Centering Measurement of Infrared Lenses with

OptiCentric® and
OptiCentric® infrared
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OptiCentric® for Infrared Lenses

Discover the Best Solutions for Centration Measurement and Assembly of Infrared Optical Systems

Whether zinc selenide or germanium, single lenses or complex objectives, TRIOPTICS offers you the measurement system that is best suited to your application in the infrared. OptiCentric® measurement systems are market leaders with over 20 years of experience in centration testing and alignment of single lenses and complex optical systems.

The OptiCentric® measurement system uses a modular design and is configured according to your application. Different air bearings, rotary units or distance sensors can be selected depending on the sample diameter and application.

The choice of measurement head is also particularly relevant for the measurement of infrared samples. TRIOPTICS provides measurement heads in VIS, SWIR, MWIR or LWIR. The majority of centration measurements can be carried out with a more cost-effective visual measurement head. An infrared measurement head is only required for the measurement of optical systems or for measurements in transmission.

A large range of additional parameters besides centration can be measured in all kinds of optics with the OptiCentric® measurement systems. All you need is to add a corresponding extension module to the system.

We recommend the following options for the measurement of infrared lenses and optics: MultiLens for the measurement of objectives, AspheroCheck® for the measurement of aspheres, OptiSpheric® for the measurement of typical lens parameters such as effective focal length or flange focal length. OptiSurf® for air gaps and distance measurement. In combination with OptiCentric® called OptiCentric®3D.

Please refer to the OptiCentric® brochure for additional information about the OptiCentric® instruments.
According to ISO 10110 a centering error of a lens is represented by a mismatch of optical and reference axis, respectively these are different in position and/or direction.

**Centering Errors of Lenses**

Centering errors have a decisive influence on the optical imaging quality of an imaging system. A centering error is present if the axis of symmetry of an optical element does not coincide with a given reference axis. The reference axis typically is the axis of symmetry of a mount or cell. The centering error is given as an angle between the optical axis of this element and the reference axis. A centering error may also be expressed as the distance, for example, of a center of curvature to the reference axis.

Fig.1 provides an overview of the opto-mechanical parameters OptiCentric® instruments are capable to measure:

1. Translational displacement of a lens
2. Tilt of a lens
3. Surface tilt error of a spherical surface
4. Cementing error
5. Tilt of the aspherical axis
6. Air gaps and center thickness

OptiCentric® is able to precisely define all of these errors in accordance to ISO 10110-6. OptiCentric® features capabilities for measuring single lenses as well as for complete objectives. The so-called MultiLens® procedure enables the measurement of the centering error of all single surfaces of a fully assembled objective without the need to dismantle it.
The Centering Error of a Spherical Surface

The centering error of a spherical surface is defined by the distance "L" of its center of curvature "C1" to a reference axis. The surface tilt error Sigma (σ) may also be used. The following correlation applies (R = radius of the surface under test):

\[ \sigma = \arcsin \left( \frac{L}{R} \right) \]

\[ \chi_D = 3438 \sigma \text{ [arc minutes]} \]
\[ \chi_D = \text{angle of the centering error in arcminutes} \]

It is also possible to provide the measured surface tilt error as eccentricity \( S \) at the lens edge if required. (Fig. 5)

\[ S = D \times \tan(\sigma) \]
\[ D = \text{lens diameter} \]

The Centering Error of a Lens

The optical axis of a single lens (see figure 3, left side) is the line connecting the centers of curvature of the two spherical surfaces. The centering error is now defined using the angle \( \sigma \) and the distance \( L \) to a given reference axis.

The centering error of a single lens can also be represented relative to the edge of a lens. In this case, the reference axis is given by the axis from one of the centers of curvature to the center of the diameter of the circumference of the lens. Measuring the relative distance of the other center of curvature with respect to this axis gives the so-called surface tilt error or wedge error of the lens (Fig. 3, right).

Fig. 3: Schematic diagram of the centering error of a lens
Centering Errors of Aspherical Lenses

In contrast to spherical surfaces, the symmetry of an aspherical surface is represented by an axis and not by a single point. Hence, the relative orientation of this axis of symmetry and the reference axis defines the centration status of an aspherical surface. For the measurement, the following two values must be determined for an aspherical surface, each with their x and y components:

- The lateral position of the paraxial center of curvature from the reference axis
- The angle between the axis of symmetry and the reference axis

Once the shift and angle of the aspherical surface have been determined, this data can be used to calculate the following parameters:

- Orientation of the asphere with respect to the primary reference axis of the measurement system (corresponding to the axis of rotation)
- Orientation of the asphere with respect to the optical axis of other optical surfaces
- In case of a double-sided asphere: relative orientation of the two aspherical surfaces

The lateral position corresponds to the classical centering error of aspherical surfaces, and is measured in the same way using an electronic autocollimator.

