TRIOPTICS

TRIOPTICS GMBH · OPTICAL TEST EQUIPMENT

# OptiCentric®

## Inspection, Alignment, Cementing and Assembly of Optics




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## OptiCentric®

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®

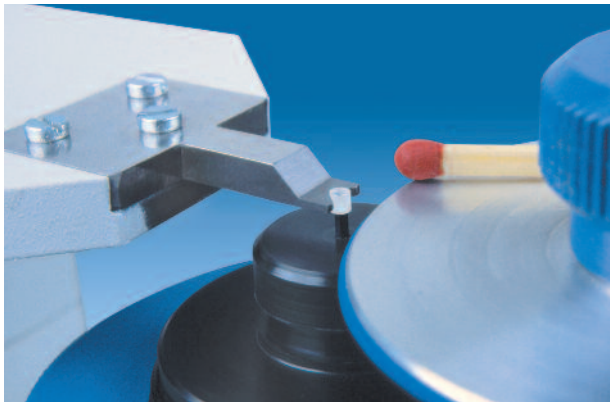
The TRIOPTICS comprehensive line of equipment under the generic name **OptiCentric®** has been specifically designed to cover applications related to any type of optical components and to respond to different accuracy degrees. The OptiCentric®-System also covers all the production steps from the centration 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 tool for miniature lenses

# Measurement of Centering 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 surfaces is used for measurement of centration errors, the measuring procedure is known as "Reflection Mode". Similarly the measuring procedure using the focal point of a lens is known as "Transmission 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. The precise reference axis is decisive for the accuracy of the measurement. The OptiCentric® product line provides different instrument modules or accessories featuring an extreme accurate reference axis for the measurement.

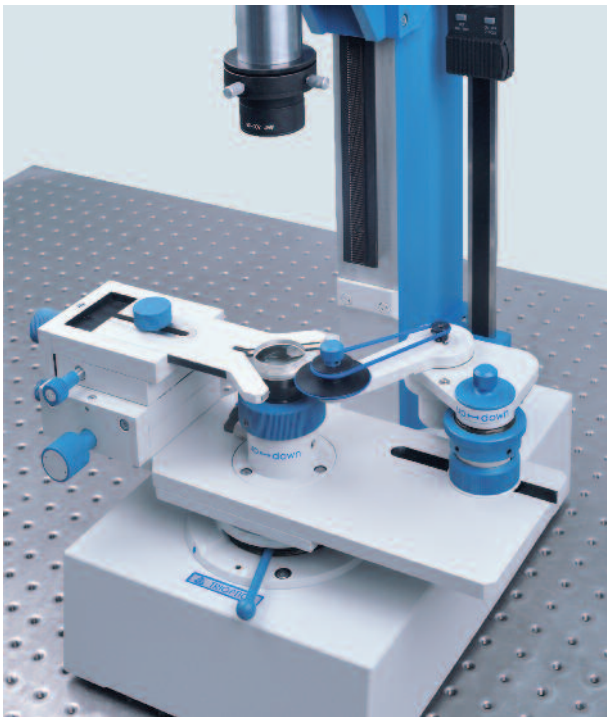
For the measurement, an autocollimator with additional optics is focussed either in the center of curvature of the surface (Reflection Mode) or in the focal plane of the lens (Transmission Mode). For the measurement in transmission a collimator is additionally needed. The parallel beam emerging from the collimator is focussed 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 controlled by the software.

When a centration error is present, the observed image describes a circle while the sample is rotated around a reference or datum axis. When using software programs the rotation of 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 or the diameter of the circle is proportional to the size of the centring errors. The result of the measurement can be given as radius of the run out circle (in $\mu$m) or as tilt of the surface or of the lens axis (in arcsec).



Lens rotation device with Vacuum Chuck

## Comparison between Reflection and Transmission Mode

Transmission and reflection measurements 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 two 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.

