

Method for mounting or determining the position of a
semi-finished optical product on a manufacturing
mandrel during the manufacture of a spheric or aspheric
lens

The field of application

The present invention relates to a method for mounting or fixing or for determining the position or orientation of a semi-finished optical product in a manufacturing mandrel during the manufacture of a spherical or aspherical lens, in which the semi-finished product has a ready ground and polished spherical or aspherical first surface on one side and a second surface lying opposite the latter, which still has to be ground and polished for the completion of the lens, and is placed with the first surface on the manufacturing mandrel and cemented.

The use of high-performance, high-precision and at the same time lightweight optomechanical imaging systems is increasingly gaining in importance in industry. The use of aspherical surfaces is playing an increasing role, since the number of lenses can be reduced and dimensions and weight can be significantly minimised.

In the production of an asphere, there is the risk of decentring both as a displacement of the vertex and also as tilting (vertex offset and axial tilt) and these being completely independent of one another. For this reason, aspherical semi-finished products have to be subjected to certain centring rules during the

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grinding and polishing process and are positioned correspondingly adjusted on the manufacturing spindles (manufacturing mandrels), in order to avoid rejects during production. A subsequent centring process, such as is common in the production of spheres, is then no longer possible.

Apart from surface shape defects, there is a need in industrial production for a quick and easily manageable characterisation and modification of internal and external centring errors to achieve the perfect assembly of lens multiplets. These requirements result in increased demands on metrological devices and on the in-situ qualification of the samples under production conditions. During the production of aspheres, there are sometimes high reject rates due to centring errors $> 0.5'$. An accurate measurement of the internal centring error on an aspherical lens is not yet available. Interferometric measurements are also unsuitable for a centring measurement. Point sensor-based sensors are unsuitable, since there are too many degrees of freedom and thus many errors occur. The measurement with point sensors can only be achieved with well centred systems.

To mount semi-finished aspheres on manufacturing mandrels in the most precise possible way is a challenge that has to be met in order to produce precise aspheres with centring errors of less than 30 arc seconds and a lateral offset L with values of less than 5 μm . Tactile devices can be used for this purpose, but high investments are required, the accuracy is limited and the measuring times for high spatial resolution are very long. In addition, optical

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components can get scratched by tactile devices. The centring dimension itself cannot be measured on both sides in one clamping fixture. For this purpose, the asphere has to be fixed in a special holder and shifted or rotated. Specific clamping errors remain, which can amount to more than $1\text{ }\mu\text{m}$ and thus mean tilt angle errors of more than an arc minute in the case of small radii $< 10\text{ mm}$.

The centring process for a spherical lens usually takes place with a clamping centring machine. The clamping takes place with precisely manufactured bells on exactly aligned spindles. The centring of the lens takes place by means of a self-centring process if the tangential angles at the edge of the lens are large enough. If the centring process functions very well, the optical axis produced by the two centres of curvature is parallel to the cylinder axis and coincides with the cylinder axis after the centring operation. If this is not the case, e.g. in the case of a meniscus lens with a large radius or a homocentric lens, the mandrel centring process is generally used. The lens is then adjusted and cemented on a mandrel using an optical measuring instrument such as for example an autocollimator.

For the alignment of a spherical-aspherical lens, the reference is generally based on a mechanical surface such as the rim cylinder. In most cases (especially in the case of a short rim cylinder), the spherical surface (base A) and the rim cylinder (base B) are used, as shown in figure 1. The aspherical axis then has an inclination and a lateral shift L from the reference axis at the vertex of the asphere. This is

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defined in ISO 10110-6 and is also referred to as "external centring error", since it refers to external dimensions and/or external surface references.

If the spherical-aspherical lens is displaced and tilted such that the aspherical axis coincides with the reference axis (reference axis = aspherical axis) (see figure 2), the centring error is reduced to only one aspect, the lateral offset of the centre of curvature C_l with respect to the aspherical axis or the equivalent inclination angle σ , in the same way as for a spherical lens. This is also referred to as an "internal centring error". The internal centring error of an asphere is thus an inherent offset of the centre of curvature of the spherical surface to the aspherical axis of the second surface. This internal centring error is an error existing more inherently in the objective.

