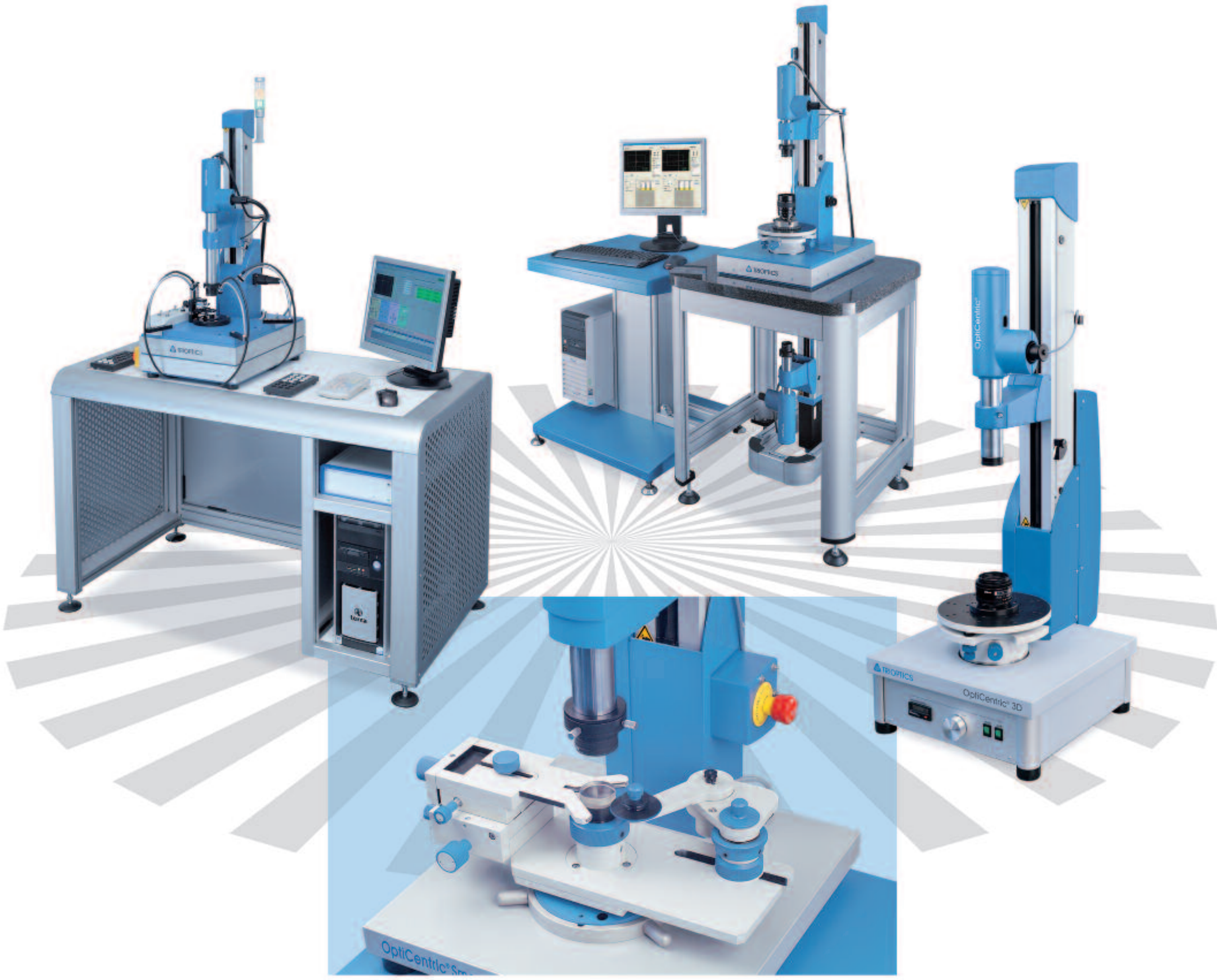
TRIOPTICS

TRIOPTICS GMBH · OPTICAL TEST EQUIPMENT

OptiCentric®

Inspection, Alignment, Cementing and Assembly of Optics



OptiTest

OptiSpheric
OptiCentric
OptiAngle

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OptiCentric® Overwiew

The Leading and Most Comprehensive Line of Equipment for Optical Alignment, Centering, Cementing, Bonding and Alignment Turning

According to ISO 10110 a centering error is present when the optical and the reference axis of a lens do not coincide, respectively these are different in position or direction.

During the process of cementing, alignment and bonding of lenses in a mount, significant centering errors can result and add to the machining errors of a lens. Consequently, the requirements of a high performance optical system can only be fulfilled when all the production steps from the centering tolerance measurement to the assembly of the lens in a mount are planned and designed as an integrated concept.

OptiCentric® MOT 100 the leading instrument for optical centration error measurement

The TRIOPTICS comprehensive line of equipment under the generic name **OptiCentric®** has been specifically designed to cover applications related to any type of optical components and to respond to different accuracy degrees. The OptiCentric®-System also covers all the production steps from the centration measurement to the alignment, cementing and assembly of optics. The OptiCentric® includes valuable tools for any application, from simple and affordable visual instruments to complex, fully automated and PC-controlled production and laboratory stations.

The modular TRIOPTICS product group is able to measure nearly all types of lenses and optical systems from the tiniest and smallest endoscope systems to precision objectives weighting several hundred kilos for wafer steppers in the semiconductors industry.

The products of the OptiCentric® range are subdivided into:

- **OptiCentric® METRO** - for metrology and comprehensive measurement of optical systems
- **OptiCentric® PRO** - for production and assembly of objective lenses

The capabilities of OptiCentric® METRO are not limited to the measurement of lens centration errors. Various enhancements and additional modules allow for measurement of many other optical parameters to be presented in the next chapters.

Measurement of Centration Errors

Measurement Principle and Typical Centration Errors

The following sections describe the measurement principle behind the OptiCentric® instruments and typical errors which occur during the assembly of lenses and objectives.

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 centration 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"**

Motorized centering and cementing equipment with vacuum chuck

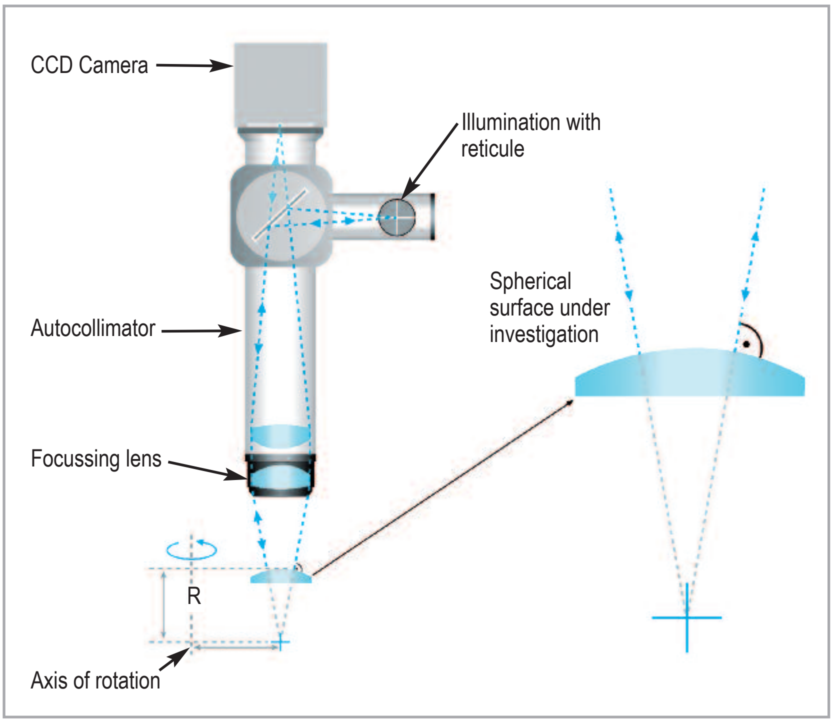


Fig. 1: Measurement in Reflection Mode

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.

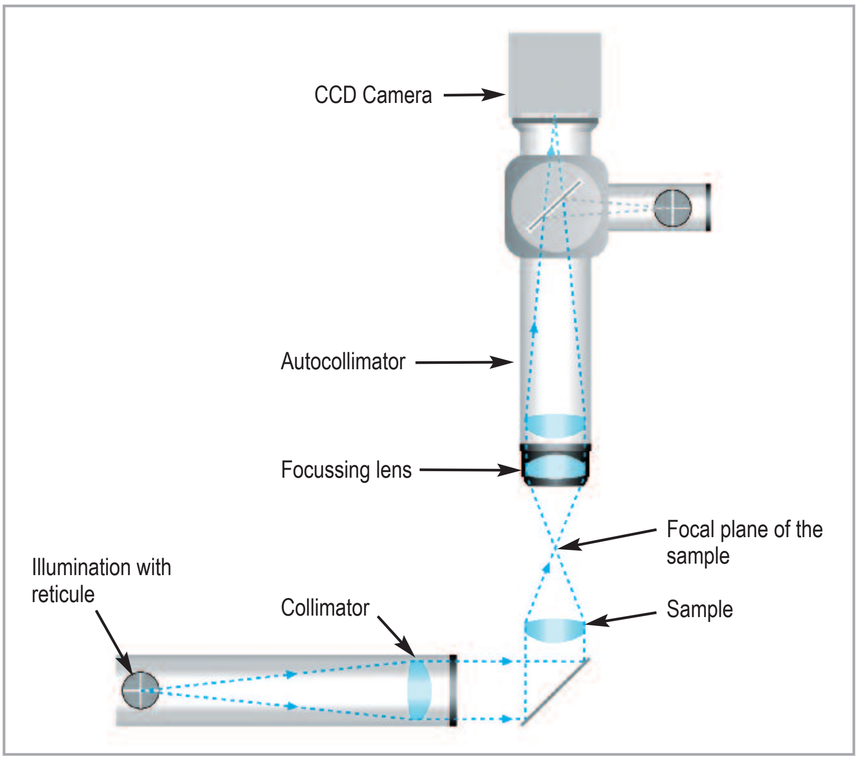


Fig. 2: Measurement in Transmission

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. In the modern instruments 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. When using software programs the rotation of the center of curvature can be followed directly 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).

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 only (without a mount) is given by:

$$T = (n - 1) \times R$$

R: Surface tilt error of top surface (Result of measurement in reflection mode)
T: Angle deviation in transmission 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.

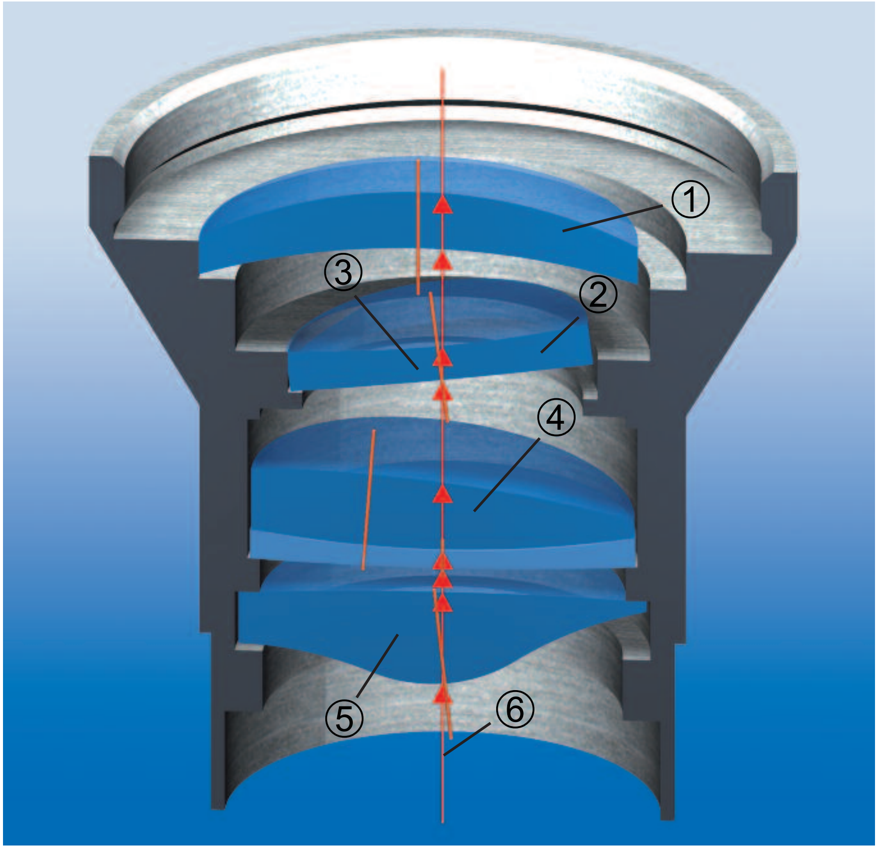


Fig. 3: Typical centration errors

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 is typically the symmetry axis 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 given as the distance between, for example, a center of curvature and another reference point on the reference axis.

Fig. 3 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.

In transmission mode it is not possible to determine which one of the surfaces of a lens is producing the centration 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 centring errors. The reflection method is the only total and true method for the measurement of centration errors. However, the reflection method is in many cases difficult to manage. On the other hand, the transmission method with some mechanical constraints gives in many cases satisfactory results. For a good economy of the optical manufacturing both methods should be considered. OptiCentric® allows both methods to be used.

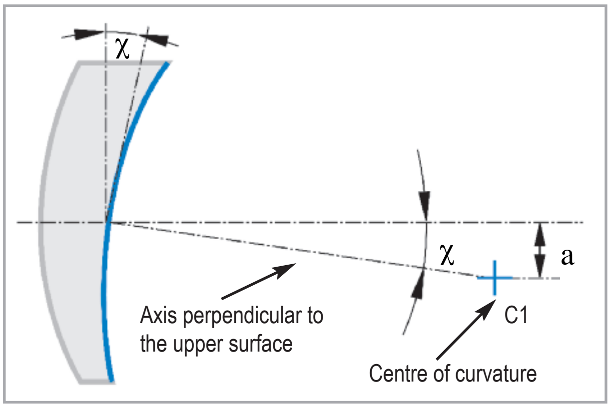


Fig. 4: Schematic diagram of the surface tilt error

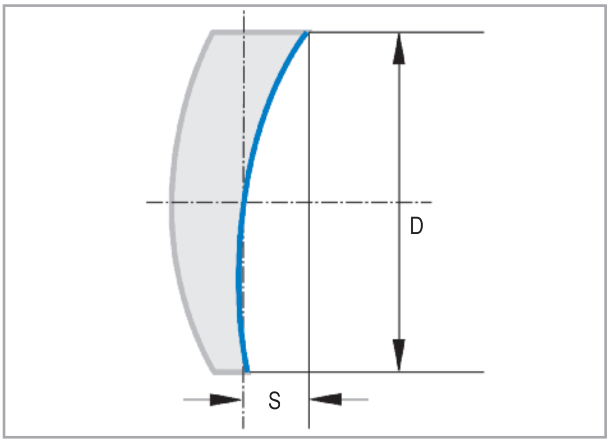


Fig. 5: Surface tilt error given as eccentricity

OptiCentric® features capabilities for measuring single lenses, surface tilt and cementing error or for the measurement of 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. Building on this comprehensive measurement function, systems have been developed to carry out the precise assembly of optical systems as an extension of the OptiCentric® system.

The Centering Error of a Spherical Surface

The centering error of a spherical surface is defined by the distance "a" of its center of curvature "C1" to a reference axis. The surface tilt error χ may also be used.