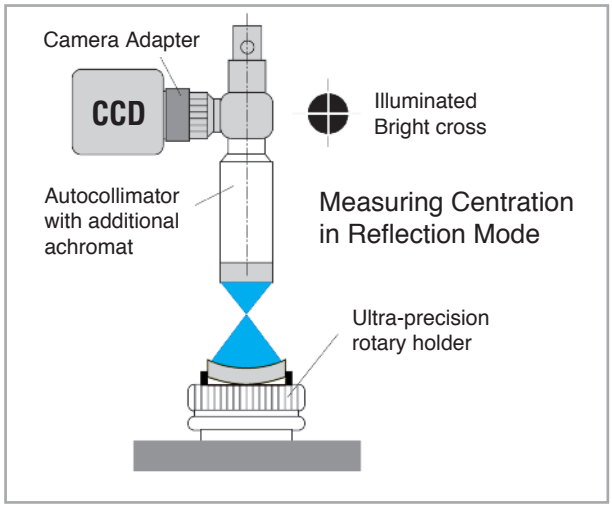



Fig.1: Measurement in Reflection Mode

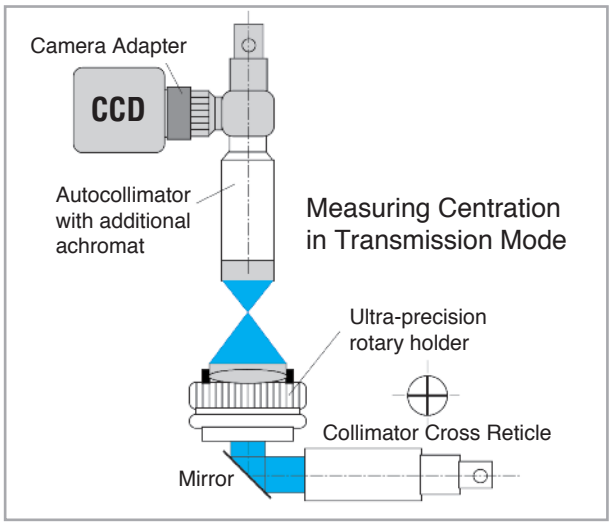



Fig. 2: Measurement in Transmission Mode

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

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

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

## 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.

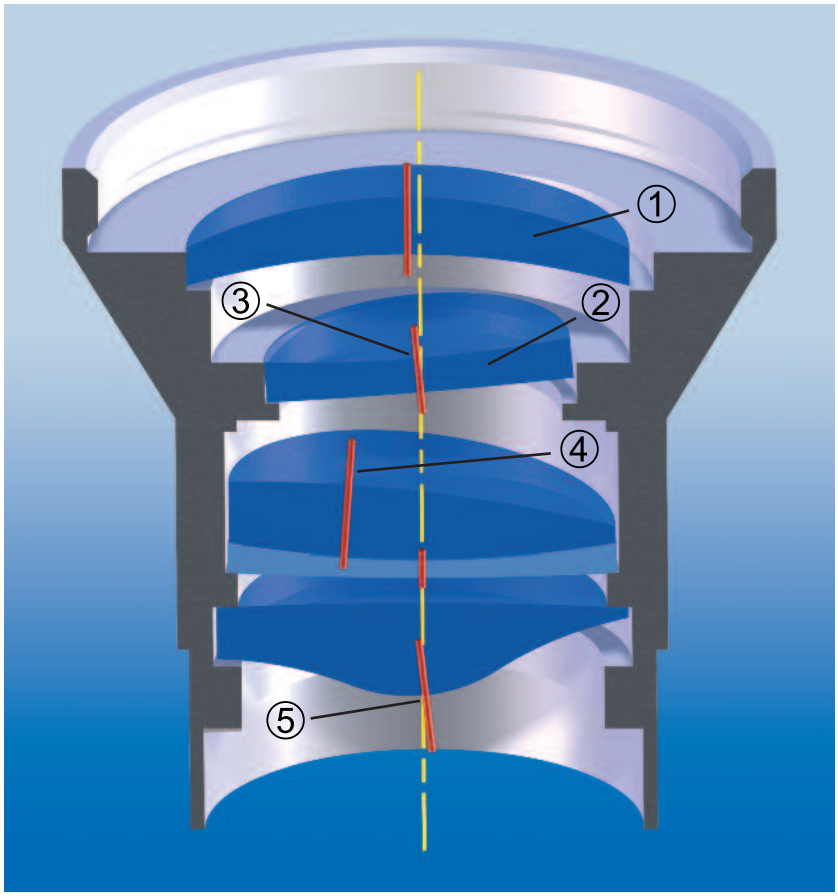



Fig. 3: Typical centering errors

Fig. 3 provides an overview of the typical centering errors.

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

OptiCentric® is able to define precisely all of these errors in accordance with ISO 10110-6. 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 "$C_1$„ to a reference axis. The surface tilt error $\chi$ 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]
$\chi_D$ = angle of the centering error in arc minutes

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

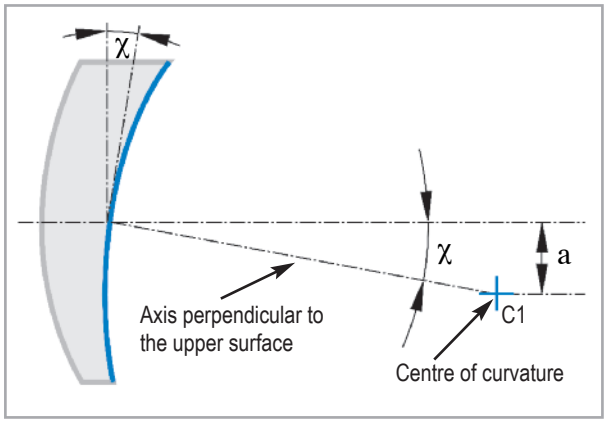



Fig. 4: Schematic diagram of the surface tilt error

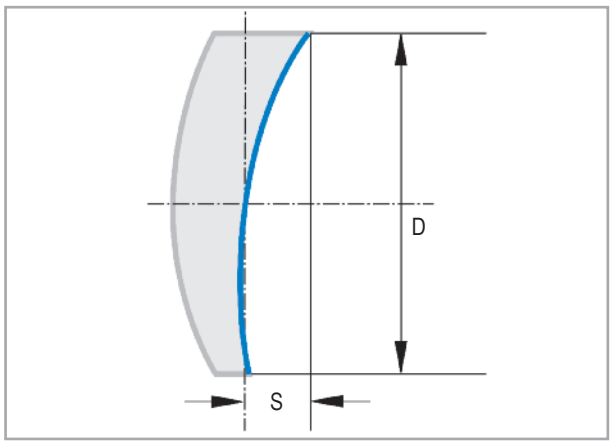



Fig. 5: Surface tilt error given as eccentricity

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

If only a single lens is being defined, then the relationship between the centering error and the processing of the lens edge is important. In this instance, the reference axis used is a line through one of the centers of curvature and the center of the diameter (see figure 6 right side). The surface tilt error of the second surface is given in relation to this tilt axis. This error is also known as the wedge error of a lens.

## Centering Errors of Aspherical Lenses

In contrast to spheres, defined by a center of curvature, aspherical surfaces have an axis of symmetry. Therefore, in order to define a centering error at least one distance information is required in addition to an angle.

The angle is defined by the angle between the aspherical axis and the reference axis. The distance may only be defined for one specific reference point on the reference axis. This could be the center of curvature in the paraxial area of the asphere, for example.