For measurement of the angle of aspherical lenses, an additional distance sensor is required that measures the run-out of the outer edge of the aspherical surface. Here, the high-resolution non-contact TRIOPTICS AspheroCheck® distance sensor is the instrument of choice.

Centering Errors of Optical Surfaces within an Assembled Objective

For the analysis of multi-surface optical assemblies, the following measurement parameters are of particular interest:

- Orientation of lenses/groups of lenses with respect to each other
- Orientation of lenses/groups of lenses with respect to a best-fit optical axis of a super-ordinated reference (e.g., the overall optical axis)
- Orientation of lenses/groups with respect to an outer mechanical reference
Measurement Principle of OptiCentric® Instruments

The following sections describe the measurement principle behind the TRIOPTICS OptiCentric® instruments. The measurement of a centering error primarily involves defining a point of symmetry in relation to a reference axis. This can, for example, be the center of curvature of a lens surface or the location of a focus point of a lens in relation to a reference axis.

When the center of curvature of a lens surface is used for the measurement of centering errors, the measuring procedure is known as Measurement in Reflection. Similarly, the measuring procedure using the focal point of a lens is known as Measurement in Transmission.

Principle of the Centering Error Measurement in Reflection and Transmission Mode

The basic procedure to identify the centering errors of a lens implies the rotation of the lens around a precise reference axis. This precise reference axis is decisive for the accuracy of the measurement. OptiCentric® product line provides different instrument modules and accessories featuring a high accuracy reference axis for the measurement.

The rotation of the center of curvature can be followed live on the monitor. The live reticule image shows the exact position of the center of curvature in the x-y plane, whereby the center of the circular path represents the reference axis.

The radius of the circle is proportional to the size of the centering errors. The result of the measurement can be given as radius of the run out circle (in µm) or when measuring in reflection as tilt of the surface and when measuring in transmission as tilt of the lens axis (in arcsec).
For the measurement an autocollimator is focused either in the center of curvature of the surface (Reflection Mode) or in the focal plane of the lens (Transmission Mode).

For the measurement in transmission a collimator is additionally needed, its parallel beam emerging from the collimator is focused in the focal plane of the sample to be measured. The images reflected from the lens surfaces (Reflection method) as well as the images projected into the focus of the lens (Transmission Method) are observed through the eyepiece of an autocollimator, of a telescope, or of a microscope. The autocollimator is equipped with a CCD Camera and the entire measurement process is software controlled. When a centration error is present, the observed image describes a circle while the sample is rotated around a reference axis.

**Comparison between Reflection and Transmission Mode**

The reflection and the transmission values are different and may be compared only to a limited extent. A simple relationship between the two measurements for the centering error of a single lens (without a mount) is given by:

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

- \( T \): Angle deviation in transmission mode
- \( R \): Surface tilt error of top surface (Result of measurement in reflection mode)
- \( n \): Refractive index of glass

Measurements in reflection and transmission essentially provide different results. The reflection measurement will provide exact information on the centering error of single surfaces, while the transmission measurement provides an “overall error” which is a combined result of the centering errors of all the single surfaces.
In transmission mode it is not possible to determine which one of the surfaces of a lens is producing the centering error. In some cases, a lens tested in transmission mode can reveal no centering error, although the lens is tilted in the mount.

The images reflected from the lens surfaces, however represent an undoubted criterion for the surface tilt and the individual centering errors. The reflection method is the only total and true absolute method for the measurement of centering errors. Especially for non-transparent lenses (such as infrared materials when measured with a VIS measurement head) the reflection method is preferably as most of the measurements can be done with a cost effective visual measurement head.

However, the transmission method with some mechanical constraints gives in many cases satisfactory results. Thus, for a time-economic evaluation of the overall centration status the transmission method is the method of choice. For a good economy of the optical manufacturing both methods should be considered. OptiCentric® allows both methods to be used and offers for measurements in Transmission infrared measurement heads.

For the characterization of assembled optical systems the centration of each optical surfaces is analyzed. Here, the measurement of outer surfaces is straightforward centration testing in reflection as described before (see Fig. 7a). When testing inner optical surfaces within an assembled system the principal concept stays the same as in the reflection mode. However, focusing into its geometrical center of curvature will not generate an autocollimation image because of refraction at preceding surfaces. In order to provide an almost perpendicular incidence of the measurement light coming from the autocollimator onto the surface under test, the refraction of the optics that were traveled through to reach the surface need to be considered. The axial position of the center of curvature of such surfaces can easily be calculated if the basic design parameters of all surfaces are known: the radius of curvature, refractive index and the lens thickness. Furthermore, these parameters have to be taken into account for calculating the lateral positions of the corresponding centers of curvature (Fig. 7b).