The following correlation applies (r = radius of the surface under test):

$$\chi = \arcsin(a/r) \text{ [rad]}$$

$\chi_D = 3438\,\chi$ [arc minutes]
χ_D = 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)

$$S = D \times \tan(\chi)$$

D = lens diameter

The Centering Error of a Lens

The optical axis of a single lens (see figure 6, left side) is the line connecting the centers of curvature of the two spherical surfaces.

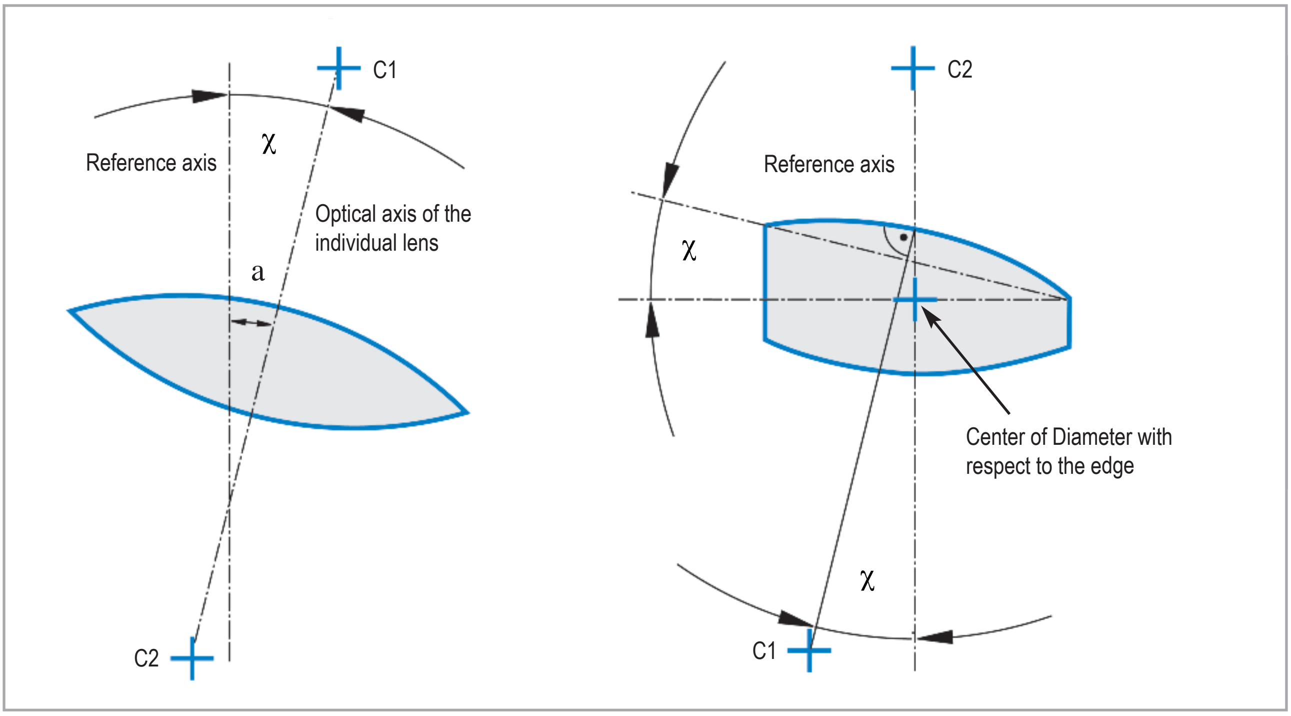


Fig. 6: Schematic diagram of the centering error of a lens

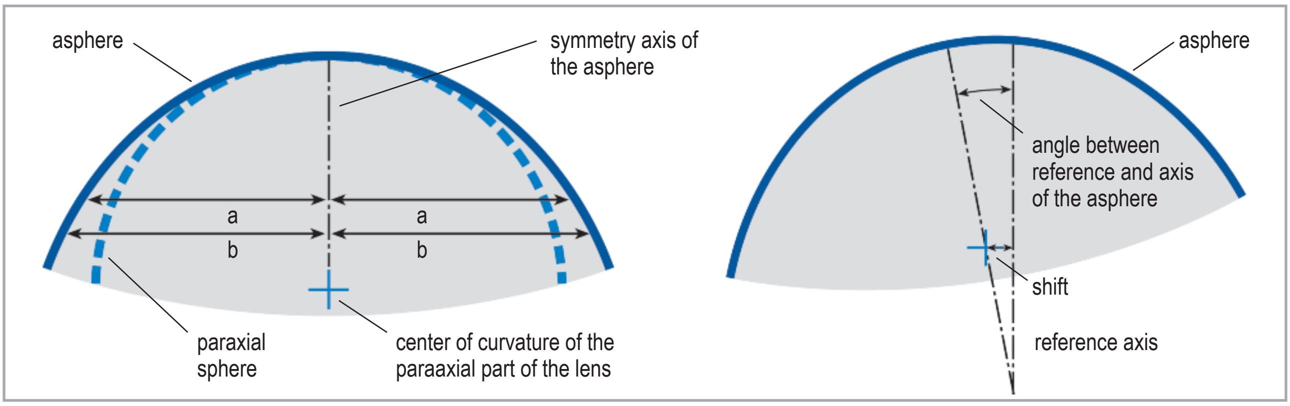


Fig. 7: Main parameters of an aspherical lens

The centering error is now defined using the angle „χ" and the distance „a" to a given reference axis.

The centration error of a single lens can also be represented relative to the edge of a lens. In this case, the centration error is called the surface tilt error or wedge error of the lens. The reference axis is taken to be a line through one of the centers of curvature and the center of the diameter of the lens. The surface tilt error of the upper surface is given relative to this reference axis (Fig. 6, right).

Centering Errors of Aspherical Lenses

In contrast to spherical surfaces, rotationally symmetrical aspherical surfaces have an axis of symmetry. The goal of centering error measurement is thus the determination of the orientation of this axis of symmetry relative to the reference axis.

To do this, the following two values must be determined for an aspherical surface, each with their x and y components:

- The shift of the paraxial center of curvature from the reference axis
- The angle of the aspherical axis of symmetry from the reference axis

The shift corresponds to the classical centering error of spherical surfaces, and is measured in the same way using the electronic autocollimator.

For measurement of the angle of aspherical lenses, an additional sensor is needed – for TRIOPTICS, this is the AspheroCheck® sensor. It measures the run out on the outer edge of the aspherical surface.

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

- Shift and tilt of the asphere relative to the primary reference axis of the measurement system (corresponding to the axis of rotation)
- Shift and tilt of the asphere relative to the "optical axis" of a single lens. The "optical axis" is the line through the centers of curvature of the spherical part of the lens
- If a lens consists of two aspherical surfaces: Angle and shift of both aspherical axes

Centering Errors of Cylinder Lenses

Cylinder lenses are lenses that have at least one optical surface that is cylindrical. Given the variety of possible combinations of surfaces and shapes, here a typical cylinder lens is shown that has one cylindrical surface and one plano surface (see Fig. 8).

One important value in the description of the centering of a cylinder lens is the apex line (see Fig. 8). In a cylinder lens free of errors, the apex line has a constant distance from a de-

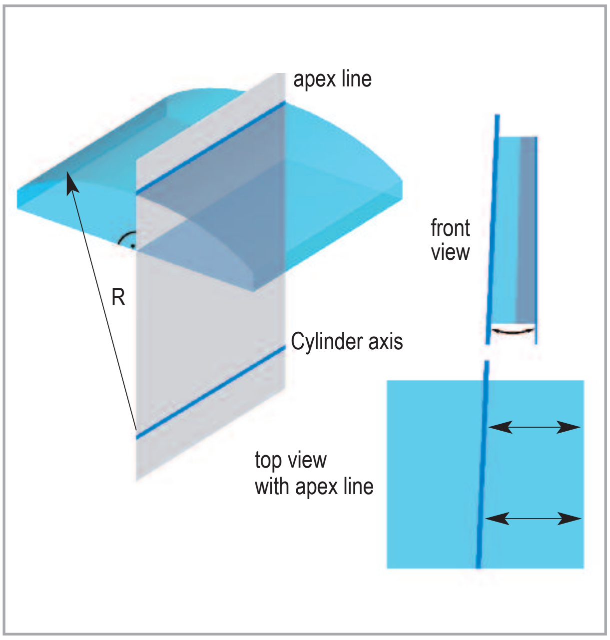


Fig. 8: Measurement of cylinder lenses

fined edge of the lens over its entire length, and it is parallel to the lower plano surface. Both the distance to the edge and the angle formed between the apex line and the plano surface can be determined using OptiCentric® instruments.

Actually, the distance from the apex line to the edge is measured at different points, so that these values are also used to calculate the angle between the apex line and the edge.

Centering Errors of Optical Surfaces within an Assembled Objective

In order to measure single optical surfaces, the exact tilt error and/or exact position of the center of curvature to a given reference axis has to be determined. Influences from optical surfaces and elements located before the surface under test are taken into account using optical calculation including the centering error of these surfaces. That means that the centering error of all further surfaces must be iterated from that of the first.

Approx. 20 surfaces can be measured from one side using this method. If a second measuring head is used, such as in the OptiCentric® MOT DUAL, which calculates the centering error from the bottom side, up to 40 or more optical surfaces can be measured.

For this application a special software module MultiLens® has been developed. The MultiLens® measurement provides the exact x,y,z coordinates of all centers of curvature in the space. The measured data support further analysis of the lens system and additionally provide the following data:

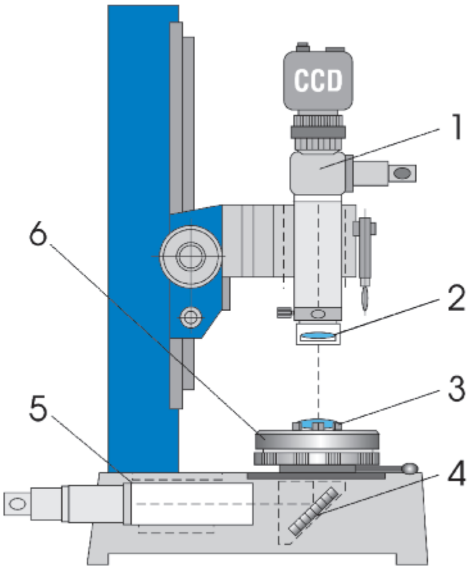
- Calculation of the optical axis of any single lens of the system.
- Assessment of the optical axis of single sub systems or the entire optical system. A „best fit" line is drawn through all the optical surfaces under consideration.
- Calculation of the distances and angles between optical axis and „best fit" line.

OptiCentric® METRO

Measurement of Centration Errors of all Kinds of Lenses and Objective Lenses

OptiCentric® METRO instruments are designed to measure centering errors and other parameter of lenses and optical systems. All instruments of the METRO series can be used to carry out measurements using the reflection mode and/or transmission mode, an exception being the OptiCentric® SMART which only works in reflection mode.

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



1. Autocollimator with CCD-Camera
2. Additional Achromat in X-,Y- adj.Mount
3. Sample
4. Mirror
5. Collimator
6. Lens rotation device

Fig. 9: Principle setup OptiCentric®

Optical 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. It is also the basic unit used for the alignment of single elements before cementing or mounting in cells.

The measuring head consist of an autocollimator equipped with additional head lenses. During operation the measuring head is focused in the image plane of the sample (transmission method) or in the centre of curvature of the lens surface under test (reflection method).

For the measurement of thermal and night vision camera lenses TRIOPTICS provides a measurement head working in the infrared range.

Stands with Travel Mechanism or Motorized Stages

The optical measuring head is mounted on a stand having capabilities to move up and down in order to adapt to a certain range of radii of curvature (for Reflection Mode) or of focal length (for Transmission Mode).

Sample Holder

Depending on applications OptiCentric® METRO provides a large variety of sample holders: self-centering holders, vacuum retention devices, hydrostatic chucks, three jaws chucks, etc.

Lens Rotation Devices

Since the viewing and the measurement of the centering errors are only possible when the lens is rotated (except for extremely expensive errorless focusing devices), the availability of a lens holding and rotary device is crucial for completing a centering measurement.

The accuracy of the centering measurement and of the alignment/mounting of lenses is determined by the two basic components of a centering/mounting equipment:

- 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.

OptiCentric® MAN with accessories

TRIOPTICS invested a large amount of work in designing a complete range of accurate devices for lens rotation:

- Motorized vacuum lens rotation device
- Ultra-precision air bearing rotary table
- Mechanical and hydrostatic lens holders

OptiCentric® MAN

OptiCentric® MAN stands for the manual operation of the stage with fine coaxial height adjustments. This is a simple and cost effective solution, although the time needed to move the measuring head up and down reduces the efficiency of the process. Moreover, the travel is limited, since the height of the stand must be selected so that the operator works in a seated position. Consequently, to cover a certain range of radii/focal length an increased number of additional optics is necessary.

This product line is the right choice when the number of surfaces to be measured is limited or the instrument is used for repetitive measurements of the same lens type. Examples of typical applications for OptiCentric® MAN are the centering error measurement of single lenses or alignment and cementing of doublets.

An important accessory of the OptiCentric® MAN instruments is the motorized vacuum lens rotation unit which can also be used for measurement or cementing of doublets.

OptiCentric® MAN has two manual stand options:

- Stand “B” with 250 mm travel
- Stand “BL” with 400 mm travel

In order to easily find the height position of different centers of curvature or focal planes of the samples to be measured, the manual stand should be additionally equipped with linear encoders displaying the position of the measuring head on the stand. For OptiCentric® MAN position measuring devices including a linear slide with LCD-Display, 0.01 mm resolution and 300/450 mm length are available.

The OptiCentric® MAN instruments may be fitted with different measuring heads depending on application and accuracy required. Following basic options are available:

- Visual measuring head (OptiCentric® MAN Visual)
- Measuring head with CCD camera and video-monitor (OptiCentric® MAN-Video)
- Measuring head with CCD camera, PC and software control (OptiCentric® MAN)

OptiCentric® MAN-Visual

The operator reads the centering error off a reticule (e.g. with millimeter graduation) through the eye piece of the autocollimator. The purely visual check is simple and therefore a cost-effective solution although accuracy and reproducibility are restricted. The measurement result depends on the skills and level of fatigue of the operator.
The OptiCentric® MAN-Visual is suitable for measuring and cementing individual lenses where the measurement does not require a high degree of accuracy or speed.

OptiCentric® MAN-Video

The measuring head consists of a CCD-camera and imaging optics mounted on the eyepiece. The CCD-Camera is connected to a Video-Monitor, the centering error can now be read on the monitor. This product version increases the comfort in operation, allows the operator to better concentrate on the rotation of sample, however, has the same limitation concerning the accuracy and repeatability.
Neither OptiCentric® MAN-Visual nor OptiCentric® MAN-Video provides records of the centering errors or of the accuracy achieved. This is an important drawback of these product versions especially when it comes to integration in modern quality assurance systems.

OptiCentric® MAN

The use of an **automated, PC-controlled optical measuring head** increases dramatically the accuracy and repeatability, provides records of the tolerances achieved and is not dependent on the skills or the level of fatigue of the operator. The CCD-camera is in this case either connected to a frame grabber or to a digital interface card mounted in the PC. The software controls the measuring process, so that the accuracy and repeatability of the measurement and the stability of the process are significantly increased.

The measurement data are automatically acquired and used for calculation of centering errors or utilized for further complex analysis. The measuring certificate includes data presented according to the standard ISO 10110, so that a direct comparison with the tolerance values is possible.

