Highly Efficient Assembly of Lenses with OptiCentric®
and OptiCentric® Cementing
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OptiCentric® Cementing

Increases Productivity when Assembling and Cementing Lenses

OptiCentric® systems are renowned worldwide for their measurement accuracy and their flexibility in centration measurement of single lenses and objective lenses.

TRIOPTICS has taken advantage of these strengths in the development of the OptiCentric® Cementing system and developed a device for manufacturing.

The OptiCentric® Cementing system automatically measures and aligns lenses, then the cement between the lenses is cured with UV illumination. This means the user can prepare the next pair of lenses in parallel, while an OptiCentric® Cementing system cements another pair of lenses. TRIOPTICS customers can easily double their throughput when cementing lenses.

The OptiCentric® Cementing device is flexible: depending on whether the achromat is fixed for further processing with the bell-clamping method or on an arbor in the alignment turning machine, the OptiCentric® Cementing Station is adapted to the respective post-process in the alignment turning machine. Tedious and time-consuming adjustments for alignment turning are not required.

The OptiCentric® Cementing Station reduces manufacturing time in lens assembly: two pairs of lenses are prepared and cemented in parallel.
The precise centration and alignment of a lens is crucial for the image quality of the optical system. According to ISO 10110 a centering error is given when the optical axis of a lens do not coincide with a reference axis, respectively these are different in position and direction. Centration errors occur when cementing, aligning and fixing lenses, so the precise requirements in optical systems can be best met if all manufacturing steps are uniformly designed and incorporated into one measurement and manufacturing system.

The following sections therefore explain the fundamental principles of centration measurement as well as the specific features of the cementing process used by the OptiCentric® Cementing Station.

**Centration Measurement in Reflection and Transmission**

In order to measure the centration of a lens, it is a requirement that the lens rotates around a precise reference axis. In most cases this axis corresponds to an air-bearing axis and is decisive for the precise measurement of the centration.

In addition, there are two different ways to measure the centration of a lens; a distinction is made between measurement in reflection and in transmission.

**Centration Measurement in Reflection**

The OptiCentric® system, equipped with an autocollimator head with reticle and corresponding head lens, is used for measurement in reflection.

To perform the measurement the measurement head with the head lens is focused on the center of curvature of the lens surface being tested. The resulting reflected image of the reticle is observed using the CCD camera integrated into the measurement head and analyzed with the software.

If there is a centration error, the observed image describes a circle while the sample rotates on the reference axis. The center of the described circle is on the reference axis. The radius of the circle is proportional to the centration error and describes the distance from the center of curvature of the lens surface to the reference axis. If the centration error is described as an angle, this is called a surface tilt error when measuring in reflection. (See also ISO 10110).

**Centration Measurement in Transmission**

When measuring in transmission the OptiCentric® system is also fitted with the autocollimator head with reticle and appropriate head lens. In addition, the system must be fitted with a collimator in the base of the measurement system for measurement in transmission.

During measurement in transmission, the parallel light from the collimator forms an image of the reticle in the sample’s focal plane, which the head lens of the autocollimator head focuses on. The image can then be analyzed using the CCD camera.
If there is a centration error the image describes a circle in the same way as with measurement in reflection. The radius of the circle corresponds to the distance between the reference axis and the focal point. As an angle the centration error can be specified as the inclination of the chief ray when measuring in transmission.

Comparing Measurement in Reflection and in Transmission

Measurements performed using the reflection and the transmission methods provide different results, which are only partially comparable to each other. Measurement in reflection indicates the exact centration error of a single surface, while measurement in transmission describes the “error” as a “sum” of the centration errors of the individual surfaces. A simple relationship between the two measurement methods can only be given for centration errors of a single lens (without mount):

\[ T = (n - 1) \times R \]

R: Surface tilt error of the top surface (as a result of the measurement in reflection)

T: Angular deviation in transmission

n: Refractive index of glass

Using the transmission method it is fundamentally not possible to distinguish which of the lens surfaces is afflicted with a centration error. In certain cases a lens measured in transmission may not display any centration errors, even though the lens is installed askew in the mount. Centration error measurement in reflection provides clear results for a single optical surface.

Both methods should be considered to achieve efficient optical production, which is possible with most OptiCentric® instruments.

Align and Cement the Smart Way with the SmartAlign Algorithm

The SmartAlign algorithm is part of the OptiCentric® software and ensures that the lenses can be aligned to any arbitrary reference axis. Depending on the manufacturing process, the reference axis is defined for example as the optical axis of the bottom lens of an achromat, as the axis of rotation or the axis of an arbor. Because of this flexibility, it is possible to adapt the OptiCentric® Cementing Station to a wide variety of turning processes in optics manufacturing.
OptiCentric® Cementing Production Systems

Extremely Accurate and Rapid Cementing of Lenses

The OptiCentric® Cementing Station is a manufacturing system that both measures and automatically aligns and cements lenses.