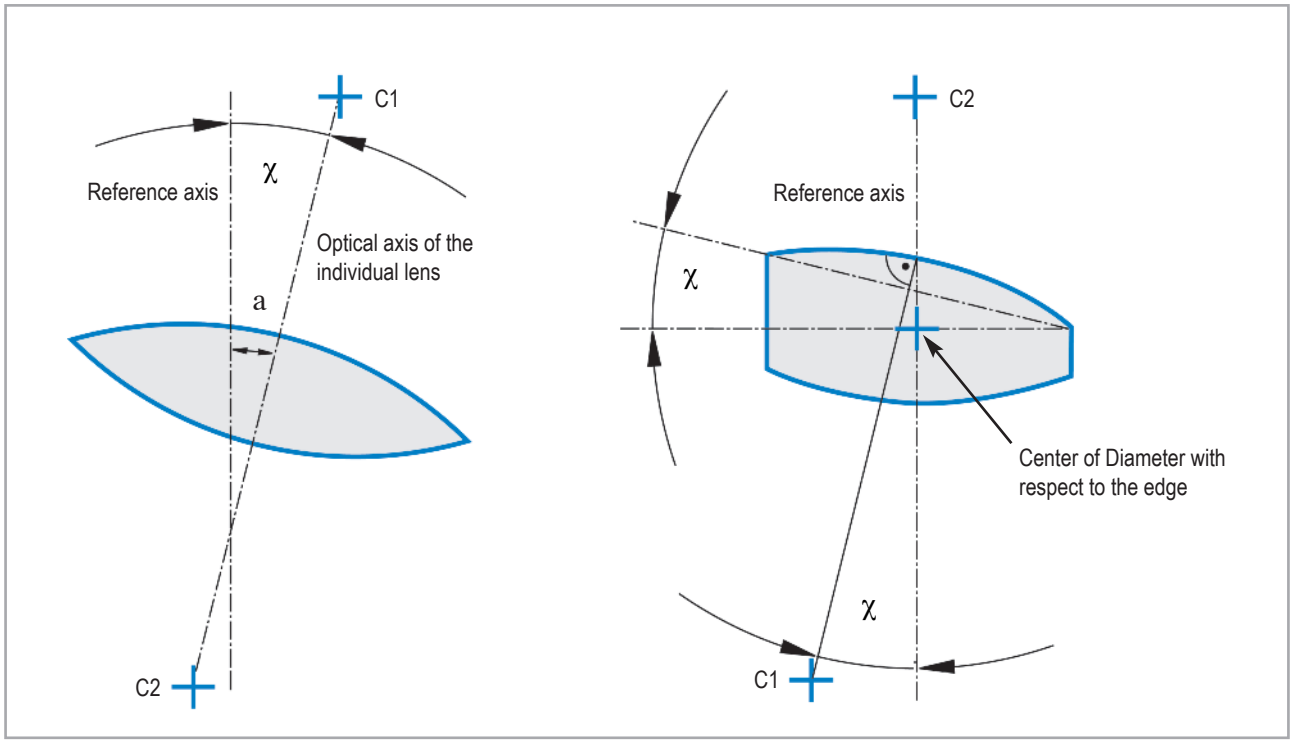



Fig. 6: Schematic diagram of the centering error of a lens

The following parameters are measured by the OptiCentric® program:

1) Shift and tilt of the asphere axis in relation to the reference axis of rotation.
2) 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.
3) When a lens consists of two aspherical surfaces the angle and shift of both aspherical axes are determined.

### Centering Errors of Cylindrical Lenses

A cylindrical surface has an axis of symmetry, called the cylinder axis. There are different centering errors related to the cylinder axis.

1) Angle between the cylinder axis and the edge of the lens
2) Offset of the cylinder axis to the edge of the lens.
3) Angle between the cylinder axis and the plane surface of the lens.

The OptiCentric® system is also able to define the centering error of the cylinder axis in assembled anamorphic objectives.