OptiCentric® SMART

Cost Effective and PC Controlled Measurement

The conceptual design of **OptiCentric® SMART** is made to measure large quantities of the same type of single lenses in reflection. However OptiCentric® SMART can be used as well for the cementing of lenses

OptiCentric® SMART is a cost-effective compact test station with an electronic measuring head and a motorized axis for focusing the measuring head. All the essential functions are integral to the standard instrument. The high-power LED illumination and control are integrated in the measuring head. The electronic autocollimator has an effective focal length of 150 mm and a slightly reduced resolution compared to the autocollimators used in OptiCentric® MOT.

OptiCentric® SMART

OptiCentric® SMART is available with two versions of the vacuum lens rotation device and is ideal for investigating the centering errors of single lenses and for cementing doublets or triplets in a production environment. The travel of the motorized focusing stage is 250 mm. The centering error measurement is accurate to 0.2 µm.

The standard OptiCentric® SMART comes with a single measuring head. As an option it is possible to mount a second measuring head underneath the sample on the base of the instrument. This measuring head enables the simultaneous measurement of the bottom surface of the sample. However, the optional attachment has a manual focus range of ±10 mm. Due to the short focusing range a large range of head lenses is neccessary. The control and analysis of the instrument is carried out using the standard OptiCentric® software.

OptiCentric® MOT 100
The Worldwide Standard for Centration Error Measurement

OptiCentric® MOT 100 is the heart of the OptiCentric® system being used in a wide range of applications, either fulfilling complex measurement tasks or accomplishing important steps in the assembly and production process of optical systems. Recognized as industry's standard for centering error measurement, OptiCentric® MOT 100 provides outstanding accuracy and flexibility covering applications from tiny endoscope and mobile phone lenses to precision digital camera lenses.

OptiCentric® MOT 100 is PC-controlled and equipped with an accurate stepper motor stage for positioning or focusing of the measuring head. The measuring head can be programmed to drive to several focus positions or centers of curvature of multielement lenses. The setup data containing the positions of centers of curvatures, radii and other design data can be saved to a file and loaded for any future measurements or analysis. In this way the centering error measurement, alignment and assembly of multi element lenses become an efficient and reliable production process.

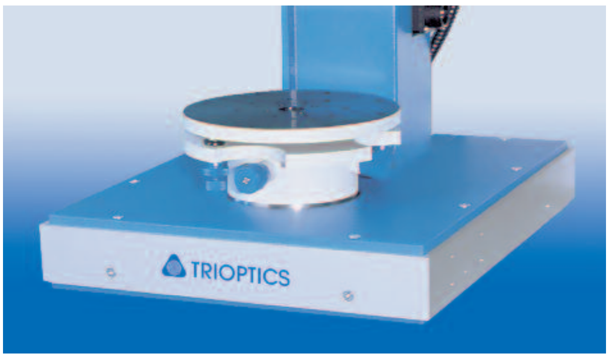
The measuring head includes a precision electronic autocollimator achieving an accuracy of 0.1 µm when measuring centering errors. In addition all instruments belonging to OptiCentric® MOT 100 can be equipped with an autocollimator with a longer effective focal length or a CCD camera with a higher resolution thus further increasing the accuracy and reliability of the measurements. For applications requiring highest accuracy, OptiCentric® MOT 100 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. For alignment needs the air bearing is equipped with a stable tilt and translation stage.

OptiCentric® MOT 100 with motorized centering and cementing equipment with vacuum chuck

The air bearing integrated in OptiCentric®MOT 100 is specially designed for optical applications requiring outstanding accuracy and stiffness (axial and radial errors of less than 0.05 µm). Typical example is the assembly of high performance multi-lens objectives.

The air bearing features a central hole for measuring in transmission mode or for checking the lens surfaces in reflection mode in connection with the dual measuring head. 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.

The TRT 200 tilt and translation table belongs to the air bearing and is used for aligning the sample or the sample holder. OptiCentric® MOT 100 systems are fitted with an AB100 air bearing which has an external diameter of 120 mm and a maximum load capacity of 20 kg.



OptiCentric® MOT 100 100 with air bearing and tilt and translation table

OptiCentric® MOT 100, AB 100 air bearing

OptiCentric® MOT 100 - Single Head

The standard instrument includes a measuring head consisting of an electronic autocollimator mounted on a motorized linear stage. The travel of the standard measuring head is 450 mm. Versions with a travel of 250 and 550 mm are also available. The linear stage is mounted on the base of the instrument. This base contains a collimator for measuring in transmission. The light of the horizontally mounted collimator is reflected by a 45 dregree deflection mirror through the sample under test.

The measuring head can be moved to any number of previously saved focal points or centers of curvature. This enables the fast and easy alignment and assembly of multi-lens objectives. The OptiCentric® MOT 100 is suitable for automated measurement process.

In addition to taking centering error measurements the instrument can also be used for measuring the radius of curvature. After the integration of extension modules effective focal length, flange focal length, back focal length and axial MTF can be determined.

OptiCentric® MOT 100 - Dual Head

For the alignment and assembly of complex and multi-lens objectives, TRIOPTICS developed a **dual head** instrument series allowing the simultaneous alignment and measurement of bottom and upper lens surfaces. Thus it is possible to determine and correct in real time the centering errors of two optical surfaces in both the x and y axis after just one rotation. This proprietary design improves dramatically the capabilities of the instrument in the field of lens assembly and measurement of centering errors. The dual head is particularly efficient at measuring multiple lenses in order to determine the centering errors within an assembled optical system. The travel of the lower axis is limited to 250 mm due to the height of the instrument.

OptiCentric® MOT 100 Dual Head

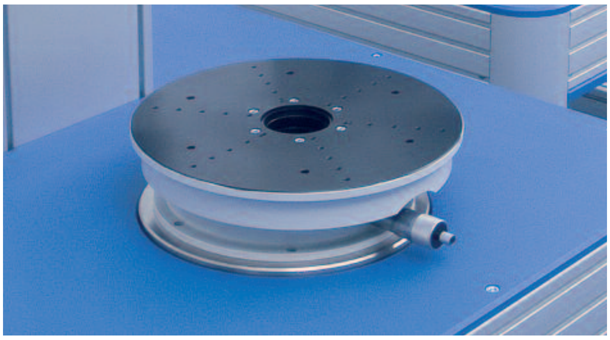
Extended Sample Diameter

The maximum diameter of a sample handled by the OptiCentric® MOT range is determined by the distance between the center of the rotation axis and the linear stage.
The standard systems presented here handle a sample with a maximum diameter of 225 mm.

OptiCentric® MOT 300

The **OptiCentric® MOT 300** range provides solid and stable instrument frames, anti-vibration isolators, heavy duty air bearings and rigid translation and tilt stages. The heavy duty air bearings have a diameter of 300 mm, extremely high stiffness, and axial and radial errors significantly lower than 80 nm. The diameter range may be increased by enlarging the distance between the rotation axis and column with the linear stage.

The OptiCentric® MOT 300 has been further developed to cover special applications in the aviation and space industry, military and astronomy. The OptiCentric® MOT 300 is able to support samples up to 2 meters in height and 300 kg in weight. The motorized focusing stage of 450 mm travel can be moved manually up to two meters in height in order to accommodate larger samples.



OptiCentric® MOT 300 with TRT400 tilt and translation table

OptiCentric® MOT 300 in production

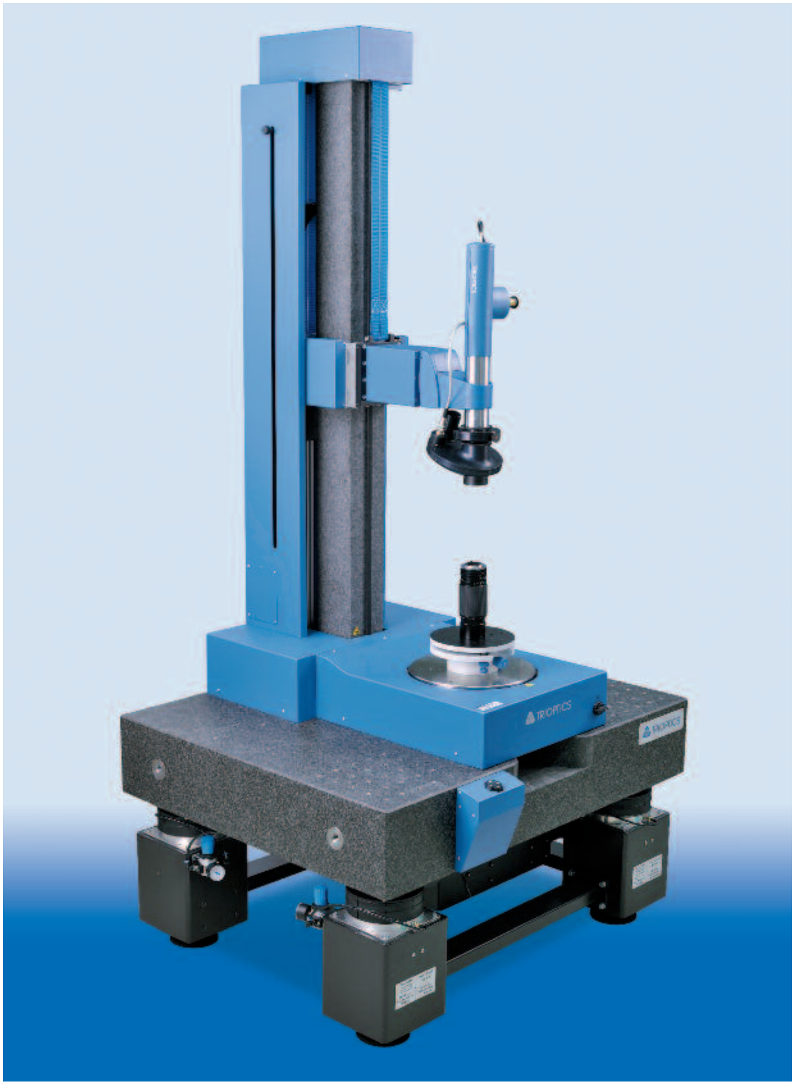
When the pre-alignment of the lens chuck or lens cell is accurately made, the ultra-precision air bearing table gives the highest possible accuracy for assembly, cementing or bonding of lenses in barrels. Using the finely ultra stable adjustable tilt and translation tables, not only tiny changes in tilt as small as 1 arcsec are achievable, but also the assembly of heavy, large objectives is possible.

OptiCentric® MOT 300 - Single Head

This measuring head can alo be moved to any number of previously saved focal points or centers of curvature (see as well single head OptiCentric® MOT 100). This enables the alignment and assembly of multi-lens objectives. The OptiCentric® MOT 300 is capable of a highly automated measurement process. It is possible to use this system to carry out all measurement and alignment tasks which can also be undertaken using the OptiCentric® MOT 100.

OptiCentric® MOT 300 - Dual Head

The dual head construction is also available on the OptiCentric® MOT 300. It is used to align and assemble complex and multi-lens objectives. It is possible to measure and align the upper and lower lens surfaces simultaneously. This proprietary design considerably improves the capabilities of the instrument in the field of optical assemblies and the measurement of centering errors. The travel on this additional axis is limited to 250 mm.



OptiCentric® MAX 300

OptiCentric® MAX
Centration Error Measurement for Large and Heavy Lenses

The **OptiCentric® MAX** is a successor to the OptiCentric® MOT 300 instruments. It is designed to measure and also to assemble extremely large, heavy lenses. The in-strument is used in the adjustment of wafer stepper lenses, for example.

OptiCentric® MAX is available in two versions that differ in terms of measurement accuracy and permissible sample weight. Furthermore, the instruments can be adapted to customer-specific requirements.

OptiCentric® MAX 300

OptiCentric® MAX 300 consists of a vibration damped table, an air bearing AB300 and a positioning unit for the measuring head. The positioning of the measuring head is controlled by a closed loop system, which allows the measurement of radii and lens distances with a high precision.

A product version with a dual measuring head is available, whereas the travel of the measuring head stage is 250 mm. With a maximum axial load of up to 500 kg and a free sample height of 1600 mm OptiCentric® MAX 300 can measure almost every large scale optic.

A typical application is the adjustment and mounting of stepper optics. Optics with a weight up to 500 kg are positioned directly on the air bearing. A tilt and translation table is not available.

The decentration of the optical elements in respect to the reference axis of the barrel is determined by measuring the barrel with a precise non-contact optical sensor or a mechanical gauge. From the measurement data the mechanical reference of the barrel is calculated and compared with the system overall reference axis (the rotation axis of the rotary air bearing). The centering errors of the optical lens elements already measured in respect of the system reference axis can now be recalculated taking as reference the mechanical axis of the barrel. The new data set can be transferred to an automated alignment device performing the accurate alignment of the optical elements on the axis of mechanical mount.


OptiCentric® MAX 600 UP with lens alignment unit

OptiCentric® MAX 600 UP

The Ultimate Solution for Alignment, Assembly and Final Inspection of Large Optics

- Ultra accurate measurement of centration errors; lens cen ter thickness and air spacing optionally available
- All-granite, all-air-bearing construction provides exceptional stiffness and thermal stability, smooth motion and unrivaled accuracy
- Additional alignment unit equipped with heavy duty piezoelectric actuators provides automated alignment with submicron accuracy

Specification OptiCentric® MAX UP

Maximal sample dimensions	
Diameter	800 mm
Height	2000 mm
Weight	1500 kg
Measurement head linear stage	
Linear stage with air bearing, autom. positioning / PC controlled	■

- Specifically designed for Microlithography and space optics with diameter up to 800 mm, height 2.000 mm and weight 1.500 kg

OptiCentric® 3D

Measuring Lens Centering, Air Spacing, and Center Thickness inside of Assembled Optical Systems with a Single Instrument

OptiCentric® 3D provides an ideal solution for the complete opto-mechanical characterization of assembled optical systems. This approach integrates different lens analysis technologies and provides a valuable tool for the evaluation of complex optical systems in R&D or routine quality inspection in production.

