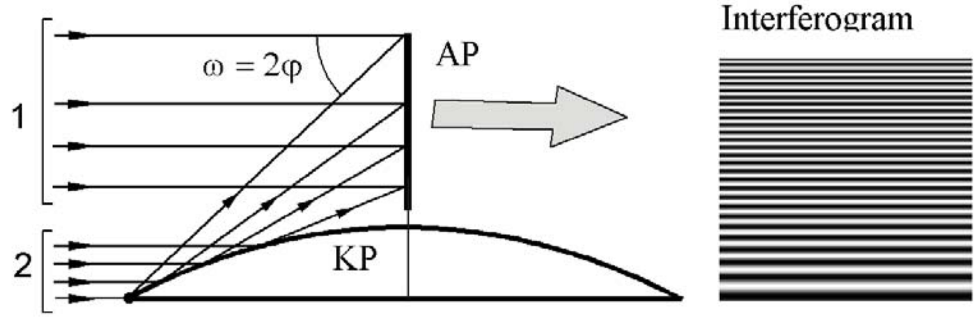

Figure 1 - Diagram of the interference control method

The interference picture is analyzed in a plane perpendicular to the original beam direction and allows to control the form and geometric parameters of the meridian profile of the surface. The form of the interferogram is unique for each monitored surface, but the interferogram is always a multi-thickness arc, and the first arc, closest to the top of the mirror, has the largest width. The radius of curvature of the interference arcs is so large, that the arcs can be considered bands.

The width of the recorded interference fringes is determined by the formula:

$$b = \frac{\lambda}{sin\omega}, \tag{1}$$

where ω is the angle between the interfering beams.

The structure of the beam reflected from the controlled surface carries information about form and quality of the surface.

Approbation of this method was carried out at Bauman Moscow State Technical University. The scheme of the experiment is shown in Fig. 2.

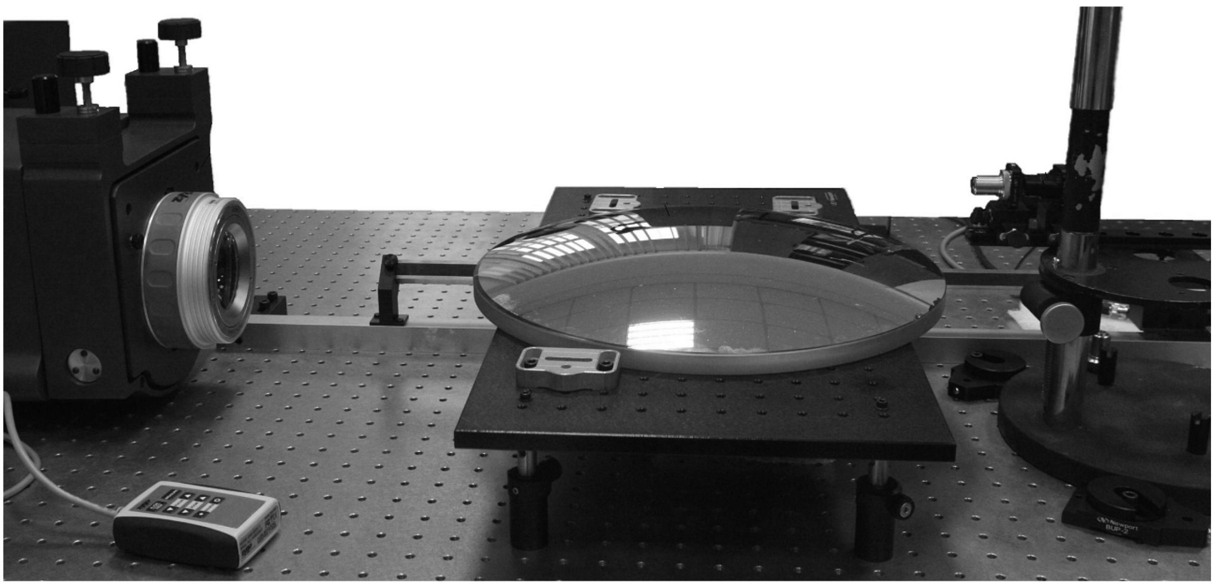

Figure 2 - Diagram of the experimental setup

To create a point source, the Zygo interferometer was used. The carried out experiment confirmed that when controlling the AS by the method of orthogonal rays, an interference picture with bands of different thickness is obtained.

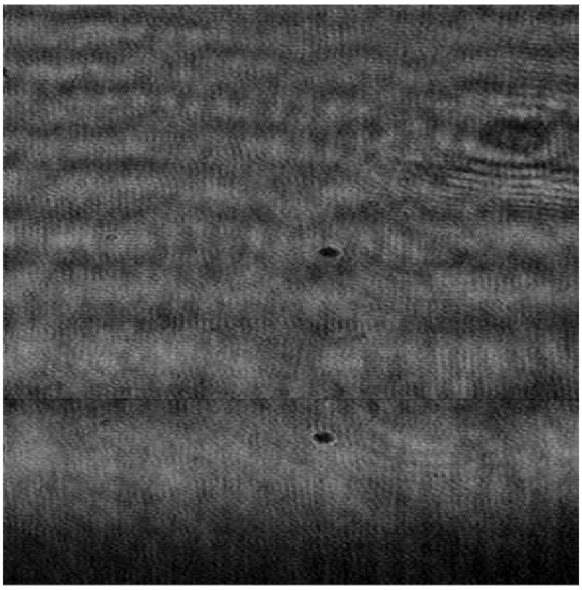

Figure 3 - Fragment of the obtained interference picture

To implement this method, it is planned to use the unit that is part of the Primary National Standard 183-2010. The unit will form a flat standard collimating beam with a diameter of 280 mm at the inlet, which is necessary for illumination of the controlled part. The monitored part will be fixed horizontally on the precision turntable. The resulting interference image will be recorded using a matrix array. During the measurements, a fragment of the monitored mirror that enters the matrix will be recorded. Next, using the rotary table, the following fragment will be recorded. The resulting fragments of interference patterns will be cross-linked into one common interference pattern, characterizing the form of the AS.

Theoretical calculation showed, that the device will be able to measure the form parameters of convex AS with a size from 50 to 250 mm with asphericity no more than 8 μm/m and an error of up to 60 nm.

Thus, the improvement state of the Primary National Standard 183-2010 will allow metrologically ensure measurements the aspherical surfaces form deviation parameters up to 250 mm in size with an error of measurement of 60 nm.

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