In the measurement the surfaces are successively analyzed for the deviation of each center of curvature with respect to the reference axis. In the presented measurement system, the rotation axis of the air bearing represents the reference of each measurement. The obtained data are processed in order to provide the shift and tilt of an individual lens or group of lenses. The centering errors can also be referred to a different axis, e.g., the best-fit axis through all centers of curvature. Alternatively, it can be the optical axis of a single element of a defined group of lenses.
In addition, the orientation of the best-fit axis itself represents a robust indicator for the alignment of the sample with respect to the reference axis.

For this application the dedicated software module MultiLens® has been developed. MultiLens® provides the exact position coordinates of all centers of curvature in space. The measured data support further analysis of the lens system and additionally provide the analysis features:

- Orientation of lenses/groups of lenses with respect to each other
- Orientation of lenses/groups of lenses with respect to a best-fit optical axis of a superordinated reference (e.g., the overall optical axis)
- Orientation of lenses/groups with respect to an outer mechanical reference

**Principle of the Measurement of Air Spacings and Center Thicknesses**

The TRIOPTICS OptiCentric® 3D feature is an upgrade to the standard OptiCentric® instrument that enables the measurement of air gaps between two lenses and lens thicknesses. Thus, it yields a different set of parameters for the evaluation of mechanical errors in optical assemblies. Lens air spacings and center thicknesses are defined as the geometrical distance between neighboring optical surfaces along the reference axis of an optical system (e.g., optical axis, symmetry axis of the lens barrel etc.). A highly accurate method to determine the positions of the optical surfaces is low coherent interferometry.

In general, low coherent interferometry is based on the determination of the position of zero group delay difference within an interferometer system. In an interferometer, e.g., a classical Michelson-type (Fig. 2a), the light coming from a low coherent light source, e.g., a spectrally broadened light source is split by a beam splitter into an object and a reference wave. The object wave illuminates the lens system along its optical axis. In every surface, a fraction of the incoming light beam is reflected. This light is guided to a photo detector where it is superimposed with the reference light that is varied in the optical path length by an optical delay line. When analyzing the resulting intensity as a function of the delay (Fig. 8), interference patterns are observed whenever the optical path lengths

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**Fig. 8: Principle of low coherence interferometry**
in the two interferometer arms coincide. There, the group delay difference equals zero. Thus, the location of every object surface can be determined from the positions of the maximal modulation in the interference pattern.

An important prerequisite for the detection of every single optical surface is a sufficient intensity of the back-reflected light. Besides the optimized focusing of the object beam to obtain reflections with balanced intensities from all surfaces, it is essential to align an accurate coincidence of the measurement axis of the low coherent interferometer and the optical axis of the sample. The particular patented (Patent EP000002458321A1) advantage of TRIOPTICS OptiCentric® 3D is the combination of the low coherent method with techniques for the centration measurement. The centration values are used for the determination of the optical axis of the lens system, e.g., the best-fit axis of all the centers of curvatures or just of selected lens elements. If the orientation of the axis of the low coherent interferometer with respect to the reference axis is known, the sample axis can be aligned to this.

Special Considerations of the Infrared Spectral Ranges

For testing single lenses and completed assemblies that are only transparent in the infrared range, TRIOPTICS provides measurement heads specifically designed for the infrared wavelength ranges that are equipped with focal-plane array infrared image sensors for ease of use. Typical applications are e.g. testing of lenses and assemblies for thermal imaging, military applications or industrial process control made from lens materials like e.g. Ge, Si, ZnSe, ZnS or CaF₂.

Infrared Spectral Ranges

The infrared wavelength range is divided in three distinct ranges for imaging applications. These bands exhibit high transmission of light through air and are separated by strongly absorbing bands in the spectrum. The three imaging infrared ranges are: short wave infrared (SWIR) from 0.9-1.7 µm, medium wave infrared (MWIR) from 3-5 µm and finally long wave infrared (LWIR) from 8-12 µm wavelength. Due to limitations in detector technology, so far no image sensor can cover all three wavelength ranges, however a LWIR system can also cover most MWIR lenses and vice versa.