The two-in-one solution for the detailed investigation of assembled objective lenses com-

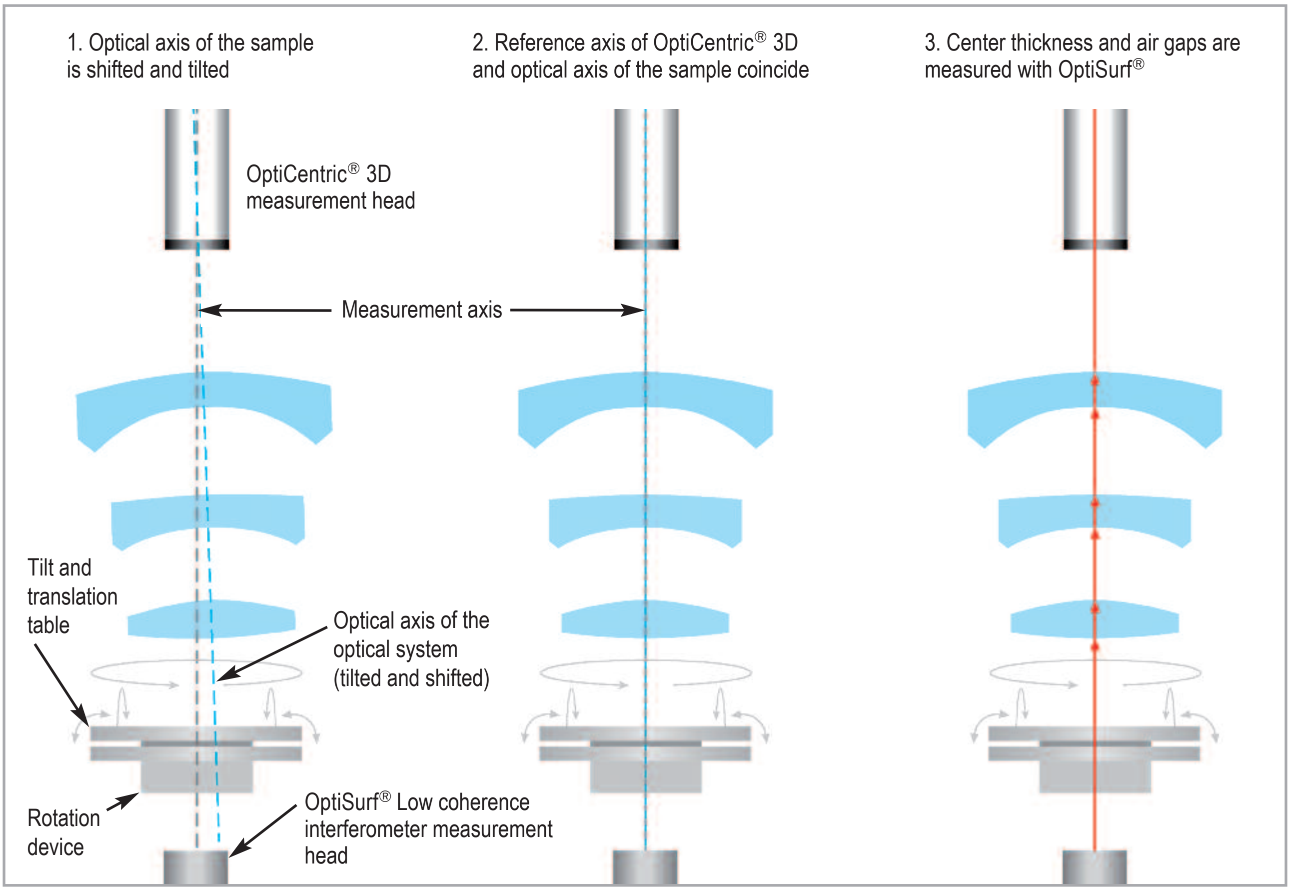
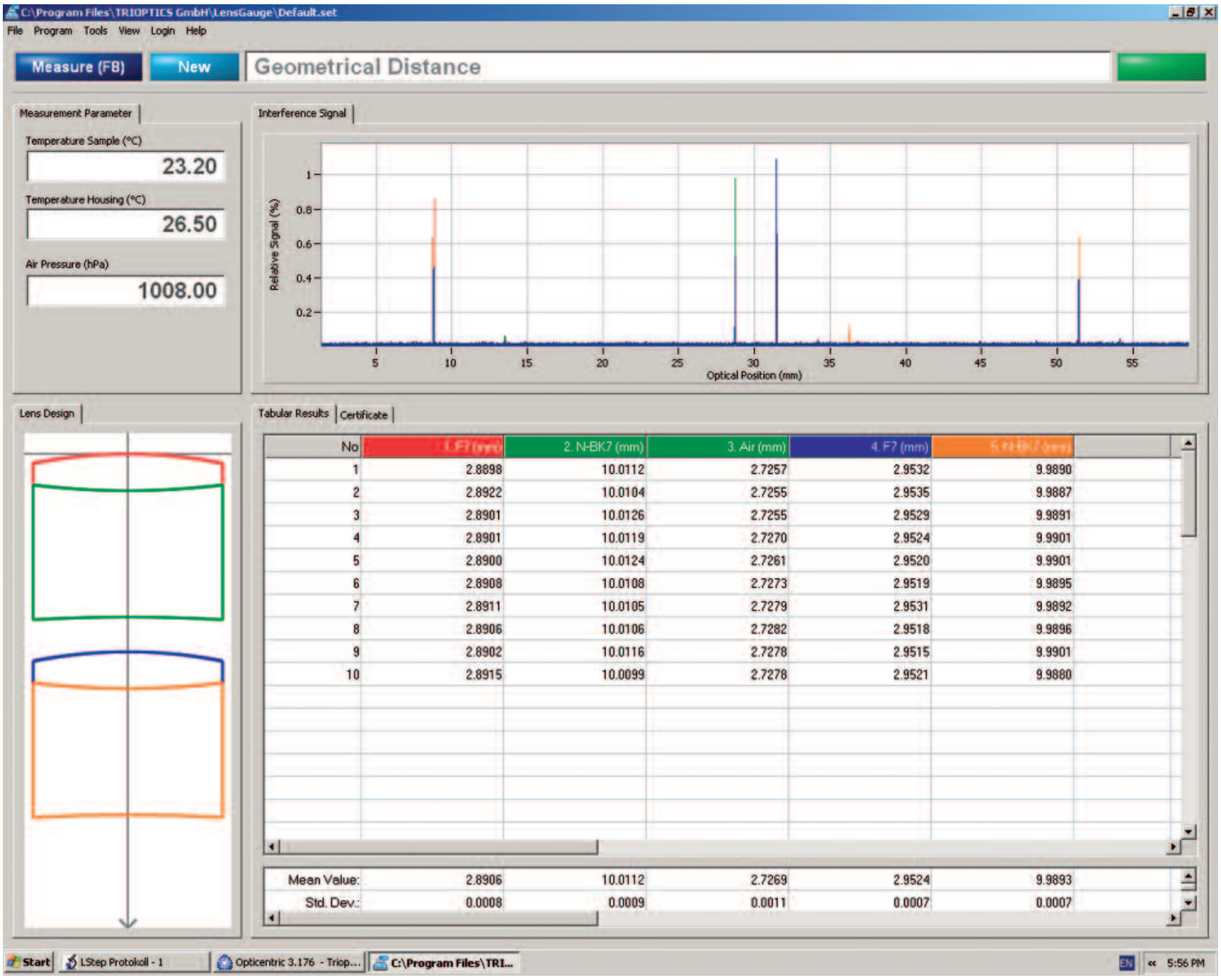


Fig. 10: OptiCentric® 3D, the different steps of the measurement process



OptiSurf® Software Module, showing the measurement results

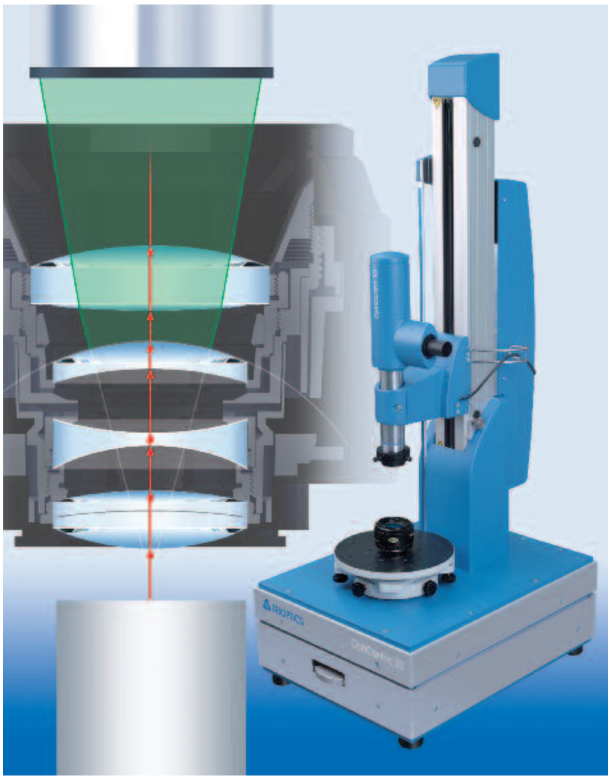
bines the OptiCentric® centering error measurement technology with a low coherence interferometer called OptiSurf®, measuring the air gaps between lens surfaces and the centre thickness of lenses within the optical system. The cross-interaction of both measurement systems allows the fast alignment of the lens system, and provides a significant increase of the overall measurement accuracy and detailed manufacturing quality information:

- centering errors of less 0.1 µm
- air spacing and centre thickness of less 1 µm

OptiCentric® 3D in Operation

Figure 10 shows how the combination of both technologies works:

1. The OptiCentric® system determines the tilt and shift in x-y direction of the optical system with respect to a reference axis.
2. With the help of the tilt and translation table or other adjusting elements the optical system under test is aligned with respect to the measuring axis of the low coherence interferometer OptiSurf. Only this accurate alignment enables the low coherence interferometer to determine precisely the position of the center of curvatures in z-direction, the air gaps between lenses and lens thicknesses.
3. After the center thicknesses and air gaps measurement with the low coherence interferometer is completed, the data are input into the MultiLens Software where the design data of the optical systems are replaced by the real measurement data obtained with OptiSurf



OptiCentric® 3D for centration error and center thickness measurement

4. As a result the accuracy of the data set containing the centration errors of the optical system, measured initially with the OptiCentric®, is significantly enhanced.

OptiCentric® 3D IR

Measuring Lens Centering, Air Spacing, and Center Thickness within IR Optical Systems

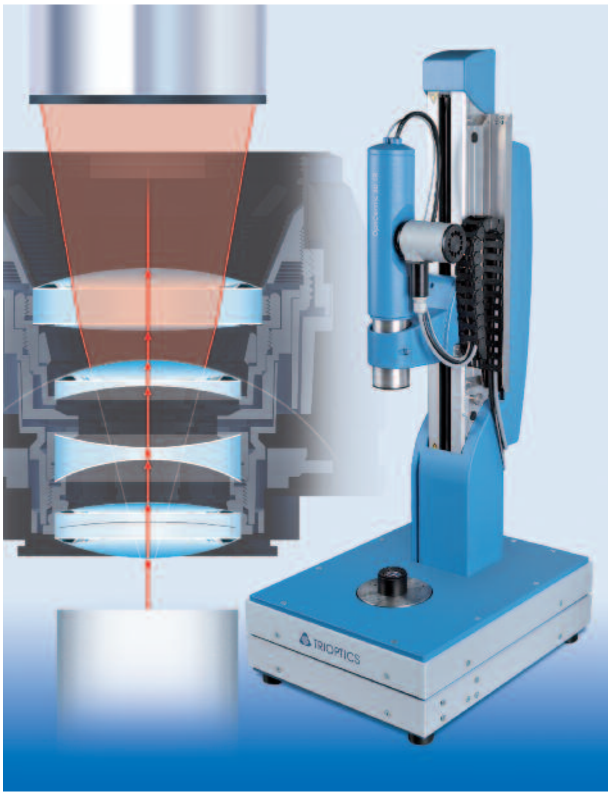
OptiCentric® 3D IR provides the ideal solution for the complete optomechanical characterization of assembled IR optical systems. The instrument integrates different lens analysis technologies and provides a valuable tool for the evaluation of complex optical systems in R&D or quality control in production environments.
The two-in-one solution for the detailed investigation of assembled IR objective lenses combines the OptiCentric® centering error measurement technology with the low coherence interferometer OptiSurf®, which characterizes the air spacing between lenses and lens center thicknesses within the assembled optical system. The combination of both technologies significantly increases the overall measurement accuracy and gives more detailed information, e.g. for quality control during manufacturing.

The typical accuracy of the system is
- Centering errors <1 µm
- Air spacing and center thickness <1 µm

OptiCentric® 3D IR in Operation

1. The OptiCentric® system determines the centering error (tilt and lateral shift) of the el ements of the optical system with respect to the reference axis.

2. The optical assembly under test then is aligned with the help of a tilt/translation stage to the measuring axis of the low co herence interferometer OptiSurf®.
The highly accurate alignment enables the low coherence interferometer to precisely determine the relative position of the lens surfaces in axial direction, the air spacing between lenses and their respective center thicknesses.



OptiCentric® 3D for centration error and center thickness measurement

Specification OptiCentric® 3D IR

Spectral range	LWIR (8-12 μm), MWIR (3-5 μm)
Centering errors	< 1 μm
Air spacing / Center thickness error	< 1 μm
Sample diameter range	1 - 800 mm
Range of sample radii of curvature	0 to ± 450 mm (larger ranges optional) and plano surface
Centering error of assembled optics (MultiLens)	yes

3. After the center thickness and air gap measurement is completed, the data measured by OptiSurf® is transferred to the MultiLens Software where it replaces the theoretical design data.
4. As a result, the accuracy of the OptiCentric® measurement is significantly increased.

OptiCentric® Custom

Customized Centration Error Measurement Solutions

In addition to the before mentioned configurations of the OptiCentric® product line, TRIOPTICS also develops and **manufactures custom specific instruments**. The development of custom instruments is based on existing TRIOPTICS hardware and software platforms, so that our customers benefit from the same level of accuracy and reliability characteristic for our standard instruments. In the following some of the OptiCentric® Custom instruments are presented:

Measurement of Laser Rods

The quality of the laser rods is mainly influenced by the parallelism of laser rod end surfaces and the homogeneity of the material. Ideally the light beam entering the laser rod should exit without changing direction.
However, if the two end surfaces of the laser rod are not parallel and perpendicular to the cylinder axis, the traversing laser beam will be deviated. Similarly, defects in the material contribute to the beam deflection.

The main parameters to be checked are:

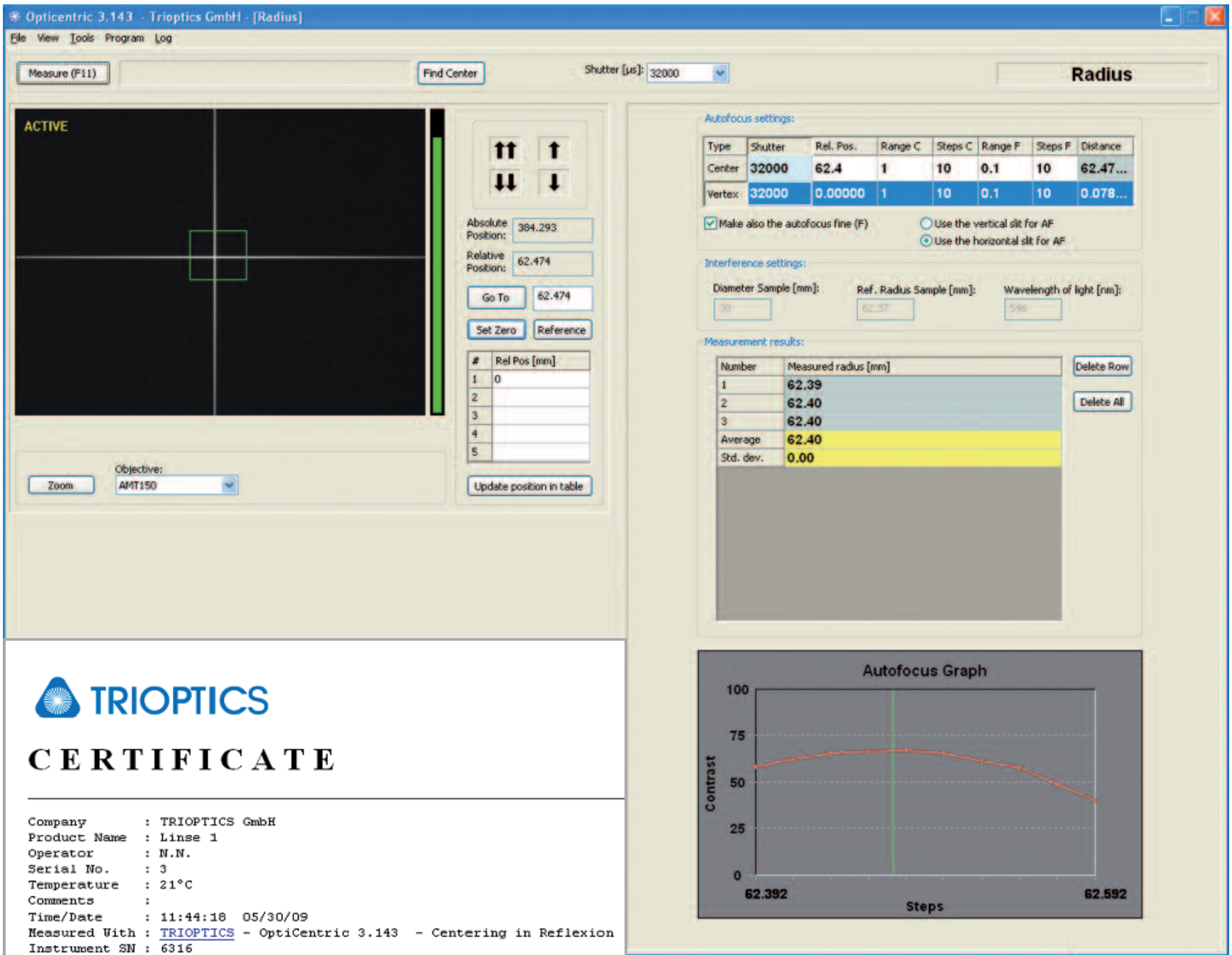
- The parallelism of the laser rod end surfaces which is measured in reflection mode
- The beam deviation through the laser rod which is measured in transmission mode
- When the cylinder axis is given as a reference, and the centering errors of the rod end surfaces to the cylinder axis are required, the laser rod is additionally rotated.

