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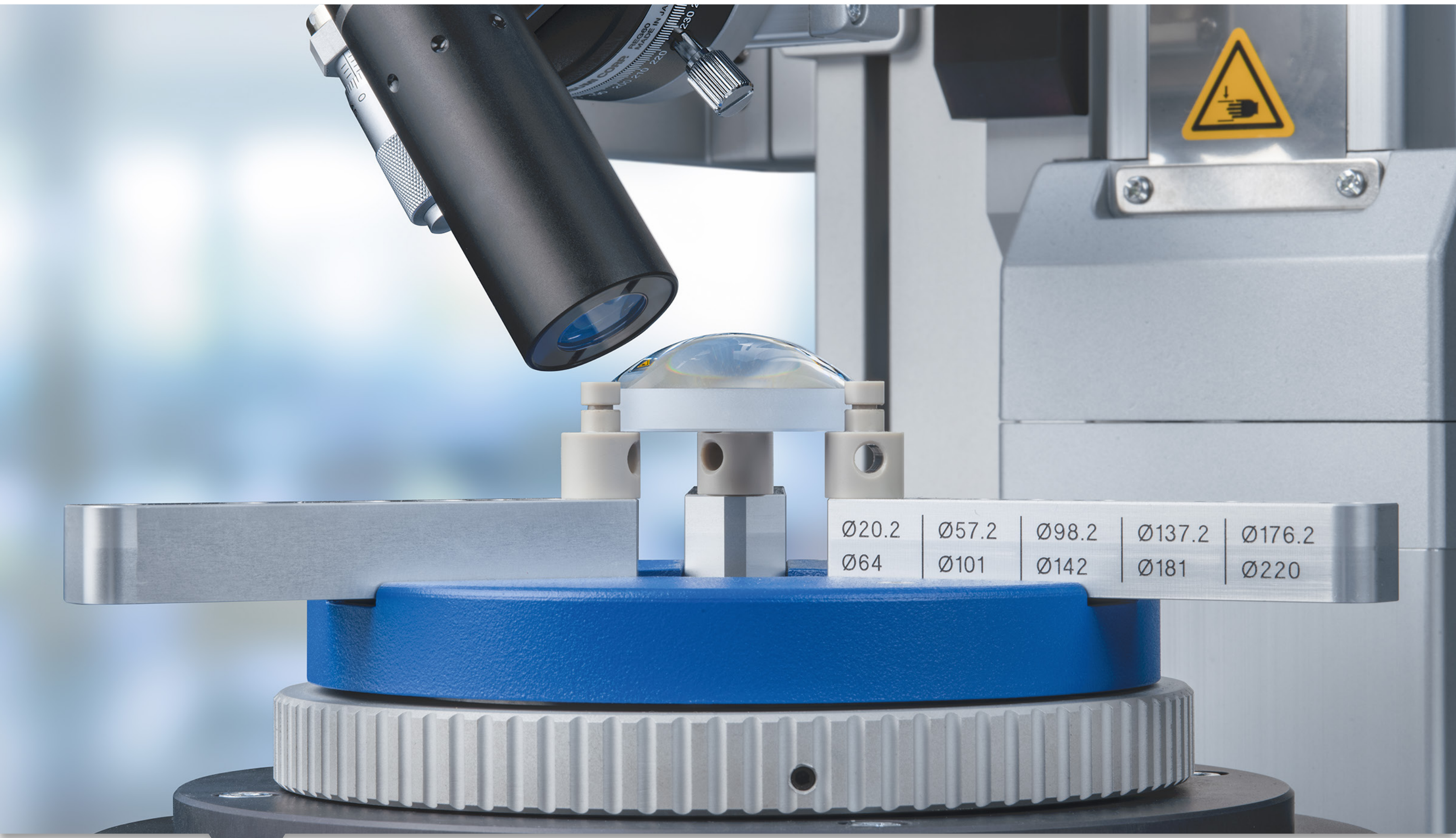