For an overview about compatible materials and the wavelength regions covered by the available measurement heads please refer to Fig. 9. Silicon is a special case as the transparent region depends on the doping level and dopant type, so a LWIR head might be a suitable depending on application.
Differences to VIS from the Operator Side

In contrast to VIS systems, the light emitted from the focused autocollimator head cannot be seen by the naked eye which is however no problem in practice for aligning the sample. Apart from that, the operation of the infrared systems is not different to the VIS systems, so a user can be quickly trained for a new wavelength range.

Differences to VIS from a Technical Perspective

From a technical side, apart from using suitable optics and illumination sources in the measurement heads, the most important difference between visual and infrared range is that in the infrared range every object, including the sample, emits light in this wavelength region, so the instrument needs to compensate for the thermal background before taking a measurement. This is done automatically by the software and requires no operator intervention. Also, the contrast between background and illuminated areas is lower than in the VIS, so specialized image processing algorithms are used to reach the required high resolution.

OptiCentric® in the standard reflection mode relies on back-reflection from the lens surface, so the light intensity of the reflected reticule image strongly depends on the type of coating used. Typically, all infrared imaging lenses are AR-coated, however there is a wide variation in efficiency which the instruments compensates by adjusting illumination power and shutter times where available.

In general, the typical accuracy of the centering error measurement is approximately 1 \(\text{µm}\), slightly higher than for the instruments in the VIS, which is due to the longer wavelength and larger pixel size of the cameras used in the autocollimators.

![OptiCentric® Measuring Heads](image)

Fig. 9: Comparison of transparent regions of typical infrared lens materials and the regions covered by available OptiCentric® measurement heads. *Depending on doping level and dopant type
OptiCentric® Principle Setup of the Instruments

Selection of OptiCentric® Modular Product Group for Infrared Lens Measurement

Measuring Heads
- VIS
- SWIR
- MWIR
- LWIR
- LASER

OptiCentric® with Single Head

Lens Rotation Devices
- Lens rotation devices with vacuum chuck
- Air bearing

Options and Modules
- OptiSurf®
- AspheroCheck
- OptSpheric® for infrared
- Distance Sensor
- Lever Gauge
Centration Measurement of all Variants of Single Lenses and Objective Assemblies

OptiCentric® instruments are designed to measure centering errors and other parameter of lenses and optical systems. All instruments can be used to carry out measurements using the reflection mode. Measurements in transmission mode are possible if a second collimator is fitted into the instrument.

OptiCentric® is of modular design, so that the instruments are upgradeable and compatible with each other. To make the selection of the suitable equipment easier, the main instrument components are presented in the following.

OptiCentric® Measuring Head

The optical measuring head of the instrument is designed to view and quantify the size of the centering error in single and multiple optical components.

The measuring head consist of an autocollimator equipped with additional head lenses. During the measurement, the measuring head is focused in the image plane of the sample (transmission method) or in the center of curvature of the lens surface under test (reflection method). The majority of infrared applications can be measured with a visual measurement head in reflection.

The autocollimators used in the OptiCentric® infrared instruments are designed for dedicated infrared use: The light source is typically a broadband thermal source or an infrared laser for higher illumination power, the reticles and lenses are made from suitable infrared lens materials and finally a thermal imaging camera is used instead of a conventional CCD camera to acquire the images. For the LWIR and SWIR range, uncooled cameras are used, whereas in the MWIR range cooled cameras are needed. The MWIR cameras are fitted with self-contained Stirling-type cryocoolers so that no manual filling of dewars with liquid nitrogen is required.

TRIOPTICS offers three different types of illumination sources: cold light/halogen for VIS and SWIR, broadband infrared for MWIR and LWIR and laser illumination at 10.2 µm for LWIR. With the broadband sources, a cross shaped reticle is usually used, whereas the coherent laser source a pinhole is used. The laser source for the LWIR is recommended for MultiLens® measurements on complex LWIR assemblies as it delivers much higher illumination power than the broadband source.

For advice on selecting illumination sources and heads please refer to your TRIOPTICS representative.

For LWIR, TRIOPTICS recommends the broadband infrared head for measurements involving single lenses or measurements in transmission, whereas for MultiLens® measurements on complex assemblies the laser illumination is needed to reach the required illumination powers. In the case of laser illumination, the instrument is equipped with a protective housing including the necessary interlocks to guarantee the eye safety of the operator.

OptiCentric® measuring heads are available with either 57 or 38 mm outer tube diameter and can be easily interchanged on the same system within minutes. No extra alignment is necessary.
Setup

Technical Specification of the Measuring Heads

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<th>LWIR Laser</th>
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<td>Wavelength range in µm</td>
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<td>Accuracy in µm (typical)</td>
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<tr>
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<td>Halogen</td>
<td>Halogen</td>
<td>Broadband</td>
<td>CO₂ Laser</td>
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Lens Rotation Devices

As the measurement of centering errors requires a stable reference axis, suitable lens holding and rotary devices are crucial.