### 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 calculations 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 co-ordinates of all centers of curvature in the space. The measured data support further analysis of the lens system and provide additionally the following data:

- Calculation of the optical axis of any single lens of the system.
- Assessment of the optical axis of single subsystems or the entire optical system. A „best fit" line is drawn through all the optical surfaces under consideration.

## OptiCentric® METRO

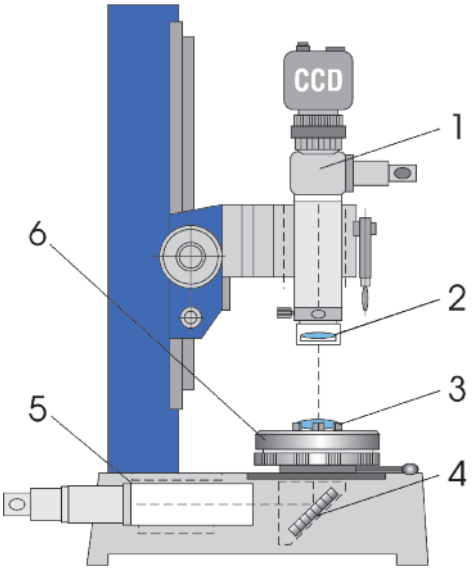
OptiCentric® METRO instruments are designed to measure centering errors and other parameter of lenses and optical systems. All instruments of METRO Series can be used to carry out measurements using the reflection mode and/or transmission mode, an exception being the OptiCentric® SMART which only works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

### 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 alignment of single elements before cementing or mounting in cells.

This is usually an autocollimator equipped with additional head lenses which is focussed in




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

Fig. 7: Principle setup OptiCentric®

the image plane of the sample (transmission method) or in the centre of curvature of the lens surface under test (reflection method).

### 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 centring 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 enough accurate and stable.

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. More-



OptiCentric® MAN with accessories

over, 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
- Stage "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 repeatablity

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

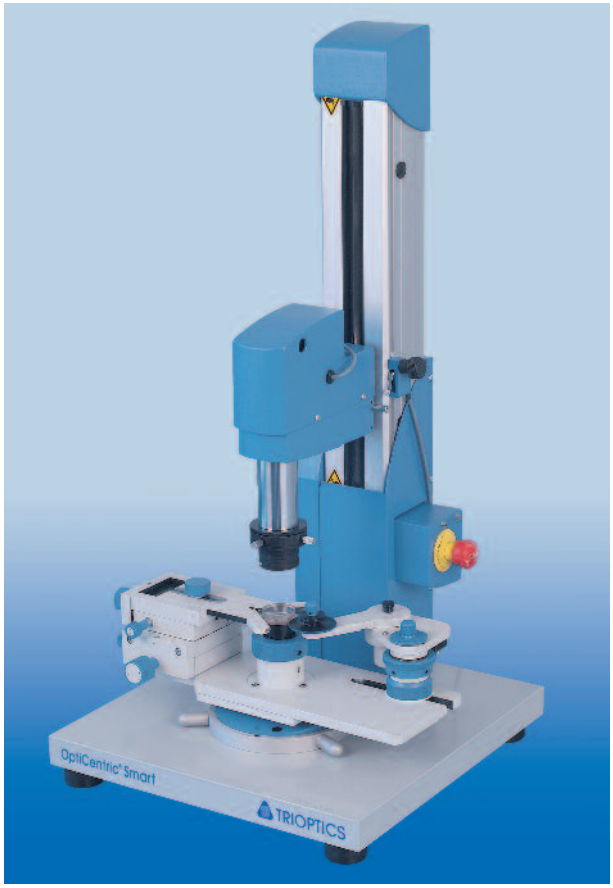
The use of an **automated, PC-controlled optical measuring head** increases dramatically the accuracy and repeatability, provides records of the tolerances achieved and is not dependent on the skills or the level of fatigue of the operator. The CCD-camera is in this case either connected to a frame grabber 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

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

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 is available with both 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 $\mu$m.