Prior art

The schematic sequence of the production process of double aspheres is shown in figure 3. A glass blank 1 is first placed on a manufacturing mandrel 2 (fig. 3a). Glass blank 1 is ground and polished at the first aspherical surface (fig. 3b). The polishing process in the polishing machine is not shown here. In the next step, a first edge treatment takes place (fig. 3c). Semi-finished product 3 with the ready ground and polished first aspherical surface is recemented on mandrel 2 (fig. 3d) and then ground and polished on the second aspherical surface (fig. 3e). The polishing process is again not shown. Finally, the final edge processing is carried out (fig. 3f).

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In the production of double aspheres, the grinding of the first aspherical surface is relatively unproblematic in the step of fig. 3b, since it is measured on mandrel 2 and a quality control can thus take place. The decisive step takes place in the re-clamping or recementing (fig. 3d) after the grinding and polishing of the first aspherical surface and the subsequent processing of the edge. A precise alignment on mandrel 2 before the grinding of the second aspherical surface is essential. This is currently carried out with measuring probes. Once clamped, the second aspherical surface is then ground and polished and the edge is finally removed. If asphere 4 is then removed from mandrel 2 for the final measurements, it can no longer be clamped again. This means that the asphere cannot be corrected and thus ends as a reject if the specifications are not met. An automatic post-correction after the grinding of the second aspherical surface is likewise not possible. Due to inadequacies during the recementing from the one lens surface onto the other lens surface or lack of intermediate results of a centring error measurement, this production technique typically results in a centring error of the end product of approx. $3 \cdot 10'$.

In the current state-of-the-art, therefore, a cut or milled glass block or a prepressed blank (so-called blank) is blocked on a mandrel and first worked in the grinding machine in the production of precision aspheres with the conventional grinding and polishing technique. For this purpose, the sphere or the best-fit sphere (BFS) in the case of aspheres is first ground with the aid of a diamond-tipped face grinding tool or

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diamond-pellet face grinding tool in the preliminary process. After the grinding of the first surface, the edge cylinder is then generally edge-centred with a further machining spindle in the same machine.

The mandrel with the test piece is taken out of the machine, the lens is blocked and then blocked again on the mandrel onto the first ground surface, in order to process the second side using a grinding technique. Depending on the requirements, the lens edge can be centred for example with a mechanical or optical dial gauge during blocking (with preferably thermal wax). The processing is then carried out as on the first side and the lens edge with an oversize (approx. 0.2 to 0.02 mm) is re-centred. The asphere thus runs exactly to the cylinder edge.

The subsequent polishing process is carried out in the CNC polishing machine. Experience shows that the side of the asphere which is now to be processed, because it runs perfectly with respect to the spindle, produces an optimum asphere surface during polishing, with a perfectly centred asphere axis over all regions of the asphere, namely centre, zone and edge. Since the path of the asphere is precisely travelled in this centred asphere due to CNC control and no decentring or eccentricity is present, the exact same footprint is expected everywhere on the surface and the polishing process is perfectly performed. Thus, there are no polishing errors due to different footprints and different dwell times and so an exactly rotation-symmetrical surface results also at the vertex of the lens.

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In the following step, the lens is re-blocked so that the aspherical surface lies downwards. In some cases, it may be provided with a protective lacquer to protect it from damage. The main aim is to bring the already finished lower surface, possibly provided with protective lacquer, onto the mandrel axis, so that the lower aspherical axis lies parallel to and coincident with the mandrel axis and thus with the machining axis. In the simplest case, the heated lens is pressed for this adjustment onto the ring cutter via the hot wax cement applied to the heated mandrel (approx. 60 °C) and the edge cylinder is mechanically centred. Here, however, large deviations are to be expected in some cases on account of the influences listed below:

- axial run-out of the mandrel 1 to 20 micron (of high quality to standard)
- radial run-out of the mandrel 2 to 50 micron (of high quality to standard)
- variation of the coating (first-order analysis) 10 to 20 micron
- roundness of the cylinder 1-5 micron
- roundness of the cylinder 1-10 micron rms
- temperature differences in blocking (20°-65 °C)
- measuring time is usually not accurate enough.

When blocking the semi-finished product onto the mandrel, various influences thus become evident, which have a significant influence on the centring process and the centring accuracy and can thus lead to an internal centring error during the production of the asphere.