The accuracy of the centering measurement relies on the quality of the two basic components of the instrument:

- Optical measuring head
- Lens rotation device

Many optics manufacturers underestimate the importance of the lens rotation devices in ensuring the required accuracy. Since the use of accurate CCD-cameras and complex image processing software provides a high accuracy of optical measuring heads, the largest error source in lens centering and mounting is in many cases the lens rotation device. Many of the lens rotation devices used in the optical manufacturing do not provide a reference rotation axis which is sufficiently stable.

High Precision Lens Rotation with Air Bearings

For applications requiring highest accuracy, OptiCentric® can be equipped with an ultra-precision rotary air bearing table. The rotary air bearing provides lens rotation facilities and an ultra-stable and ultra-accurate reference (rotation) axis for the measurement of centering errors. Typically, the run-out of the rotation axis is <50nm. For alignment needs the air bearing is equipped with a stable tilt and translation stage.

The air bearing features a central hole for measuring in transmission mode or for checking top and bottom surfaces in reflection mode using a dual measuring head, or for thickness measurement with OptiSurf®. The precision rotation motor provides smooth rotation - without any vibrations - and, if necessary, accurate angular positioning. For a long operational life, the air bearings are supplied with a complete air conditioning control unit including a membrane dryer, filter and manometer.

For the pre-alignment of the lenses to a given reference axis a tilt and translation tables can be used with the air bearing.
Motorized Lens Rotation Device with Vacuum Chuck

The vacuum unit is a rotation device ideally suited for cost-effective single lens measurement in reflection.

It measures the centering error of single lenses with the outer edge as the reference. The lens is rotated using a motor-driven friction wheel against a V-block. The lens is held in position by vacuum. The control of all functions such as pressure, rotational speed and vacuum pump is integrated in one control unit. A compressed air line system is not required. The vacuum rotation fixture exhibits an excellent level of accuracy and reproducibility. Possible errors relating to the roughness of the outer cylinder are averaged out so that the results have a very high repeatability.

Stands with Travel Mechanism

The optical measuring head is mounted onto a motorized vertical stage for the positioning of the focal plane of the collimator to a certain center of curvature position (for Reflection Mode) or to a focal length (for Transmission Mode).

Sample Holder

Depending on the applications OptiCentric® provides a large variety of sample holders: self-centering holders, vacuum retention devices, hydrostatic chucks, etc.
Measurement Examples for the Most Common Infrared Lenses

In order to find the OptiCentric® measurement configuration that fits exactly with your needs here are some typical measurement tasks and their solutions presented.

Centration Testing of Single Lenses

Measurement Task: Centration testing of non-VIS-transparent or -transparent single lenses with OptiCentric®. The required instrument is equipped with a lens rotation device and a visual measurement head.

Measurement: The lens under test is placed onto the ring chuck support of the lens rotation device. Thus, the center of symmetry of the bottom surface is fixed in space. When the lens rotates with its edge against the V-block, the lens rotation axis is given by the geometrical center of the circumference and the center of curvature of the bottom surface. In this way the rotation axis corresponds directly to the reference axis for the determination of the wedge error. So the remaining parameter to be measured is the center of curvature position of the top surface which can easily be tested by OptiCentric® in reflection mode.

Conclusion: Single lens centration testing with OptiCentric® in reflection mode with the lens rotation device allows the evaluation of infrared lenses with a cost effective instrument without the need for expensive infrared devices.

Instrument Configuration: OptiCentric® with lens rotation device with vacuum chuck.
Centration Testing of Highly Sensitive Single Lenses

Measurement Task: The easiest way to protect highly sensitive lenses like calcium florid lenses against scratches is a minimum of handling during the production and testing process.

The OptiCentric® Dual instrument in combination with an air bearing and a non-contact distance sensor fulfill this requirement, instead of using the lens rotation device with V-block.

Independently from the material properties of the lens under test an OptiCentric® Instrument with cost-effective visual measuring heads is used.

Measurement: The lens is carefully placed in the lens holder. During the measurement the dual autocollimators measure the center of curvature positions of the top and bottom surfaces; the distance sensor measures the radial run-out of the lens edge. In the analysis the software determines the reference axis from the center of the circumference and the bottom surface. The measured offset of the top surface to this axis gives the lens’ centering error.

For lenses that are transparent in the VIS range the centering error can alternatively be measured in transmission. Therefore, the top autocollimator measures the run-out of the focus spot when the lens under test is illuminated with collimated light by the bottom (auto-) collimator.