The setup of the instrument is horizontal in order to allow the precise rotation of long laser rods up to 150 mm. A special software module controls the measurement and provides specific data sets and measurement certificates.

Measurement of C-lenses

A typical example from the field of micro optics is the measurement of C-lenses used for the light transmission in glass fibers.

Customer specific instrument for the measurement of laser rod end surfaces



Measurement of the radii of curvature


TRIOPTICS

CERTIFICATE

Company : TRIOPTICS GmbH
Product Name : Linse 1
Operator : N.N.
Serial No. : 3
Temperature : 21°C
Comments :
Time/Date : 11:44:18 05/30/09
Measured With : TRIOPTICS - OptiCentric 3.143 - Centering in Reflexion
Instrument SN : 6316

Number	Center X [µm]	Center Y [µm]	Center [µm]
1	59.38	-8.24	59.95
2	59.59	-8.38	60.18
3	59.72	-8.36	60.30
4	59.77	-8.59	60.38
5	59.79	-8.68	60.42
Average	59.65	-8.45	60.25
Std. dev.	0.15	0.16	0.17

Radius : 25.000 mm
Objective : AMT50

As a rule, C-lenses have an optical window on one side and a spherical surface on the other and are typically long in relation with the diameter. A special rotation device has been developed allowing for horizontal positioning and rotation of the C-lenses during the measurement. The rotation of lenses is accomplished manually; the centering error of the spherical surface is measured in relation to the cylindrical axis.

Accurate Radius Measurement

All OptiCentric® systems include an option for the measurement of radii of curvature. The measurement principle is analog to that of the interferometric measurement procedure: The autocollimator is initially focused on the upper surface of the sample and in a second stage into the center of curvature of the same surface. Due to the accurate autofocus feature, both positions can be detected with high sensitivity. The distance between the two positions, corresponding to the radius of curvature of the surface, is measured using precision linear encoders mounted on the instrument stand.

Customer specific instrument with linear air bearings

In order to achieve the required 0.01% accuracy of the radius measurement, a linear air bearing has been mounted instead of the standard linear stage of the OptiCentric® system. The excellent straightness of the linear air bearing contributes essentially to the overall measurement accuracy.
In addition to the accurate radius measurement this instrument is able to fulfill all the other jobs related to measurement of centering errors in multilens systems or complex alignment tasks. Due to the high accuracy of the linear stage a rotation bearing is not required with this setup thus it is easier to measure lenses with a large diameter.

OptiCentric® Software

The advanced software is designed to work with 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.

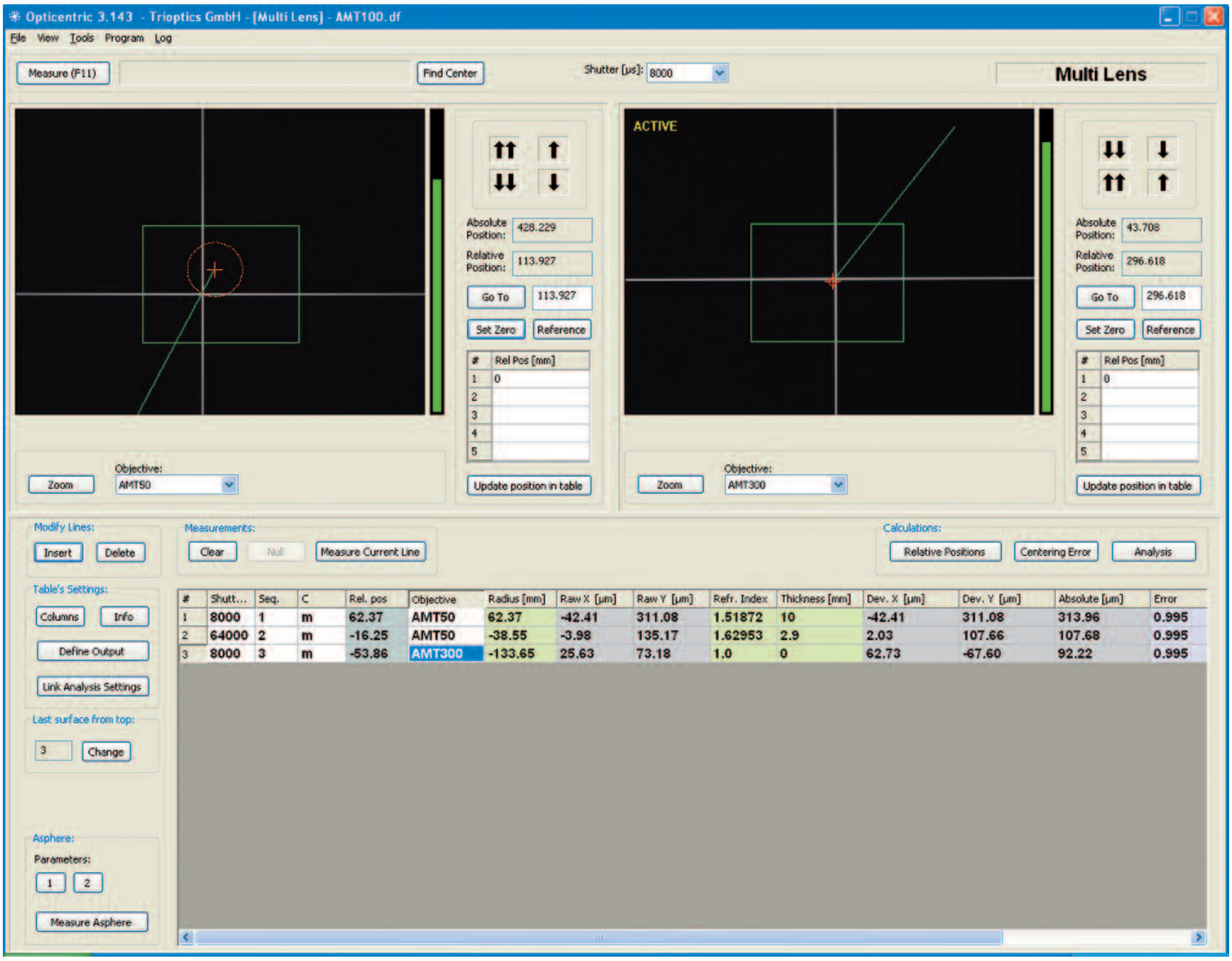
The software modules „Centration in Transmission" and „Centration in Reflection" provide an outstanding accuracy even in difficult measuring situations such as poor contrast, anti-reflection coated surfaces, very small lenses, etc. With the OptiCentric® Dual Head instrument the software optionally provides 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. different reticule patterns (bright cross, dark cross, pinhole, etc.).

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

- Real time monitor display of the camera image from one or two measuring heads
- Real time, continuous display of the measurement values
- Vector display of the size and direction of the centering error
- HTML certificate output
- Computer generated tolerance circles or angle graduations for the quick analysis of production quantities
- Automatic adjustment to the sample reflectivity
- Automatic calibration procedure by means of a calibrated sample, the calibration can be verified at customer site
- Artificial crosshair for the initial alignment assistance

OptiCentric® MOT Extension Modules

Thanks to the modular design of the instrument software, new options and software modules can be easily integrated in order to extend the measurement capabilities of the instrument.

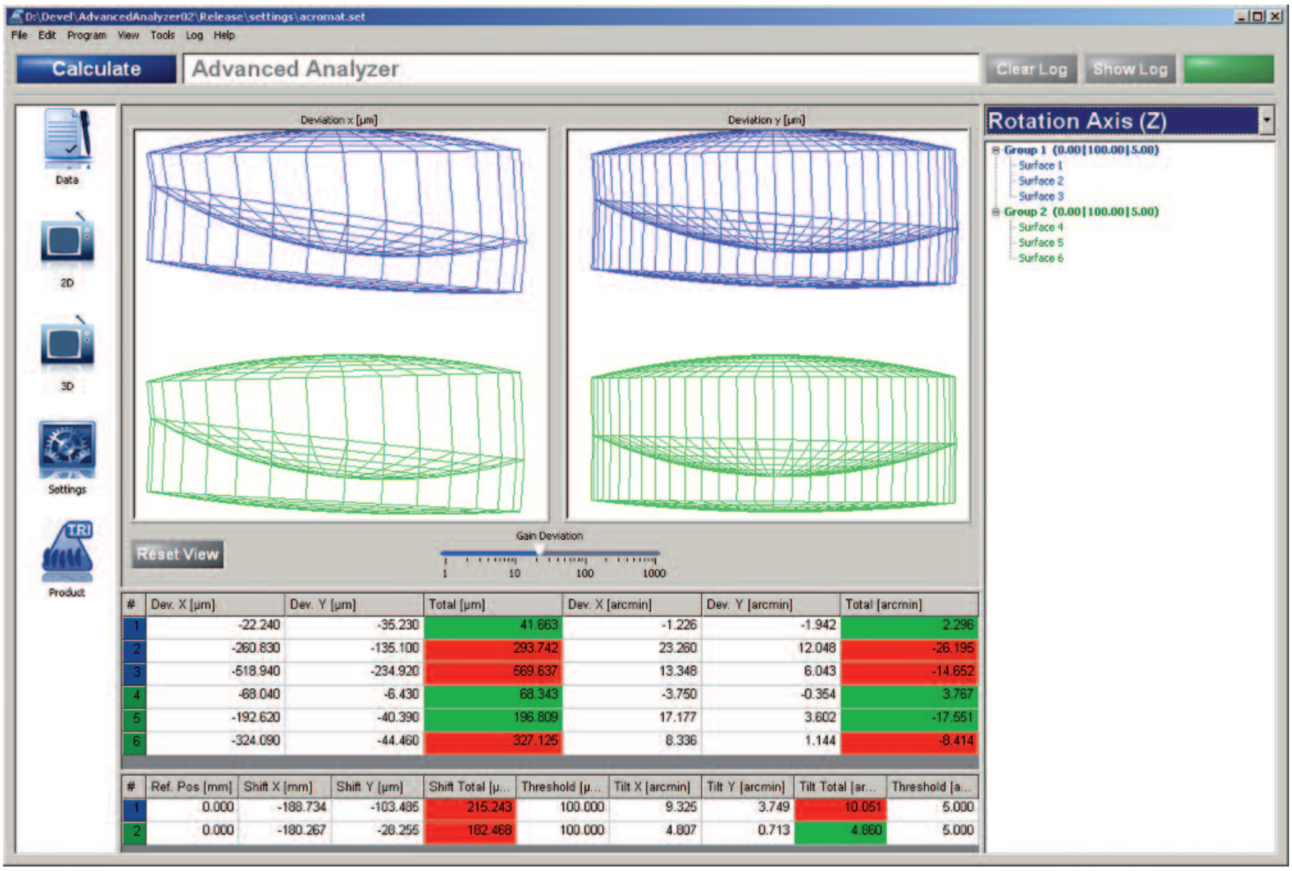


MultiLens® window: Dual live image

MultiLens®

This complex software module is used either for the measurement, alignment and assembly of objective lenses or 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® software delivers in a nondestructive way the complete information about the individual centering errors of all surfaces in an assembly. The PC controlled OptiCentric® instrument performs stepwise a reflection mode centering measurement starting with the first surface closest to the measuring head and continuing with the following surfaces.

The MultiLens® software performs a ray tracing through the optical system based on the lens design parameters and the measured centering values. Finally, the operator obtains a numerical and graphical output of the complete centering status regarding shift and tilt of each measured surface.
The module can calculate the best-fit optical axis of the objective lens and all surface centering data can be referenced to this axis. Combining these features with adequate assembly techniques, high performance objective lenses with tolerances in the micron range can be easily centered to best performance.



Software AdvancedAnalyzer

Advanced Analyzer

The Advanced Analyzer is a software tool in addition to the MultiLens® software with even more analysis features and comprehensive 3D graphical output. When it is run on the instrument's PC, the measurement data is transferred automatically between the applications. As it is a self-contained software application a separate copy can be ordered to perform a detailed centering analysis independently from the instrument's PC.
The initial measurement data refer to the air bearing's axis of rotation, which is usually not the desired result. The Advanced Analyzer software therefore calculates the following situations:

- Calculation of the optical axis of a lens
- Calculate the optical axis passing through two or more centers of curvature. Weighting factors can be applied to calculate the regression line depending on the optical power of the surfaces
- Reference relatively to the mechanical axis
- Reference all other surfaces and optical elements relatively to any user defined optical axis
- Calculate angle and distance between two optical axes (e.g. two single lenses)
- Calculate the surface tilt error of any surface relatively to the axis of reference.

AspheroCheck®

AspheroCheck® (Patent application 10 2006 052 047.5-51) is a hardware and software module designed to measure the tilt and shift 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.