The OptiCentric® Cementing Station is more accurate and twice as fast as conventional cementing methods. Since the cementing process is automated, the production personnel can prepare a new pair of lenses for cementing while OptiCentric® Cementing aligns and cements two lenses to each other.

In addition to the OptiCentric® Cementing system, which is derived from the classic OptiCentric® measurement systems, TRIOPTICS also offers an OptiCentric® Cementing Workstation. Both systems are similar in the way in which they accomplish measurements. However, the OptiCentric® Workstation is equipped with an ergonomic work desk that has been adapted to the requirements of a production environment.

OptiCentric® Cementing Cementing Lenses: Quick and Easy

The OptiCentric® Cementing Instrument is based on the established OptiCentric® 100 system for centration measurement. For the cementing process, the system is adapted to the customer’s respective manufacturing process and the appropriate cementing unit is added.

This brochure focuses on the cementing and lens assembly application. For detailed information about the OptiCentric® systems, please refer to the OptiCentric® brochure.

Setup of an OptiCentric® Cementing System
OptiCentric® Cementing Workstation: drawer with head lenses

OptiCentric® Cementing Workstation Perfectly Adapted to the Requirements of Optics Manufacturing

The OptiCentric® Cementing Workstation is a further development of the OptiCentric® Cementing system that has been adapted for use in optics manufacturing. It is characterized by the following enhancements compared to an OptiCentric® Cementing system.

- OptiCentric® system inset into the table top for ergonomic working in manufacturing
- Additional and increased storage space for manufacturing components
- Integration of all components such as controllers, PC, etc.
- Drawer for head lenses or other accessories
- Stable aluminum base frame with vibration-damped worktop
- Pivoting monitor bracket
OptiCentric® Cementing Workstation
with UV housing
For many lens manufacturers assembling two or three optical elements is a complex process that is often performed manually and is therefore prone to error. The TRIOPTICS OptiCentric® Cementing Station employs an automated cementing process, so that the cementing results do not depend on the skill of the user.

The cementing process can be adapted to the different processing methods used in optics manufacturing. The three most common methods are presented below:

- Cementing against a V-block, by means of a motorized lens rotation device (manual cementing process)
- Cementing on a centering arbor (automated or manual cementing process)
- Cementing with alignment of the optical axes to each other (automated cementing process)

For all processes the lenses need to be prepared for the cementing process. For best cementing results the production environment as well as the lenses need to be dust free. The cement needs to be applied carefully and in an appropriate amount on the top surface of the bottom lens. Then the upper lens is put on the bottom lens. By carefully moving around and by applying little pressure on the upper lens the optical cement will be distributed homogenously and free of bubbles.

Manual Cementing on Lens Rotation Device

Production task: A pair of lenses is manually cemented on the motorized lens rotation device.

Unlike the processes explained below, here alignment is done to a rotation axis which results from the lens circumference and the spherical bottom surface. In this case, the alignment accuracy is limited by the manufacturing tolerances in the edge finishing of the guide lens (bottom lens).
The motorized lens rotation device can be used for cementing in both reflection and in transmission.

**Measuring and aligning the sample:** The sample with cement is placed on the ring chuck of the motorized lens rotation device and pressed against the V-block by the friction wheel. The center of curvature of the lower sphere and the circumference of the lens describe the axis of rotation. Vacuum ensures that the lens does not lift from the ring chuck during the process. The second lens is positioned and aligned manually.

When measuring in transmission the top lens is aligned so that the focus point is on the axis of rotation. When measuring in reflection the center of curvature of the top lens surface is aligned with the axis of rotation. Then the cement is cured. (Fig. 3 and Fig. 4)

**Advantages of the method:** Simple, efficient method to cement lenses together. No subsequent turning is necessary because the guide lens usually has a small centering error with respect to the edge.

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**Recommended production systems:**
- OptiCentric® MAN with lens rotation device and OptiCentric® software
- OptiCentric® Smart with lens rotation device and OptiCentric® software
- OptiCentric® 100 with lens rotation device and OptiCentric® software
**Cementing with Alignment of the Optical Axes to Each Other**

Production task: Lens pairs are to be aligned to each other with a reproducible accuracy of better than 2 μm. Then the sample can be processed further. For example, the sample or the barrel in which the sample was previously glued is corrected for centration by turning off some of the edge. The optical axis is parallel to the edge of the sample after processing.