Ensure precision in aspheric lens manufacturing with advanced metrology solutions

Aspheric lenses have become a useful go-to solution in a number of industries and use cases, where high-precision image quality is important. To achieve this, their optical surfaces require exact form and positioning. While this is true for all lenses, it is particularly critical for optics with an aspherical element to avoid aberrations if the aspheric surface is not in exactly the correct form, centration and positioning. This White Paper looks at the role of metrology and alignment processes in ensuring that this is achieved. It also introduces an innovative centration measurement technique that was specifically designed for aspheric lenses, and outlines some of the advantages it provides over other widely used methods.

Introduction

First documented as a concept back in ancient Egyptian and Roman times, aspheric lenses as we know them now, came into being in the 1950s. Today, aspheric lenses are used in a variety of optical systems, including medical imaging, telescopes, lasers, consumer electronics, and lidar applications. This is largely thanks to their complex, non-spherical shapes, which can provide better light manipulation by reducing spherical aberrations compared to their traditional spherical counterparts. However, it is vital to ensure that their form, inner centration and position are within the required tolerances in order to achieve optimal system performance.

What is an aspheric lens?

An aspheric lens, or asphere, is a rotationally symmetric lens in which the surface profile is not a portion of a sphere or cylinder. Unlike traditional spherical lenses, aspheres have a varying curvature across their surface, which allows for more precise control over how light is refracted. This means that light rays entering the lens at different positions can individually be refracted to ensure a better performance by reducing spherical aberrations. As such, an aspherical surface achieves what can otherwise only be realized by several spherical surfaces.

Because of these properties, aspheric lenses are used in a wide range of applications, especially in space-restricted optical systems, e.g., smartphone optics. They can help to enhance image clarity and brightness in projectors, increase resolution and image quality in microscopes and improve light gathering and image sharpness in telescopes.

They have many uses in medical imaging devices for better image clarity and precision, and also offer thinner, lighter, and more aesthetically pleasing lenses in eyeglasses and head-mounted displays.

Why measure aspheric lenses?

Once the objective lens is assembled, it can be difficult to assess the accuracy of the asphere placement, and only general image quality measurements can be used to validate objective lens performance. Measuring the asphere after production but before assembly will ensure that only aspheres which meet the design specifications are used to build the objective lens. As the cost for corrections increase in the advancing process, measuring aspheres in advance is a simple and logical step to reduce overall assembly costs.

Traditional asphere measurement methods: benefits and limitations

Traditionally, asphere measurement has relied primarily on profilometry or shape measurement techniques. These involve scanning the lens surface with a tactile or optical probe to generate a detailed profile or interferometric measurement, in combination with a computer-generated hologram (CGH).

These techniques test the complete form of the asphere, and are usually performed during or after the production of single components. They have documented benefits when it comes to capturing surface topography, but they also have their limitations. For example, they can be time-consuming, with a slow scanning process that can have an impact on production efficiency. They may also be inflexible, expensive and can require a complex pre-adjustment when it comes to interferometers. In addition, extracting relevant information, such as asphericity, tilt, and centration errors from the generated point cloud can be computationally intensive. Then take into account that some profilometers may not be suitable for measuring aspheres with more complex geometries or coatings. Specialized equipment and skilled operators for these techniques could also increase overall costs.

Centration errors of aspherical surfaces can occur due to a number of reasons within the applied manufacturing processes:

1. Grinding and polishing / diamond turning

- Unintentionally induced wedge angle between the lower surface and preci sion lens mount/holder
- Reduced precision of the lens mount

2. Molding / injection molding production

- Misalignment between mold mountings
- Additional misalignment between mold inserts.

A solution is available: Asphere centration measurement

To address some of the challenges posed by the limitations of traditional methods, a novel approach known as asphere centration measurement has emerged. This technique focuses on measuring the alignment of the aspheric axis with the optical axis, a critical parameter for ensuring optimal image quality.