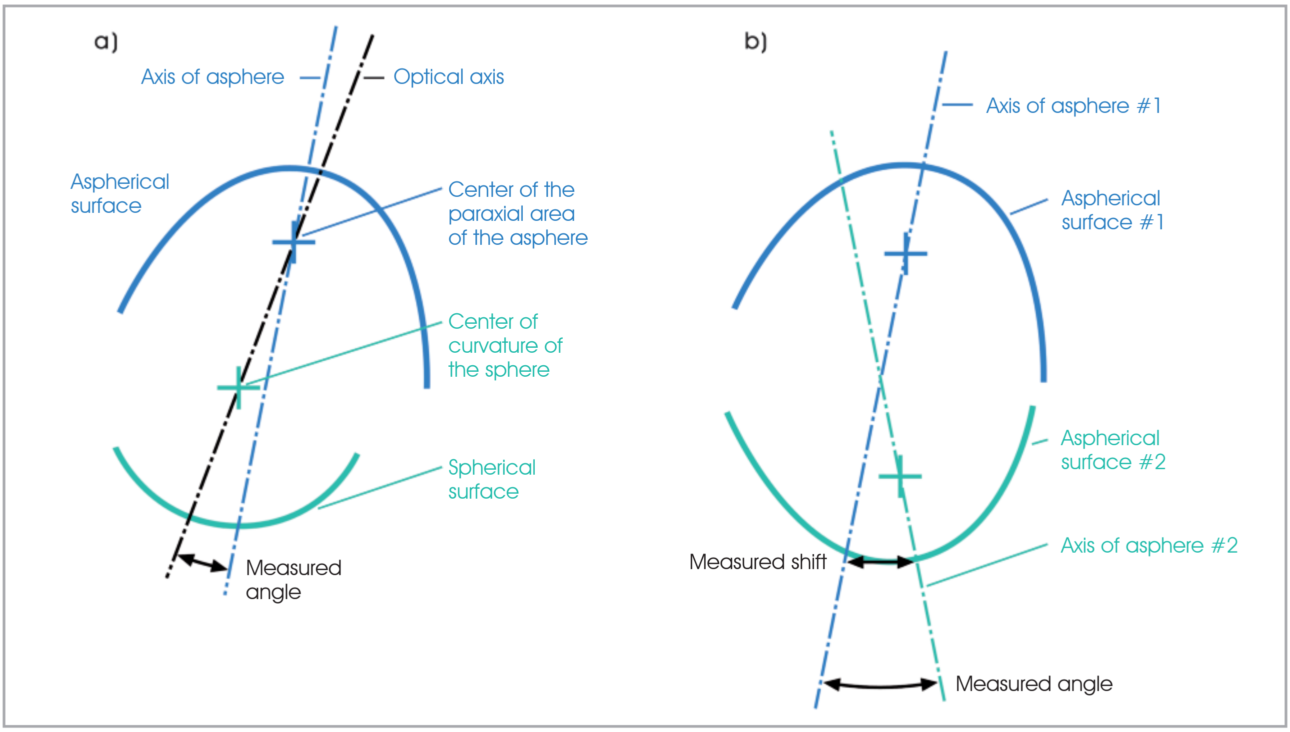


Fig. 11a: Lens with an aspherical and spherical surface

Fig. 11b: Lens with two aspherical surfaces

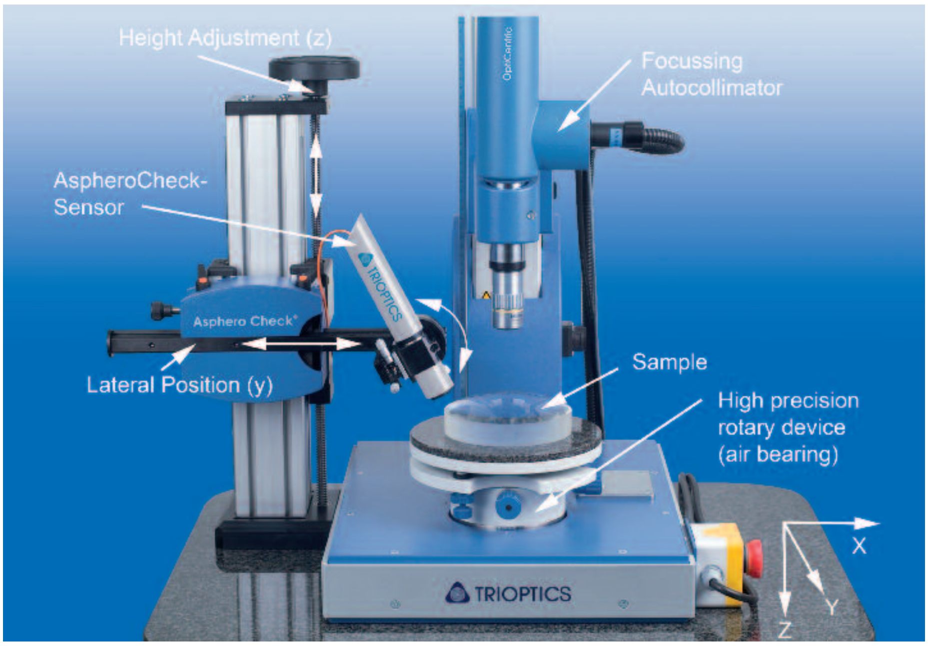
The AspheroCheck® module consists of a high-precision AspheroCheck® distance sensor mounted on a x-z linear stage system. The angle of the sensor can be adjusted square to the sample surface by a rotary stage. Every point along the radius of the sample can thus be reached by the sensor. The standard module is operated manually, a motorized version is available on request.

During the measurement, the AspheroCheck® sensor is moved close to the outer edge of the lens in order to capture the eccentricity of the surface during rotation.

At the same time, the autocollimator determines the centering error of the surface in the paraxial area.

Both values are then combined to determine the position and the tilt of the aspherical axis.

The following parameters of aspherical lenses can be measured:



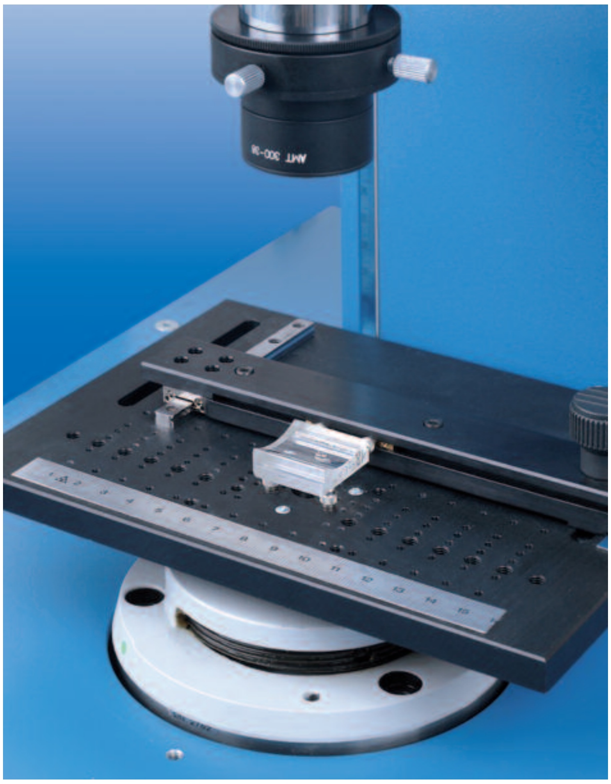
OptiCentric® AspheroCheck®

- Shift and tilt of the asphere axis in relation to the reference axis of rotation.
- Shift and tilt of the asphere axis in relation to the optical axis of the lens. The "optical axis" is considered to be the line running through the centers of curvatures of the spherical portions.
- When a lens consists of two aspherical surfaces the angle and shift of both aspherical axes are determined.

CylinderCheck®

CylinderCheck® is a module for the precise measurement of centering errors in cylindrical surfaces. Depending on the application, different parameters of the cylindrical surface can be measured using the CylinderCheck® module.

- The angle (azimuth) between the cylindrical axis and a given edge or other reference line
- The offset of the cylindrical axis from a given edge



Measurement of cylinder lenses

- The tilt of the cylindrical axis from a plano base surface (optional)

For this measurement task special sample holders are required, (see picture).

Furthermore, the OptiCentric® system is capable of measuring the centering error of cylindrical surfaces in mounted anamorphotic lenses.

OptiSurf® Center Thickness Measurement

Besides measuring centering errors, the OptiCentric® system is able to determine the distance between optical surfaces inside of an optical system.

An individual distance, e.g. the center thickness of a lens, but also a complete set of distances, including the center thickness of lenses and air gaps, can be measured non-destructively in an assembled objective lens. Similar as in the MultiLens measurement, this procedure requires the optical design data of the sample. OptiCentric® offers two methods for this measurement.

The first method refers to the OptiSurf® sensor, specifically developed for measuring distances inside optical systems. OptiSurf® is based on low coherent interferometry and is able to measure all center thicknesses in an objective lens with an accuracy of about 1 µm. The OptiSurf® low coherent interferometer measures lens distances within a range of 0 to 600 mm with an accuracy of 1 µm. Longer distance ranges i.e. optical paths are available on request.
The second method uses an autocollimator with a lens attachment in order to determine the cat's eye surface reflection position of the surface under test. The difference between two measured positions is used in conjunction with the design data (radii and refractive index) to calculate the actual distance. This method works extremely well with a limited number of surfaces but can be noticeable

problematic when measuring optical systems with large numbers of optical elements. The OptiSurf® sensor is the preferred choice for measurement of multi-lens optical systems.

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

Besides the software functions, the OptiSpheric® module consists of an additional collimator mounted with a 90° deflection mirror in the base of the instrument. It is equipped with a selection of test targets for the different measurement options.

OptiAngle®

The software module OptiAngle® and some additional mechanical fixtures convert the OptiCentric® instrument into a powerful tool for angle measurements, including:

- Wedges
- 90°-prisms
- Parallelism of parallel plates
- Deviation angle through wedges and prisms
- Mirror tilt
- Alignment of CD/DVD optical heads
- Wobble of rotating disks

More detailed information on the measurement of plano optics is included in the TRIOPTICS TriAngle® brochure.

Assembly of Optics

Automated Cementing of Lenses

For many lens manufacturers, the cementing of two or three optical elements is a expensive process that must be carried out manually and is thus prone to error. In the conventional fabrication process, two different cementing procedures have been used. First, all the centers of curvature can be aligned on a reference axis. Complex, costly positioning elements and/or sample holders are needed for this. In the other process, the upper lens is adjusted on a reference axis defined by the edge and one center of curvature of the lower lens. In this case, the alignment accuracy

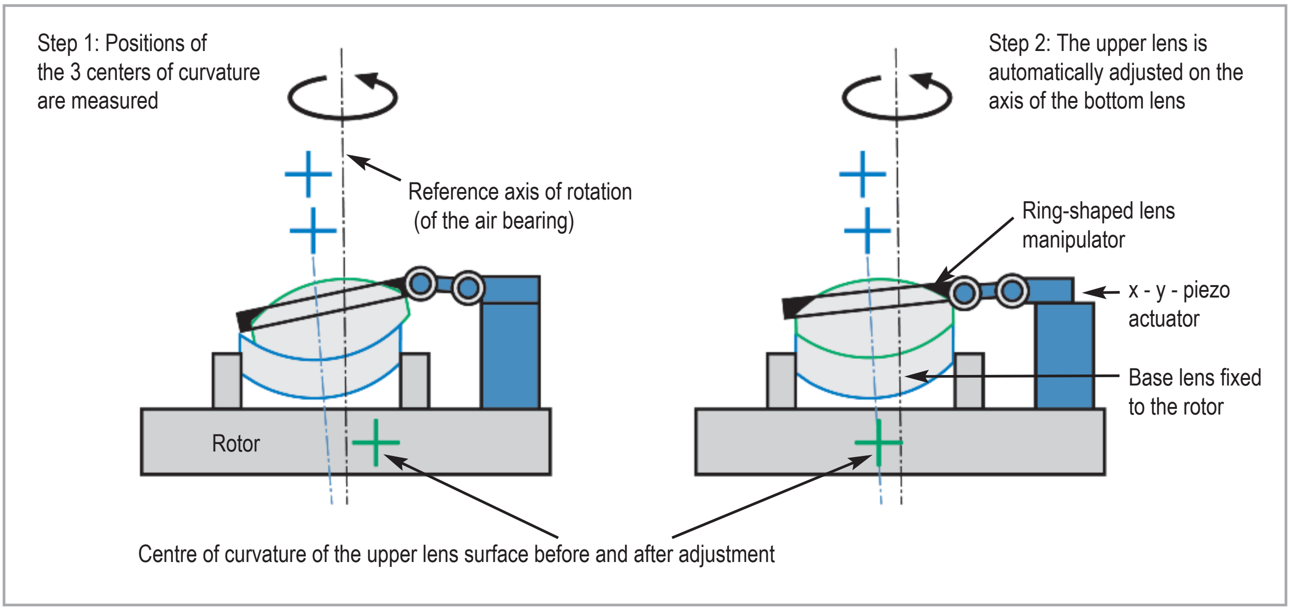


Fig. 12: The SmartAlign technology is used for the automated alignment of achromatic lenses in the cementing process

is limited by the fabrication tolerances of edge processing of the lower lens. Both processes are carried out manually, so the alignment accuracy also depends on the skills of the operator.

The technology developed by TRIOPTICS overcomes the disadvantages of both processes. The basic idea is that the three centers of curvature of both lenses are measured exactly and adjusted onto a line. Exact prepositioning of the lower lens is thus no longer necessary.

The complete process is shown in Figure 11. In the first step, the centers of curvature are found for the three lens surfaces. Measurement takes place within a few seconds and with a precision in the submicrometer range relative to the exact axis of rotation.
Then the measurement results, including the three centers of curvature, are converted into parameters for exact adjustment and transmitted to a piezo actuator.
Quickly, the upper lens is aligned to the lower lens with a precision better 1 µm. The entire process takes no longer than ten seconds. If necessary, a unit for automatic UV hardening is also integrated into the system.

In summary, the SmartAlign® technology is a software and technology concept for the cementing of lenses. It permits the highest possible degree of accuracy and repeatability without requiring mechanical adjustment. In addition, this cementing process is very stable and fast.

Bonding of Lenses in a Mount

The bonding of lenses into a holder is the right choice when high-precision adjustment of the lenses is required. For military and scientific applications as well, where large temperature variations or extreme vibration can occur, the bonding of lenses instead of mechanical mounting is the right choice.

For a lens to be bonded accurately into a holder, the lens must be oriented in the holder in such a way that the optical axis of the lens matches the reference axis of the lens holder. In the final step, the cement is applied and the optical unit hardened with UV light.

The best results are obtained measuring in reflection. Another prerequisite for good results is that there must be a precise reference axis, for example an air bearing.

To align reference axis of the holder with the reference axis of the lens, there are two different procedures to choose from:

First, the holder can be clamped in a hydrostatic clamp. The clamp is then aligned with the reference axis of the air bearing. The prerequisite for precise results is that the sample must be fastened in the clamp with repeatable accuracy.

If the hydrostatic clamp is used, the precision of alignment of the holder to the reference axis depends on the accuracy of the holder itself. The accuracy of the holder is 1-3 µm. It requires a relatively large investment, since the accurate holder can only be adapted to a single diameter. This procedure is thus best suited for mass production.

The second option for determining the reference axis of the holder is to measure the reference axis using a high-precision probe or with an optical sensor. This procedure has the advantage that a cost-effective mechanical clamp can be used, and that higher precision is obtained in the bonding process.
For the complex area of optical production, TRIOPTICS has developed the automatic OptiCentric® Bonding workstation. The workstation simplifies optical fabrication, reduces the risk of alignment and centering errors, and thus significantly increases the efficiency and stability of the process. The core of the system is the extensive, stable software that controls the monitoring, alignment, bonding, and hardening process. With the OptiCentric® Bonding Station, the customer can use either hydrostatic clamps or mechanical clamps.

TRIOPTICS SmartAlign® technology, integrated into the software of the workstation, permits the use of the mechanical clamps. The reference axis for the holder is determined using the sensor or probe, and compared with the reference axis of the optical system. The measured centering error of the lens can then be calculated relative to the axis of the holder. The calculated data is then sent to an alignment unit that positions the lens precisely.

An overview of the complete process is presented here in Figure 13:

In the first step, glue is applied to single lenses and they are placed in a holder. Since the centering need not be exact due to the subsequent mechanical processing, a slow-hardening glue can be used. In contrast with processes in which the glue must harden very quickly, here it is ensured that the lens is fastened in the holder with no stress.

Alignment Turning

To fabricate a high-precision optical assembly, alignment turning is used to fabricate the subassemblies mechanically precisely to the optical axis, with optics already mounted, so that they need only be inserted into the tube. The advantage of this process is that the mechanical fabrication can be carried out more easily with very close tolerances than the optical adjustment.