**Measuring and aligning the lens:**
The sample is either placed on a vacuum ring or a chuck. The OptiCentric® Cementing Station uses the MultiLens algorithm to determine the optical axis of the bottom lens in reflection and is able to monitor the position of the center of curvature of the top lens. Then the SmartAlign algorithm calculates how the top lens has to be shifted so that the center of curvatures of the top lens surface is located on the optical axis of the bottom lens.

The top lens is shifted into the target position by the actuator. The movement is monitored by the high-resolution electronic autocollimator. Once the desired position is achieved with the required accuracy, the cement is cured with UV illumination. The centers of curvature of all the surfaces are now on one line, the optical axis of the system. (Fig. 5)
Further processing: There are various options available for further processing. Firstly, the cemented lens pair can be bell-chuck centered directly in the alignment turning machine and turned to the optical axis. Alternatively, the lens is first glued into a barrel and the barrel’s axis is then turned in parallel to the optical axis of the lens system. (Fig. 6)

Advantages of the method:
Two lenses are automatically aligned to each other and cemented with an accuracy of better than 2 μm without having to use highly accurate and expensive sample holders. With a remaining centration error of better than 2 μm, ideal optical properties are achieved without aberrations.

Recommended production systems:
OptiCentric® Cementing 100 and OptiCentric® Workstation including Cementing software with integrated SmartAlign algorithm.
Cementing on a Centering Arbor

**Production task:** A single lens or a lens system is to be assembled directly on the centering arbor, so that the optical axis of the lens system coincide with the axis of the centering arbor.

**Measuring and aligning the sample:** A prerequisite for accurate measurement is that the precision chuck is aligned on the OptiCentric® system's air bearing and the aligned arbor is clamped in place. Ideally, the air bearing axis and the axis of the arbor match. If this is not the case, a probe is used to determine the displacement of the arbor axis to the air bearing axis. The distance can then be compensated by software.

Then cement is applied on the arbor and the first lens is placed on the centering arbor. The position of the optical axis of the lens is determined in relation to the rotation axis of the air bearing. (Fig. 7)

![Fig. 7a: The location of the centering arbor is determined in relation to the rotation axis of the air bearing](image)

![Fig. 7b: The first lens is placed on the arbor](image)

![Fig. 7c: All lenses of the system are successively aligned to the axis of the arbor and cemented](image)

![Fig. 7d: The lens is clamped into the high-precision chuck of the alignment tuning machine and turned symmetrically to the arbor axis](image)
Then the lens is aligned to the axis of the arbor using the Smart Align algorithm and cemented (Fig. 7b). Once the first lens is aligned, cement is applied on the upper surface. A second lens is placed on top and the centration measured. The second and all subsequent lenses are aligned to the arbor axis and cemented.

**Advantages of the method:** Cementing takes place directly on the centering arbor, which is then clamped into the turning machine.

The accuracy of the lens system depends on the manufacturing accuracy of the centering arbor and the chuck. These are manufactured with high precision in order to achieve a manufacturing accuracy for the lens system of 2 μm. Better accuracy can be achieved if the axis of the centering arbor is measured using the gauge and corrected by the SmartAlign algorithm.

**Recommended production system:** OptiCentric® Cementing or OptiCentric® Cementing Workstation with Cementing Software and SmartAlign algorithm.

For manual aligning and cementing on an arbor TRIOPTICS offers an OptiCentric® system equipped with a chuck for the centering arbor and the OptiCentric® Software.

**Process Comparison**

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<th>Automated cementing on a centering arbor</th>
<th>Cementing with alignment of the optical axes to each other</th>
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<tr>
<td><strong>Accuracy</strong></td>
<td>Depends on the edge finishing of the guide lens</td>
<td>Better than 2 μm</td>
<td>Better than 2 μm</td>
</tr>
<tr>
<td><strong>Alignment duration</strong>*</td>
<td>*depending on the skill of the operator</td>
<td>*4 sec</td>
<td>*4 sec</td>
</tr>
<tr>
<td><strong>Lens size</strong></td>
<td>4-100 mm**</td>
<td>1-100 mm**</td>
<td>4-150 mm**</td>
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* Without UV curing
** Other diameters on request

During the manual alignment the operator monitors the live image of the center of curvature of the top surface on the screen and aligns the center of curvature to the reference axis.
Optical Metrology
The Entire Spectrum

- MTF measurement instruments
- Optical alignment, cementing and bonding
- Interferometers
- Wavefront measurement with Shack-Hartmann Sensors
- Goniometers
- Spectrometers
- Test station for cameras and sensors
- Electronic autocollimators
- Visual collimators, telescopes and autocollimators
- Ophthalmic metrology instruments
- Prisms, polygons and optical flats calibrated to N.I.S.T. standards
- Customized Products

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