How does asphere centration measurement work?

Asphere centration measurement is used for direct measurement (single component) and lens alignment. It is suitable when the form of the asphere is verified to be fitting or if the form errors are less relevant than the centration of the asphere. In molding processes, once the molding parameters are accurately set, the shape of the final product is determined solely by the mold inserts. These inserts need to be verified only once to ensure consistent production. The position of the mold inserts must be repeatedly checked and readjusted during the manufacturing period.

The measurement process involves three key steps

1. Optical axis measurement:
The paraxial optical axis is determined by measuring the two positions of the centers of curvatures with an autocollimator.

2. Asphere axis measurement:
A non-contact optical distance sensor (such as a confocal chromatic sensor) is used to measure the run-out of the aspheric surface in one peripheral zone and in one single lens rotation.

3. Data analysis:
The measurement data is processed to determine the asphere centration error using the nominal aspheric design.

The benefits

By combining an autocollimator with a chromatic confocal sensor, asphere centration measurement offers a number of benefits, including:

- **Speed and efficiency:** Asphere centration measurement is a faster process than profilometry, as it requires only one single lens rotation. Once verified as functional, the part can be installed in optical assemblies. Here, the conventional autocollimator measurement allows fast alignment with live feedback on the location of the paraxial centers. By leveraging the known relationship between the asphere axis and optical axis, active alignment of the asphere axis is also possible. The preferred alignment method – paraxial optical axis or aspheric axis – is determined by tolerance requirements.

- **Accuracy:** Asphere lens elements are analyzed not only against mechanical references but also against the paraxial optical axis, the internal reference. This is particularly advantageous for double-sided aspheres, as it eliminates the need for external reference points (like a sample holder) to combine measurements from both sides.

- **Cost:** The equipment needed to enable asphere centration measurement is generally less expensive than that required for profilometry. If a centration testing device (OptiCentric®) or an alignment turning machine (ATS) is already available, it only requires the additional sensor.

- **During assembly:** The measurement can be easily integrated into the assembly process, allowing aspheric lenses to be aligned using the asphere axis rather than the paraxial optical axis.

It is important to consider that local defects may affect the measurement results. However, they can be detected and either excludes from the sample data or avoided by moving to a different zone.

Technical considerations

There are a number of technical considerations to take into account when it comes to asphere centration measurement.

- **Accuracy of the sensor positioning:** As the aspherical centration is determined in relation to the nominal asphere data, the exact positioning of the sensor needs to be correctly set. Automated sensor positioning solutions with application-specific positioning accuracies are available to meet this requirement.

- **Dependence on the sample design:** The accuracy of centration measurements for aspheric samples increases with the difference between their peripheral and paraxial surface curvatures.

The TRIOPTICS solution

This innovative centration measurement technique is integrated into various TRIOPTICS products, including:

OptiCentric® 101 with AspheroCheck®

A versatile platform for precision lens handling, OptiCentric® excels at centration testing and even automated assembly. With centration accuracy down to 0.1 µm, it can handle a wide range of lenses. Combined with OptiCentric® AspheroCheck®, the motorized sensor enables centration testing of most aspheric lenses, whether aligned manually or automatically.

AspheroCheck® UP

The AspheroCheck® UP is a fully automated system designed for the rapid and precise testing of aspheric lens centration and tilt even for very small samples. Built on the OptiCentric® platform, it is designed for a highly accurate and automated sensor and lens positioning. The streamlined process provides results on the position of the aspheric axis relative to the paraxial optical axis in less than a minute, making it ideal for production environments.

ATS with AspheroCheck®

The ATS alignment turning station is a precision machine that aligns and machines mounted lenses. It combines OptiCentric® and AspheroCheck® centration measurement with turning technolgy for accurate adjustment of lens position and mount dimensions. The lens can be centered on either the paraxial axis or the aspheric axis. The overall process provides a faster and more effective solution when building high-quality objective lenses with minimal operator influence.

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