Conclusion: A minimum of handling protects the sensitive surfaces of the lens. Both surfaces are measured in one step with cost-effective visual measurement heads.

Instrument Configuration: OptiCentric® 100 Dual or OptiCentric® 300 Dual with distance sensor.
Centration Measurement of Infrared Single Lenses with Plane Reference Flange

Measurement Task: Lenses with plane reference flange are often used in infrared optical systems. The preferred instrument to measure these lenses is the OptiCentric® Dual, with two visual measurement heads and lens rotation device with vacuum chuck.

Measurement: The lens is placed with the support flanges onto the ring chuck and rotates against the V-block. The upper autocollimator focuses in the center of curvature of the top surface. The lower autocollimator focuses in the center of curvature of the lower surface. Thus, the measurement is accomplished in reflection.

In this case the reference axis given by the center of symmetry of the circumference and the normal of the support flange. The result of this measurement gives information about the centering errors of both surfaces with respect to the reference.

For VIS-transparent lenses the centration can be measured in transmission as well.

Conclusion: Both surfaces are measured in one step with cost-effective visual measurement heads and lens rotation device with vacuum chuck.

Instrument Configuration: OptiCentric® Dual with vacuum chuck
Centration Testing of Aspherical Lens Surfaces

Measurement Task: The use of aspheric surfaces in optical systems’ design allows to achieve better spot size performance, or alternatively achieve similar performance while using fewer elements in the system. Therefore, especially for infrared optics aspherical surfaces are commonly applied.

Aspherical infrared lenses are preferably measured with an OptiCentric® Dual instrument equipped with AspheroCheck® Module. This configuration achieves the best results and allows for a simple handling.

Measurement: The lens is put with the aspherical surface to the top in the lens holder. During the measurement the lens rotates and the three parameters required for centration testing are measured:

- Center of curvature position of the spherical bottom surface
- Paraxial Center of curvature position of the top aspherical surface
- Eccentricity of the outer edge of the aspherical surface under rotation

These three measurements are accomplished at the same time during the rotation of the lens:

The lower measuring head focuses in the center of curvature of the spherical bottom surface and measures its centration. The centration of the paraxial area of the upper surface is measured with the help of the upper measuring head in reflection mode as well. Third, the AspheroCheck Module measures the eccentricity of the aspherical surface.
Application

Conclusion:
The results of these measurements of aspherical infrared lenses give information about:

- Orientation of the asphere with respect to the primary reference axis of the measurement system (corresponding to the axis of rotation)
- Orientation of the top asphere with respect to the axis of bottom sphere and center of circumference
- In case of a double-sided asphere: relative orientation of the two aspherical surfaces (Fig.: 10b)

Instrument Configuration: OptiCentric® 100 Dual or OptiCentric® 300 Dual with AsphereCheck Module

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Fig. 10a: Lens with an aspherical and spherical surface
Fig. 10b: Lens with two aspherical surfaces
Assembly of Optical Systems

Measurement Task: The precise assembly of lenses in a barrel is a decisive step during the production of objective lenses.

An OptiCentric® instrument with an air bearing and distance sensor strongly improves the accuracy of the production process and the performance of the final product.

Measurement & Assembly: At first the barrel axis is aligned with the help of a distance sensor (e.g. a lever gauge) to the axis of the rotary air bearing. The first lens is placed into the barrel. The autocollimator measures the center of curvature position of the top surface with respect to the reference axis. Then the lens can be realigned in magnitude and direction according to the measured values.

Depending on the mechanical design of the sample the lens is fixed in position e.g. by using retaining rings or glue. This procedure is iteratively repeated for all further lens elements until the optical system is completed.

Conclusion: An optimized mechanical alignment of optical infrared systems is reached using an OptiCentric® instrument.

Because of the step-by-step measurement and alignment procedure of freely accessible lens elements, here a cost-effective visual measurement head can be applied without considering the lens material properties.

Instrument Configuration: OptiCentric® 100 or OptiCentric® 300 with distance sensor.
Characterization of Complex Lens System

Measurement Task: In the quality inspection of lens systems, testing solely the final optical performance is often not sufficient as it does not reveal the causes of potential substandard performance. Instead, a full opto-mechanical characterization of the samples is required to identify potential issues in the assembly process.

An OptiCentric® 3D Instrument equipped with an infrared measurement head, rotary air bearing, tilt and translation table, MultiLens and OptiSurf Module fulfills these requirements.