The problem of the present invention is to avoid or at least reduce the internal centring error during

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the production process of spherical-aspherical lenses or double-sided aspherical lenses.

Description of the invention

The problem is solved by the method according to claim 1. Advantageous embodiments of the method are the subject-matter of the dependent claims or can be derived from the following description or from the examples of embodiment.

The proposed method serves for mounting or fixing an optical semi-finished product on a manufacturing mandrel during the production of a spherical or aspherical lens. It can also be used to determine the position or orientation of the semi-finished optical product on a manufacturing mandrel during the production of a spherical or aspherical lens. In the proposed method, the semi-finished optical product already has a ready ground and polished spherical or aspherical first surface on one side and a second surface opposite the latter, which still has to be ground and polished to complete the lens. In the method, the semi-finished product is placed on the manufacturing mandrel with the first surface, preferably thereby adjusted and then cemented or blocked. The method thus relates to the recementing onto the mandrel of figure 3d described above. The method is characterised in that the adjustment or position or orientation of the semi-finished product is checked and determined with a special optical process and/or the adjustment (in particular the above centring process) is carried out with the aid of the special optical process. In this optical process, a transparent

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optical auxiliary element with a polished upper surface and a lower surface adapted to the second surface of the semi-finished product is applied onto the second surface of the semi-finished product via a medium for the index adaptation as an intermediate layer, in particular an immersion oil. The optical auxiliary element is irradiated with an optical beam (or also with a plurality of optical beams), in such a way that the optical beam is partially reflected at the upper surface of the auxiliary element and partially at the first surface of the semi-finished product. At least the beam portion reflected by the first surface of the semi-finished product, preferably both reflected beam portions, is or are detected with at least one spatially resolving optical detector.

In spite of the not yet polished second surface of the semi-finished product, this procedure makes it possible to obtain a reflection of the measuring beam or optical beam from the first surface on the semi-finished product, and thus to carry out the adjustment of the semi-finished product on the manufacturing mandrel before the cementing on the basis of the detected reflections. The manufacturing mandrel is preferably set in rotation during the measurement. The use of the reflection from the already finished spherical or aspherical first surface is only made possible by the mounted auxiliary element and the medium thereby used for index adaptation. Otherwise, the measurement cannot be carried out for adjustment, but only the detection of the position or orientation of the semi-finished product, in particular the lower surface thereof, in order to then to correctly carry

out the processing of the second surface on the basis of this information.

In the case of a plane second surface of the semi-finished product, an auxiliary element is preferably used that is designed as a plane-parallel plate or as a concave or convex lens with a plane lower surface. In the case of a convex or concave second surface of the semi-finished product, an auxiliary element is preferably used that has a concave or convex lower surface and a plane, concave or convex upper surface.

In the proposed method, the auxiliary element is preferably designed in such a way that it completely or almost completely covers the second surface of the semi-finished product. The measurements with the optical beam or with two of the optical beams for detecting the reflected beam portions are preferably carried out in the method both in the centre and at the edge of the semi-finished product.

Brief description of the drawings

The proposed method is explained in greater detail below with the aid of examples of embodiment in combination with the drawings. In the drawings:

- Fig. 1 shows an exemplary representation of the external centring error of a spherical-aspherical lens with an inclined aspherical axis and a lateral offset L at the vertex of the aspherical surface (vertex);
- Fig. 2 shows an exemplary representation of the internal centring error of a spherical-

aspherical lens with the aspherical axis as the reference axis and the offset of the spherical centre of curvature;

- Fig. 3 shows the diagrammatic sequence of the production process in the production of a double asphere;
- Fig. 4 shows a representation of the determination of the orientation of a semi-finished optical product on a manufacturing mandrel according to an exemplary embodiment of the proposed method with a plane-parallel plate as an optical auxiliary element;
- Fig. 5 shows two exemplary representations of the use of differently designed auxiliary elements depending on the shape of the semi-finished product in the proposed method; and
- Fig. 6 shows two exemplary representations of the measurement of the semi-finished product at two different positions in the embodiment of figure 5.

Ways of performing the method

The proposed method is used in the production process of a spherical or aspherical lens, as has already been described by way of example in the introductory part of the description in conjunction with figure 3.