In the first step, glue is applied to single lenses and they are placed in a holder. Since the centering need not be exact due to the sub-

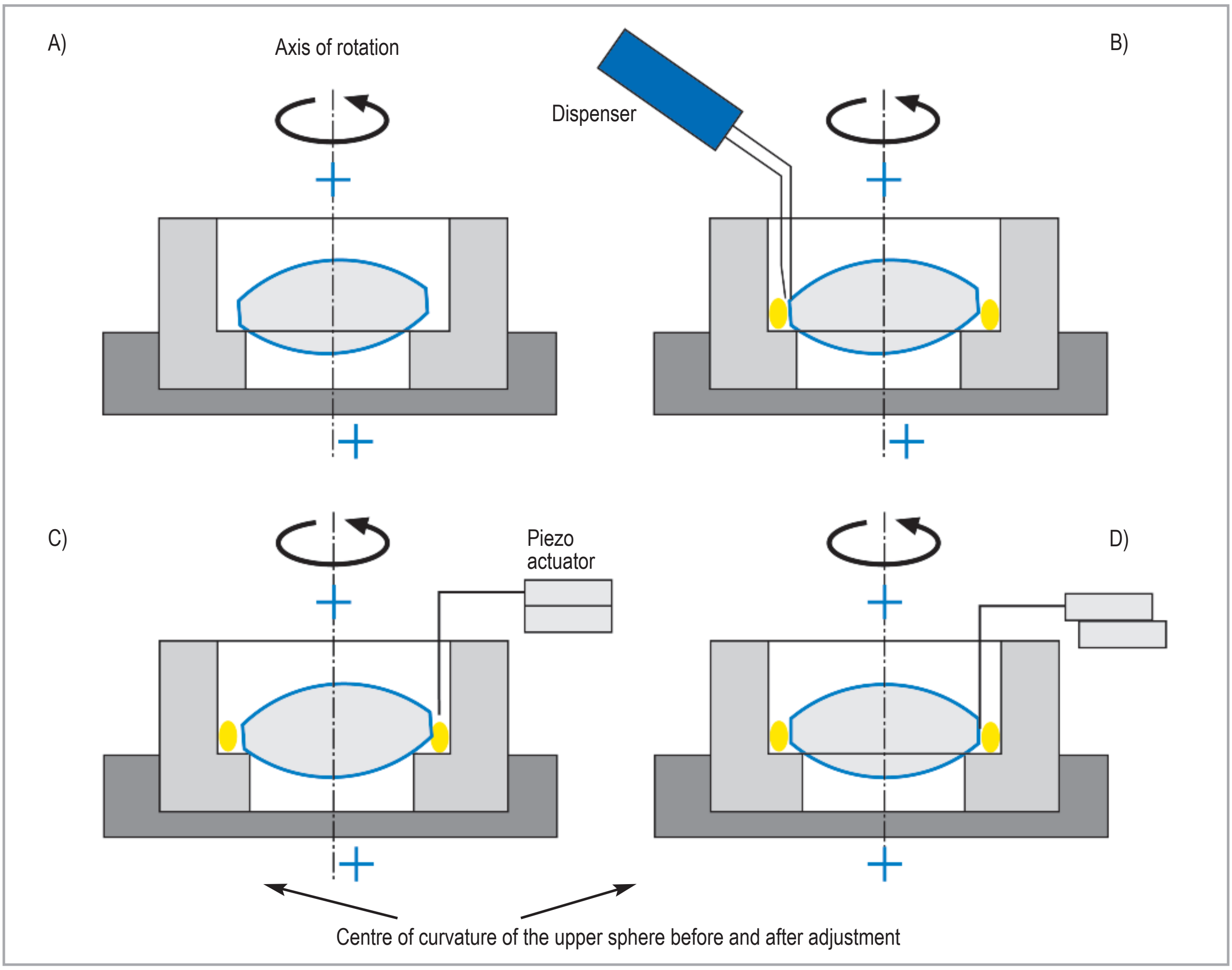


Fig. 13: Automated bonding of lenses into a mount

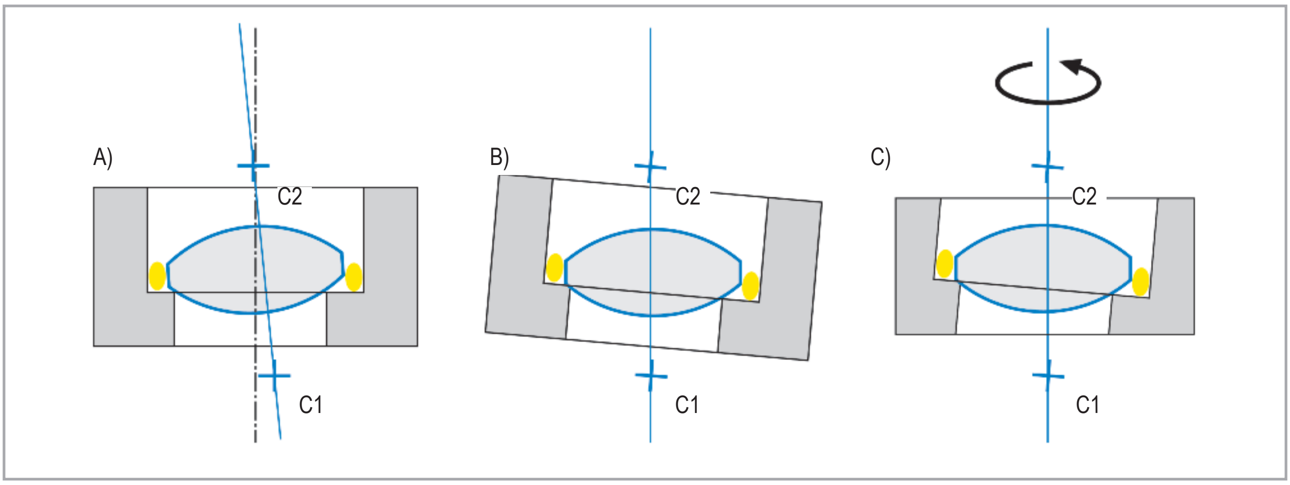


Fig. 14: Alignment turning of lens cells

sequent mechanical processing, a slow-hardening glue can be used. In contrast with processes in which the glue must harden very quickly, here it is ensured that the lens is fastened in the holder with no stress.

In the second step, the holder with the lens is clamped onto the axis of a lathe. The workpiece is then aligned in such a way that the optical axis coincides with the axis of rotation of the machine. Two autocollimators are used for the measurement, focused on the centers of curvature of the lens surfaces. Alternatively, a signal autocollimator can be used to measure both surfaces one after the other in MultiLens® mode.
Once the optical axis is aligned, in the third step the holder and flange surfaces are processed. Elements fabricated in this way can easily be inserted into a tube with exact inner fit.
The alignment turning method ensures high quality and is generally used for lenses with very high precision requirements.

OptiCentric® PRO

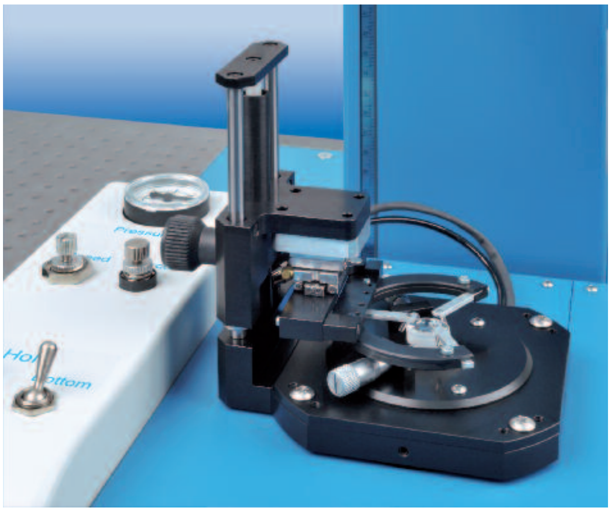
The OptiCentric® PRO line for production offers a range of **fully automated cementing, bonding and alignment turning stations**. The powerful products are fully automated and comply in the basic configuration with the OptiCentric® MOT 100. All sub assemblies like a glue dispenser or the motorized stepper are PC controlled.

OptiCentric® Cementing Station

Lens manufacturing not only includes glue bonding of a lens to a barrel, but also the centering and cementing of two lenses to a doublet. For this purpose TRIOPTICS has developed the **OptiCentric® Cementing Station** as a supplement to the TRIOPTICS OptiCentric® System.
It includes a 2-axis x-y piezoelectric fine positioning stage and a lens specific grabber. The grabber does the precise positioning of the upper lens to the optimally centered position with respect to the lower lens. The centering procedure relies on the proprietary TRIOPTICS MultiLens® algorithm. It determines first the optical axis of the lower lens and calculates the target position for the top lens. The top lens is then pushed by the piezo driven grabber to the target position under control of the high resolution CCD autocollimator. With this technology, doublets with centering accuracies below 1 micron can be achieved. Similar to the Bonding Station, the complete process is computer controlled. Driven by customer demands in the high volume market of plastic molded lenses the process has been optimized for throughput. The complete cement-

OptiCentric® Cementing Station

ing cycle including UV curing and manual sample handling is performed within less than 10 seconds.


OptiCentric® Cementing Station with piezo electric fine positing guide

OptiCentric® Cementing Workstation

The **OptiCenteric® Cementing Workstation** is a perfect supplement for optical edging machines. As a preliminary step of the edging process the workstation aligns and cements lenses on an arbor. Equipped with an electronic autocollimator and a precise air bearing the station enables precise lens alignment and significantly increases the cementing accuracy.

Additionally, the whole alignment and cementing process becomes easier to handle and allows for fast and reproducible cementing results. This OptiCentric® System comprises all equipment necessary for the cementing process and is designed as an ergonomic and comfortable turnkey station.

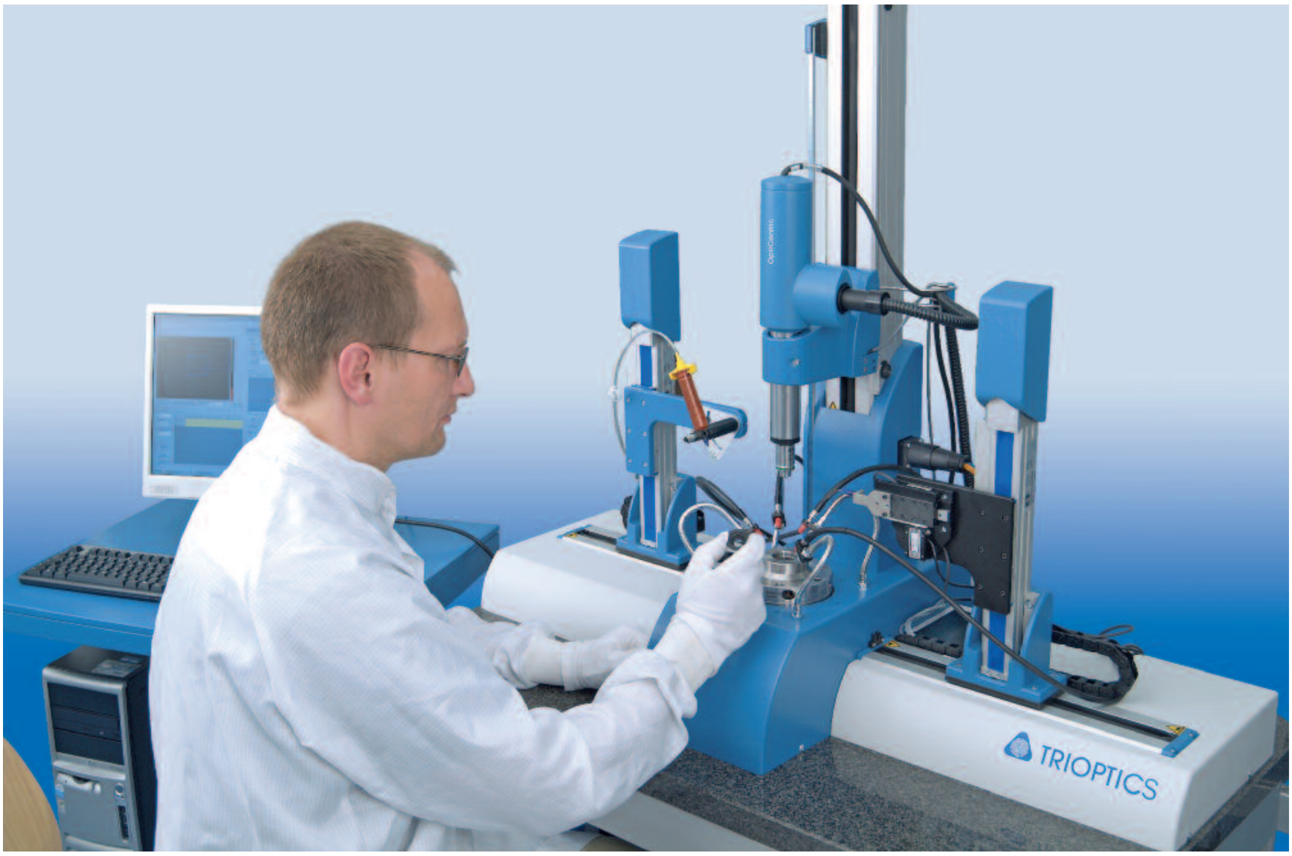
OptiCentric® Cementing Workstation

Like all OptiCentric® Systems this Workstation also measures the centration errors of single lenses and achromats.
For operation the arbor prepared with cement is clamped in the hydrostatic holder, then the lens is positioned on the top of the arbor and manually aligned while the air bearing rotates. The OptiCentric® Software supports this process with its strong SmartAlign® feature.

For further comfort the OptiCentric® Cementing Workstation can be fully automated with a 2-axis x-y piezoelectric fine positioning stage and lens specific grabber.

OptiCentric® Bonding Station

The **TRIOPTICS Automatic Bonding Station** extends the capabilities of the OptiCentric® System into automatic manufacturing processes of optical components and systems. Modern objective lenses rely more and more on glue bonded components which, besides the lower cost, save space and weight. The OptiCentric® Bonding Station includes all the devices necessary for the precise and automated centering and glue bonding of lenses into barrels and other optical subassemblies.



OptiCentric® Bonding Station in operation

A glue dispenser is mounted on a motorized x-z stepper motor stage for the automatic positioning of the dispenser tip to the gluing position. The dispensing process is computer controlled and the glue can be dispensed continuously or segmented around the lens.

A second x-z stepper motor stage moves a precision piezoelectric manipulator to the edge of the lens to be centered. The piezo manipulator allows for a fine positioning of the sample lens with submicron step resolution and accuracy.

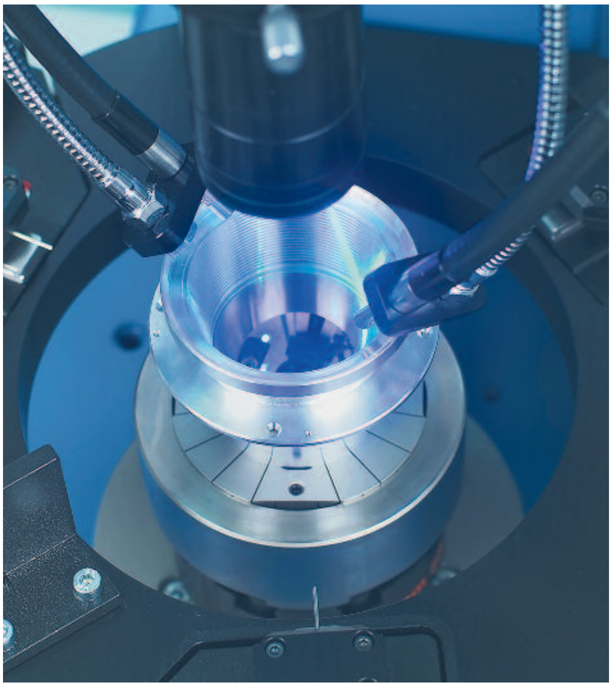
The centering process is controlled by the OptiCentric® System which relies on a high resolution CCD autocollimator and the precise sample rotation with an air bearing. High-precision centering results better than 2.5 microns are typically achieved in 2 min processing time including UV curing time. The UV curing of the glue after lens alignment is enabled by a computer controlled UV light source and several light guide outlets.