Measurement: After the objective lens to be tested is placed onto the sample table, the center of curvature positions of all single lens surfaces are measured following the MultiLens concept. Therefore, the autocollimator iteratively focuses into the center of curvature positions (respectively their image positions according to the MultiLens calculation) of all sample surfaces and measures their relative position with respect to the reference axis. In the following analysis, the relative orientation of the single elements’ or groups’ axis is evaluated with respect to each other or a mechanical barrel axis.

As the precise coincidence of sample and measurement axis is a particular requirement for the measurement of the center thickness and air gaps, data from centration testing is used for the precise alignment of the sample axis with the tilt and translation table. Then, the axial lens surface positions are measured.

Conclusion: OptiCentric® 3D 100 Infrared is the only instrument which accomplishes the complete opto-mechanical characterization of infrared lens systems and delivers detailed information about the assembly of the instrument.

Instrument Configuration: OptiCentric® 3D 100 Infrared, OptiCentric® 3D 300 Infrared or OptiCentric® 3D Dual. If the objective lens only consists of lenses that are transparent in the visible range, standard VIS measurement heads can be used.
The functionality of OptiCentric® Instruments is extended with the help of extension modules. For the measurement of infrared lenses, especially MultiLens, AspheroCheck, OptiSurf® and OptiSpheric® Modules are recommended.

For further reading about OptiCentric® Extension Modules TRIOPTICS recommends the OptiCentric® Brochure.

**OptiCentric® 3D and Optical Head with Low Coherence Interferometer**

For a complete opto-mechanical characterization of an optical system OptiCentric® Instruments are optionally equipped with the Low Coherence Interferometer OptiSurf (Patent EP000002458321A1) The combination of OptiCentric® and OptiSurf® is called OptiCentric® 3D and allows for highest accuracy:

- Lens centering errors down to 0.1 µm
- Air spacing and center thickness of less ±1 µm
The standard OptiSurf with 1.3µm measuring wavelength covers the majority of the infrared materials. A model working at longer wavelength for the measurements of all infrared materials will be available soon.

**MultiLens**

This comprehensive software module is used for measuring the centering errors of completely mounted optical assemblies. The inspection of mounted objective lenses provides precise data about the assembly quality. In this way, the MultiLens® software becomes an indispensable tool for optimizing the manufacturing process. The MultiLens® module delivers in a nondestructive way the complete information about the individual centering errors of all elements inside of an assembly.

**AspheroCheck®**

AspheroCheck® (Patent 10 2006 052 047.5-51) is a hardware and software module designed to measure the orientation of an aspherical axis with respect to a defined reference axis. The module is available as an upgrade for all OptiCentric® Systems equipped with a rotary air bearing sample stage.

**OptiSpheric®**

With the extension module OptiSpheric®, the measurement functionality of an OptiCentric® instrument can be extended by the following optical parameters:

- EFL - Effective Focal Length
- BFL - Back Focal Length
- FFL - Flange Focal Length
- Radius of Curvature
- MTF on-axis

Available for all spectral ranges.

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**Accessories**

The following accessories are offered to extend the use of OptiCentric® instruments:

- Motorized Centering and Cementing
- Revolving Turret (manual/motorized)
- Tactile and non contact distance sensors
- Extension of Measurement Range, large set of head lenses available
- Calibration Check
- Alignment Set

The advanced software is designed to work with Microsoft Windows® systems. It fulfills the need of the optical shop for easy, intuitive operation and features a number of options to accommodate a large variety of specific requirements.

**Software**

The software modules „Centration in Transmission“ and „Centration in Reflection“ provide an outstanding accuracy even in difficult measuring situations such as poor contrast, antireflection coated surfaces, very small lenses, etc. With the OptiCentric® Dual instrument the software optionally provides simultaneous measurement data with two live images for both lens surfaces. The software features selectable options to adapt the system to different hardware configurations e.g. infrared measurement head or different reticule patterns (bright cross, dark cross, pinhole, etc.).

Several different measurement units like mm, arcsec, etc. can be selected. To increase the production efficiency, the optimized process parameters can be saved for future use.
Key Features

• Live view monitoring of the camera image from all measuring heads
• Real time measurement
• Vector display of the size and direction of the centering error
• HTML certificate output
• Display of tolerance ranges for quick go/no go decisions
• Automatic adjustment to the sample reflectivity and correction of the thermal background

• Dedicated algorithms for high accuracy measurement of infrared optics
• Automatic calibration procedure by means of a calibrated sample, the calibration can be verified at customer site
• Artificial crosshair for the initial alignment assistance

Furthermore, almost every upgrade includes a software part which enables the software to analyze the measurement results.
### Technical Data