Fig. 4 shows an exemplary representation of the determination of the orientation of optical semi-finished product 3 on a manufacturing mandrel 2 according to an embodiment of the proposed method. In this example, the semi-finished product has a plane second surface. Here, a plane-parallel plate is used as optical auxiliary element 5. In this regard, figure 4 shows semi-finished product 3 with a first surface which is spherical in the present example and on which a corresponding lacquer is applied. Manufacturing mandrel 2, onto which this semi-finished product 3 is placed and with which it is to be cemented, is merely indicated in the figure. Auxiliary element 5, in this example a plane-parallel plate, which correspondingly has a polished upper side, is then placed on the as yet unprocessed, in this case plane, second surface. Located between the underside of this auxiliary element 5 and the second surface of semi-finished product 3 is an immersion oil (not shown in the figure) for the index adaptation.

In this and also the other possible embodiments of the method, the so-called vignetting field stop technology (VSF or V-SPOT) is preferably used for the trans-illumination with the optical beam, with which both reflections, i.e. the reflection from the upper surface of auxiliary element 5 and the reflection from the first surface of semi-finished product 3, can be detected on a detector without changing any focuses. With this technology, it is possible to precisely detect the local meridional gradient error in the zone or at the edge of the aspherical surface and, together with the centring deviation of the vertex, to determine

the aspherical axis and thus the internal centring error.

Through the use of this VFS technology with the corresponding measuring device EP shown in figure 4, the two reflections shown at the top right in the figure are obtained, to which the beam path of the correspondingly extended measuring beam 6 is indicated in the figure. The instantaneous position or orientation of semi-finished product 3 can then be determined from the position of these reflections.

An exemplary implementation of the fixing of this semi-finished product 3 on manufacturing mandrel 2 is explained briefly in the following example.

Example:

1. The test piece is a semi-finished product consisting of
 - ready polished sphere or asphere on one side;
 - rear side ground plane;
2. Application of an immersion oil corresponding to the refractive index of the semi-finished product (1,4 – 1,6) on the rear side of the semi-finished product;
3. Placing of a plane-parallel plate of high quality made of glass as an auxiliary element in a corresponding size;
4. Setting the measuring device EP (ELWIMAT) via angle α according to DoE, so that a reflection from the front and rear side can be simultaneously evaluated on the detector;

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5. Adjustment of the semi-finished product by suitable positioning of the semi-finished product on the mandrel (smallest centring circles);
6. Fixing the semi-finished product; optionally filling the gap with adhesive;
7. Allowing to cure or cool and checking the result at room temperature;
8. Remove plane plate; clean surfaces;
9. Grind and then polish semi-finished product on the second side (according to known production processes).

In cases in which the not yet ready processed second surface is curved, for example has a convex or concave shape, an auxiliary element 5 is used which has a correspondingly complementary shape on the underside.

In order that the measuring beams emitted from the measuring device strike the already processed first surface of semi-finished product 3 as near as possible to the edge, auxiliary element 5 can be formed with a correspondingly concave or convex upper surface, as shown diagrammatically in figures 5 and 6. In these figures, semi-finished products 3 with a concave and with a convex (polished) aspherical first surface are shown as examples. The second surface is merely ground plane. Immersion oil 7 between auxiliary element 5 and semi-finished product 3 is indicated in these figures. The two auxiliary elements 5 are plane-concave or plane-convex elements which are polished on both sides and which also perform the function of an auxiliary lens. The use of such a plane-convex or plane-concave lens as an auxiliary element 5 instead of a plane-parallel plate is recommended for curved or negative

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(hollow) surfaces or for measurements right at the edge (in the case of bad mandrels), in order to obtain a better conformation of the positions of both reflections with good angular resolution.

In the proposed method for the adjustment or measurement, either two of the measuring devices EP are preferably used for the measurement at two different positions, both in the centre and also at the edge of semi-finished product 3, or measurements are carried out at two different positions one after the other by means of one measuring device EP. This is shown diagrammatically in figure 6.