The complete bonding process is controlled by an integrated software program for all functions. A simple script language allows the flexible programming of the bonding process. The complete manufacturing cycle can be programmed with an easy teach-in procedure using the manual stage controls. Of course, different procedures for varying sample types can be saved in files for later use.

OptiCentric® Alignment Turning

In alignment turning, optical units are processed by mechanical machining. The holder with the lens is first placed into a clamp, and the centering error measured. The clamp is then aligned in such a way that the optical axis and rotational axis coincide. The holder is then lathed away in a second process step.

The most important components in this fabrication process are the centering lathe with a



OptiCentric® Bonding Station with three piezo manipolatord for fast alignment of the lenses

high-precision axis, the **OptiCentric® Alignment Turning System** for precise measurement of the centering error, and the mechanically adjustable clamp. The axis of rotation ensures that the fabrication process is carried out stably and precisely. It is mounted on hydrostatic bearings and its radial deviation is less than 0.08 µm.

The **OptiCentric® Alignment Turning System** determines the orientation of the optical axis of the workpiece relative to the axis of rotation. The system is available in variants with one or two electronic autocollimators. If two autocollimators are used, both centers of curvature of the lens can be measured at the same time. With only a single autocollimator, two measurements are taken one after the other, and the position of the optical axis is determined using the MultiLens® algorithm.

The sample is then translated and tilted in the X and Y directions using the adjustment clamp in such a way that the optical axis of the sample coincides with the axis of rotation.

Accuracy in the submillimeter range can be achieved in this way. The mechanical interlock on the adjustment clamp ensures that the position of the optical axis relative to the axis of rotation does not change while the holder is centered to the rated diameter. In addition, both flange surfaces of the holder are also machined.

An optical sensor that measures the distance between the flange surface and the vertex of the optical surface of the workpiece can optionally be used.

The specification of the alignment turning station is:

Centering accuracy:	< 0.1 arcmin (tilt)
	< 2 µm (decenter)
Machining tolerances:	< 2 µm
Flatness of plano surfaces:	< 1 µm
Cylindricity of lens cell:	< 1 µm.

Accessories

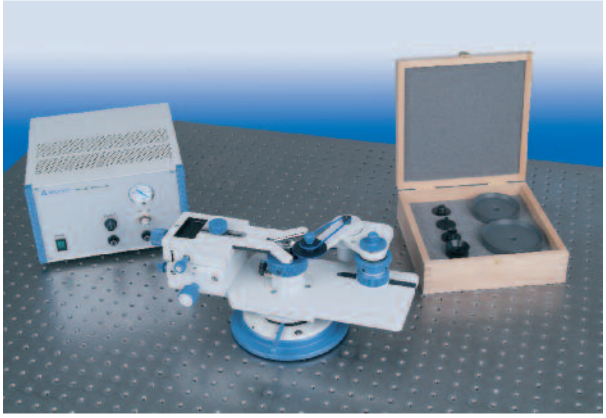
The following accessories are offered to extend the use of OptiCentric® instruments.

Motorized Centering and Cementing Equipment with Vacuum Chuck

The vacuum unit is a rotation device to measure 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 the 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



Motorized Centering and Cementing equipment with vacuum chuck

are averaged out so that the results have a very high repeatability.

The maximum sample diameter for measurements with the standard vacuum unit is 75 mm. A modified unit for measuring samples up to 210 mm diameter is available. The vacuum unit is the standard tool of OptiCentric® MAN instruments but may be purchased as an accessory for OptiCentric® MOT to enable lens cementing.

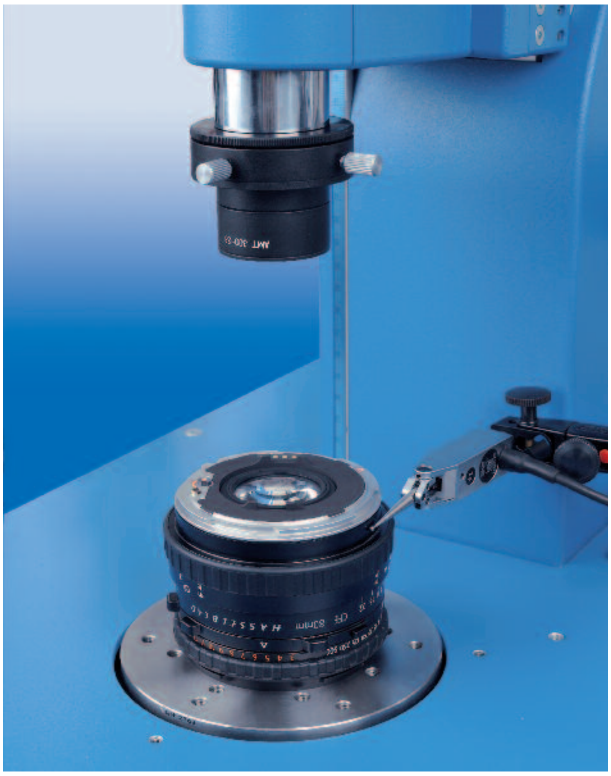
Extension of Measurement Range

Measuring range of the OptiCentric® system is limited by the size of the upper surface radius when measuring in reflection mode or the effective focal length when measuring in transmission mode. TRIOPTICS provides a set of additional head lenses to extend the range of radius and focal length up to ± 2000 mm. On request special lenses can be provided for larger values. Plano surfaces (radius = ∞) can be measured at any time with the bare autocollimator using the parallel optical path by removing the head lenses.

Measuring Sensor and Linear Measuring Gauge

On request different mechanical measuring gauges are supplied with the OptiCentric® instrument. Following gauges are available:

- A gauge for the linear stage of the measurement head to measure its position with ±2 µm accuracy. The length of the linear measuring scale is aligned with the track of the OptiCentric® system. This gauge is required for precision measurement of radius of curvature or thickness.
- A lever gauge (Force 0.02 N, measurement range of 0.6 mm, repeatability 0.1 µm) is used to measure or align sample housings with respect to the axis of rotation.
- A mechanical gauge with absolute accuracy of 0.2 µm and measurement range of 25 mm. It is used for alignment purposes, too.



Measuring the lens barrel with the lever gauge

Alignment Set

In order to align sample holders or directly adjust the sample barrel and housing, a set with two high-precision parallel flats (25 and 50 mm diameter) and two glass balls with diameters of 4-12 mm and 14-28 mm is offered.

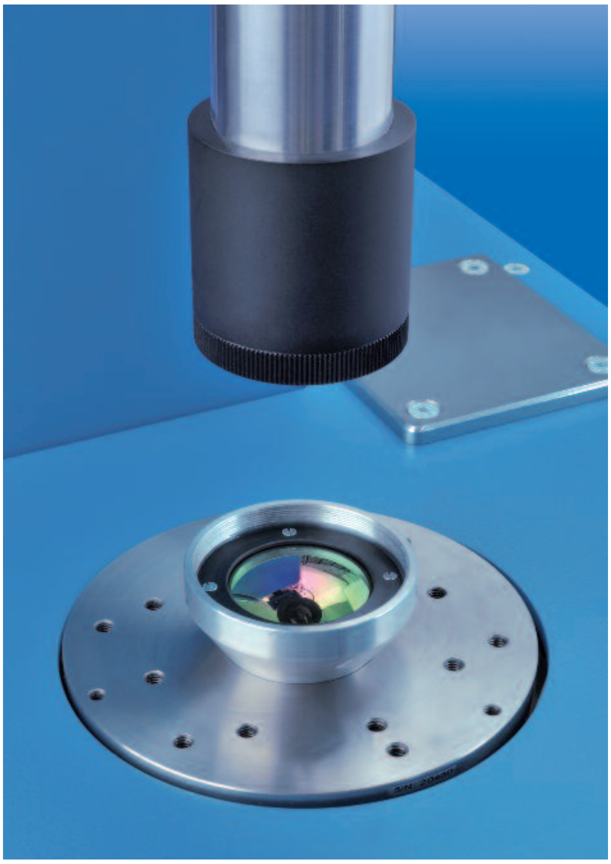
Illumination

Every OptiCentric® system is provided with a suitable light source. This is usually a 150 W halogen cold-light source with a 1 m optical fibre light guide. All TRIOPTICS autocollimators and collimators are fitted with a standard interface for the illumination so that various light sources can be exchanged for one another. The following light sources are available:

- 150 W cold-light source with light guide
- 250 W cold-light source with light guide
- 20 W halogen lamp mounted directly on the autocollimator lighting assembly for increased IR output
- 5 W filament bulb
- 100 and 300 mW high-power light emitting diodes (LED)

Every collimator and autocollimator is also fitted with a spectral filter. Depending on the application a green or white light filter is applied.

For the measurement of IR optics TRIOPTICS provides a measurement head developed for measurement tasks in the IR range.



OptiCentric® measuring IR optics

Revolving Turret

The turret is recommended for the quick and simple change of the head lenses. OptiCentric® offers a manual 4x changer and a motorized 6x changer. On request both changers can be supplied assembled on the measuring head.

Calibration Tool

TRIOPTICS offers calibration wedges for the regular inspection of the measurement accuracy of the OptiCentric® system. The certified wedge angle is traceable back to international standards. The wedge angle is certified to an accuracy of 1 arcsecond.

Application Overview

Standard ■
Option □

Application	OptiCentric® MAN	OptiCentric® SMART	OptiCentric® MOT 100	OptiCentric® MOT 300	OptiCentric® MAX	OptiCentric® Bonding	OptiCentric® Cementing	OptiCentric® Alignment turning
Measurement in reflection mode	■	■	■	■	■	■	■	■
Measurement in transmission mode	■		■	■	■	■	■	■
Use in mass production	□	□	■	■	■	■	■	■
Measurement of single lenses	■	■	■	■	■		■	
Measurement of objective lenses			■	■	■	■	■	
Measurement of wafer optics					■			
Cementing manual / automated	□/–	□/–	□/–	□/–	□/–	□/–	□/■	–/–
Bonding manual / automated	□/–	□/–	□/–	□/–	□/–	□/■	□/–	–/–
Alignment turning								■

OptiCentric® Bonding Station

Overview of Available Configurations

Standard ■
Option □

	OptiCentric® MAN	OptiCentric® SMART	OptiCentric® MOT 100	OptiCentric® MOT 300	OptiCentric® MAX	OptiCentric® Bonding	OptiCentric® Cementing	OptiCentric® Alignment turning
Illumination								
150 W cold-light source	■		■	■	■	■	■	■
250 W cold-light source	□		□	□	□	□	□	□
20 W halogen lamp (NIR)	□		□	□	□	□	□	□
100 or 300 mW LED	□	■	□	□	□	□	□	□
IR light source		□	□	□	□	□		□
Bearings								
Air bearing AB 100 (sample diameter 0,5-225 mm)			□			□	□	
Air bearing AB 300 (sample diameter 0,5-600 mm)			□	□	□			
Air bearing AB 600 (sample diameter 0,5-600 mm, max. 800 kg)					□			
Vacuum unit (sample diameter 1-5 mm)	□	□	□	□	□		□	
Vacuum unit (sample diameter 5-60 mm)	□	□	□	□	□		□	
Vacuum unit (sample diameter 1-120 mm)	□	□	□	□	□		□	
Vacuum unit (sample diameter 120-150 mm)	□	□	□	□	□		□	
Vacuum unit extension (sample diameter up to 210 mm)	□	□	□	□	□		□	
Measuring Head								
Single Head	■	■	■	■	■	■	■	■
Dual Head		□	□	□	□	□	□	□
Range of radii or effective focal length of the sample								
0 to +/- 200 mm and plano surface		■						
0 to +/- 250 mm and plano surface	■		□	□	□	□	□	
0 to +/- 400 mm and plano surface	□							
0 to +/- 450 mm and plano surface			■	■	■	■	■	■
0 to +/- 2000 mm and plano surface	□	□	□	□	□	□	□	□
Automated measurement data evaluation					■			
Measurement data								
Visual reading on eye piece scale	□							
Visual reading on monitor	□							
PC + Software evaluation	■	■	■	■	■	■	■	■
Measurement head linear stage								
Linear Stage, manual positioning	■							
Linear Stage, automatic positioning / PC controlled		■	■	■	■	■	■	■
Linear stage with air bearing, autom. positioning / PC controlled			□	□	■			
OptiCentric® extension								
MultiLens® / AdvancedAnalyser (centering error of assembled optics)		□	□	□	□	□	□	
AspheroCheck® (centering error of aspherical surfaces)			□	□	□		□	□
CylinderCheck® (advanced alignment of assembled optics)		□	□	□	□		□	
SmartAlign®			□	□	□	□	□	□
Central thickness / high accuracy radius measurement			□	□	□			
Plano optics (OptiAngle®)	□	□	□	□	□		□	
OptiSpheric® (EFL, BFL,FFL,MTF, etc.)			□	□	□			
OptiSurf® (lens center thickness, air gap distance)		□	□	□	□	□		

Order Information

OptiCentric® Instruments	Order Numbers
OptiCentric® MAN*	
OptiCentric® MAN - / 250 / Single Head	4-100-02
OptiCentric® MAN - / 400 / Single Head	4-103-02
OptiCentric® MOT*	
OptiCentric® MOT - / 225 / Single Head	4-400-02
OptiCentric® MOT - / 225 / Dual Head	4-405-02
OptiCentric® MOT 100 / 225 /Single Head	4-400-02 + 4-300-49
OptiCentric® MOT 100 / 600 / Single Head	4-401-06 + 4-300-49
OptiCentric® MOT 100 / 225 / Dual Head	4-405-02 + 4-300-49
OptiCentric® MOT 100 / 600 / Dual Head	4-405-06 + 4-300-49
OptiCentric® MOT 300 *	
OptiCentric® MOT 300 / Single Head	4-401-08 + 4-305-49
OptiCentric® MOT 300 / Dual Head	4-405-60 + 4-305-49
OptiCentric® MAX	
OptiCentric® MAX 300	4-143-00
OptiCentric® MAX 600	4-146-00
OptiCentric® SMART	
OptiCentric® SMART / Single Head	4-139-00
OptiCentric® SMART / Dual Head	4-139-00 + 4-141-00
OptiCentric® 3D	4-151-00
OptiCentric® 3D IR	

* OptiCentric® bearing / max sample diameter / head

Extension Moduls	Order Numbers
MultiLens®	4-400-90
AdvancedAnalyzer	4-400-91
AspheroCheck®	4-400-99
CylinderCheck®	4-300-074
OptiSurf®	on request
OptiSpheric®	4-600-380
Measurement of plano optics	4-600-240

Accessories	Order Numbers
Motorized lens rotation device with vacuum Chuck	4-400-90
Extension of measument range	4-400-91
Alignment tool set	4-400-99
Manual revolving turret	4-300-074
Precision, motorized and software controlled revolving turret	4-400-86
Complete device for calibration check	4-600-380

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