#### Spectral Range

<table>
<thead>
<tr>
<th>Range</th>
<th>Standard</th>
<th>Optional</th>
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<tbody>
<tr>
<td>VIS</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>SWIR</td>
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<td></td>
</tr>
<tr>
<td>MWIR</td>
<td>☑</td>
<td></td>
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<tr>
<td>LWIR Laser</td>
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#### Bearings

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<tr>
<th>Sample Diameter</th>
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<td>0.5-225 mm</td>
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<tr>
<td>0.5-600 mm</td>
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<td>1-5 mm</td>
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<td>5-75 mm</td>
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<td>125-200 mm</td>
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#### Measuring Head

<table>
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<th>Head Type</th>
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<td></td>
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<tr>
<td>Dual</td>
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#### Range of radii or effective focal length of the sample

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<th>Standard</th>
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<tr>
<td>0 to ± 400 mm and plane</td>
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<td>0 to ± 2000 mm and plane</td>
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#### Measurement value analysis

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<td>PC evaluation</td>
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#### Measurement head linear stage

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<tr>
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<th>Standard</th>
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<td>Automated positioning, PC controlled</td>
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#### OptiCentric® extension

<table>
<thead>
<tr>
<th>Extension Type</th>
<th>Standard</th>
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</tr>
</thead>
<tbody>
<tr>
<td>OptiSurf®, instruments called OptiCentric® 3D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MultiLens® (centering error measurement of aspherical lenses)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AspheroCheck® (centering error measurement of aspherical lenses)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OptiSpheric®/OptiSpheric® Infrared (EFL, BFL, FFL, MTF)</td>
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## Order Information

<table>
<thead>
<tr>
<th>OptiCentric®</th>
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<tr>
<td>OptiCentric®</td>
<td>4-100-02</td>
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<tr>
<td>OptiCentric® 100</td>
<td>4-400-02</td>
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<td>OptiCentric® 100 Dual</td>
<td>4-405-02</td>
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<tr>
<td>OptiCentric® 300</td>
<td>4-401-08</td>
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<tr>
<td>OptiCentric® 300 Dual</td>
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<table>
<thead>
<tr>
<th>OptiCentric® with Infrared Measuring Head</th>
<th>Order Number</th>
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</thead>
<tbody>
<tr>
<td>OptiCentric® 100 SWIR</td>
<td>4-400-02 SWIR</td>
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<tr>
<td>OptiCentric® 100 MWIR</td>
<td>4-400-02 MWIR</td>
</tr>
<tr>
<td>OptiCentric® 100 LWIR</td>
<td>4-400-02 LWIR LASER</td>
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## Upgrades for OptiCentric® VIS Instruments

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<th>Upgrade Description</th>
<th>Order Number</th>
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<tbody>
<tr>
<td>Upgrade OptiCentric® VIS for the SWIR spectral range (0.9-1.7µm, broadband)</td>
<td>SWIR UP</td>
</tr>
<tr>
<td>Upgrade OptiCentric® VIS for the MWIR spectral range (3-5µm, broadband)</td>
<td>MWIR UP</td>
</tr>
<tr>
<td>Upgrade OptiCentric® VIS for the LWIR spectral range (8-12µm, laser)</td>
<td>LWIR UP LASER</td>
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## Extension Moduls

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<th>Modul Description</th>
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<tr>
<td>MultiLens®</td>
<td>4-400-90</td>
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<tr>
<td>MultiLens® IR</td>
<td>4-400-90-IR</td>
</tr>
<tr>
<td>AspheroCheck®</td>
<td>4-400-99</td>
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<tr>
<td>OptiSurf® with 1.3µm light source</td>
<td>Depending on measurement length</td>
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<tr>
<td>OptiSpheric® Infrared</td>
<td>4-600-380 / on request</td>
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## Accessories

<table>
<thead>
<tr>
<th>Accessory Description</th>
<th>Order Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorized lens rotation device with vacuum Chuck</td>
<td>4-400-90</td>
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<tr>
<td>Extension of measurement range ± 2000</td>
<td>4-400-91</td>
</tr>
<tr>
<td>Alignment tool set</td>
<td>4-400-99</td>
</tr>
<tr>
<td>Manual revolving turret</td>
<td>4-300-074</td>
</tr>
<tr>
<td>Precision, motorized and software controlled revolving turret</td>
<td>4-400-86</td>
</tr>
<tr>
<td>Complete device for calibration check</td>
<td>4-600-380</td>
</tr>
</tbody>
</table>
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Testing of Lenses and Complex Optical Systems in NIR, SWIR, MWIR and LWIR.

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