The vignetting field stop method preferably used in the proposed method, as is also known from EP 1636542 B1, is a measuring principle which uses vignetting as a physical effect to measure an inclination angle or inclination angles on surfaces by reflected light. The measuring beam is a quasi-parallel set of beams of infinite light sources on a splayed illuminated field near the focal point of a collimator lens. A beam splitter brings the reflected light onto a camera or a correspondingly spatially resolving detector. In addition to a plane mirror or a lens in front of the system, the exit pupil of this collimator system is projected into the image field behind the focal point of the collimator. This is referred to as the exit hatch, and since the camera is in the focal plane, there is an unsharp image of the exit hatch on the camera. The unconcentrated exit hatch never creates the problem of coming out of focus, as in the conventional AC (autocollimator). The field of view is no longer limited due to this physical effect of

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vignetting. Therefore, only the camera or detector size, which preferably corresponds to the size of the illuminated field, limits the field of view, which depends only on the focal length of the collimator and the size of the unfocussed exit pupil (V-SPOT) on the camera. The size of the V-SPOT is then dependent on the distance to the plane mirror from the exit pupil or with a curved surface dependent on the attachment lens and the radius of curvature of the DUT.

Through the use of this method instead of a conventional AC, vignetting is no longer a problem, but rather a simple solution in order to measure surface profiles and centring deviations on non-spherical surfaces with high resolution.

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List of numbers

1	glass blank
2	manufacturing mandrel
3	semi-finished product
4	asphere
5	optical auxiliary element
6	measuring beam
7	immersion oil
EP	measuring device
C	centres of curvature
R	radii

Claims

1. A method for mounting or fixing or for determining the position or orientation of a semi-finished optical product (3) on a manufacturing mandrel (2) during the manufacture of a spherical or aspherical lens, in which the semi-finished product (3) has a ready ground and polished spherical or aspherical first surface on one side and a second surface lying opposite the latter, which still has to be ground and polished for the completion of the lens, and is placed with the first surface on the manufacturing mandrel (2) and cemented, wherein the position or orientation of the semi-finished product (3) on the manufacturing mandrel (2) is determined with an optical process and/or an adjustment of the semi-finished product (3) on the manufacturing mandrel (2) is carried out with the aid of an optical process, in which a transparent optical auxiliary element (5) with a polished upper surface and a lower surface adapted to the second surface of the semi-finished product (3) is applied onto the second surface of the semi-finished product (3) with an interposed medium (7) for the index adaptation and is thus irradiated with at least one optical beam (6), in such a way that the optical beam (6) is partially reflected at the upper surface of the auxiliary element (5) and partially at the first surface of the semi-finished product (3) and at least the beam portion reflected by the first surface of the

semi-finished product (3), preferably both reflected beam portions, are detected with at least one spatially resolving optical detector.

2. The method according to claim 1, characterised in that, in the case of a plane second surface of the semi-finished product (3), the auxiliary element (5) is designed as a plane-parallel plate or as a concave or convex lens with a plane lower surface.
3. The method according to claim 1, characterised in that, in the case of a convex or concave second surface of the semi-finished product (3), the auxiliary element (5) has a correspondingly concave or convex lower surface and a plane, concave or convex upper surface.
4. The method according to any one of claims 1 to 3, characterised in that the auxiliary element (5) is designed in such a way that it completely or almost completely covers the second surface of the semi-finished product (3), and that measurements with the optical beam (6) or with two of the optical beams (6) for detecting the reflected beam portions are carried out both in the centre and at the edge of the semi-finished product (3).
5. The method according to any one of claims 1 to 4, characterised in that, for the performance of the optical method, use is made of a measuring device (EP), in which the

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optical beam (6) is produced by an extended light source and is collimated via an optical arrangement before striking the semi-finished product (3), wherein an aperture limiting the optical beam (6) is placed between the light source and the optical detector, which aperture acts as a vignetting field diaphragm and through which the beam (6), after reflection at the upper surface of the auxiliary element (5) and at the first surface of the semi-finished product (3), is imaged out-of-focus as a light spot or light spots on the optical detector and is detected with the optical detector.

6. The method according to claim 5, characterised in that a diaphragm with a fixed or adjustable diaphragm opening is used as the aperture limiting the beam (6).
7. The method according to any one of claims 5 or 6, characterised in that the extended light source is provided with a light area which has at least the size of a detection area of the optical detector.
8. The method according to any one of claims 1 to 7, characterised in that the semi-finished product (3) with the manufacturing mandrel (2) is rotated about the axis of rotation of the manufacturing mandrel (2) during the measurement or the performance of the optical method.