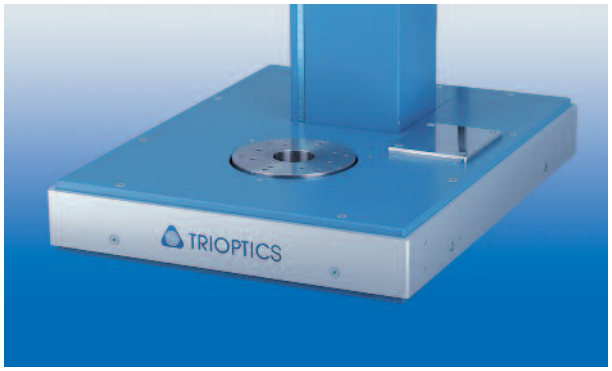
The standard OptiCentric® SMART comes with a single measuring head. As an option it is possible to mount a second measuring head underneath the sample on the base of the instrument. This measuring head enables the simultaneous measurement of the bottom surface of the sample. However, the optional attachment only 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

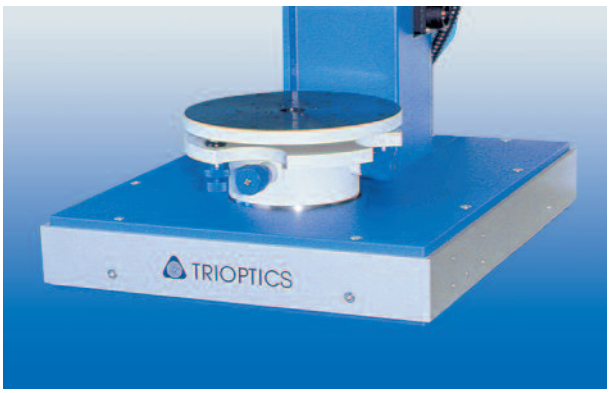
**OptiCentric® MOT 100** is the heart of the OptiCentric® system being used in a wide range of applications, either fulfilling complex measurement tasks or accomplishing important steps in the assembly and production process of optical systems. Recognized as industry's standard for centering error measurement, 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 multi element 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 becomes an efficient and reliable production process.

The measuring head includes a precision electronic autocollimator achieving an accuracy of 0.1 $\mu$m 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



OptiCentric® MOT 100, AB 100 air bearing



OptiCentric® MOT 100 with air bearing AB 100 and TRT200 tilt and translation table




OptiCentric® MOT 100 with air bearing and accessories

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 measurement of centering errors. For alignment needs the air bearing is equipped with a stable tilt and translation stage (see left page).

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 - Single Head



OptiCentric® MOT 100 with revolving turret

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 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 upgraded to measure radius of curvature or can also be upgraded to measure effective focal length, flange focal length and axial MTF.

## 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. The diameter range may be increased by enlarging the distance between the rota-



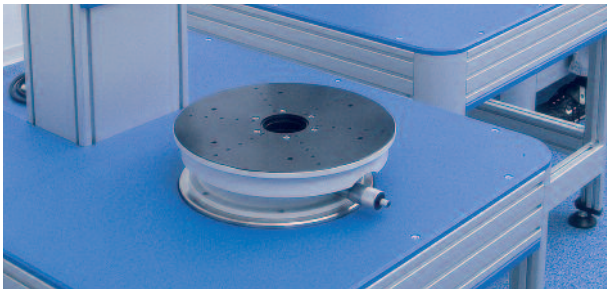
OptiCentric® MOT 300 UltraStable under production

tion axis and column with the linear stage.

## OptiCentric® MOT 300 UltraStable

The **OptiCentric® MOT 300 UltraStable** 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 OptiCentric® MOT 300 UltraStable has been further developed to cover special applications in the aviation and space industry, military and astronomy. The OptiCentric® MOT 300 Ultra Stable 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 accomodate larger



Air bearing OptiCentric® MOT 300 UltraStable with tilt and TRT 400 translation stage

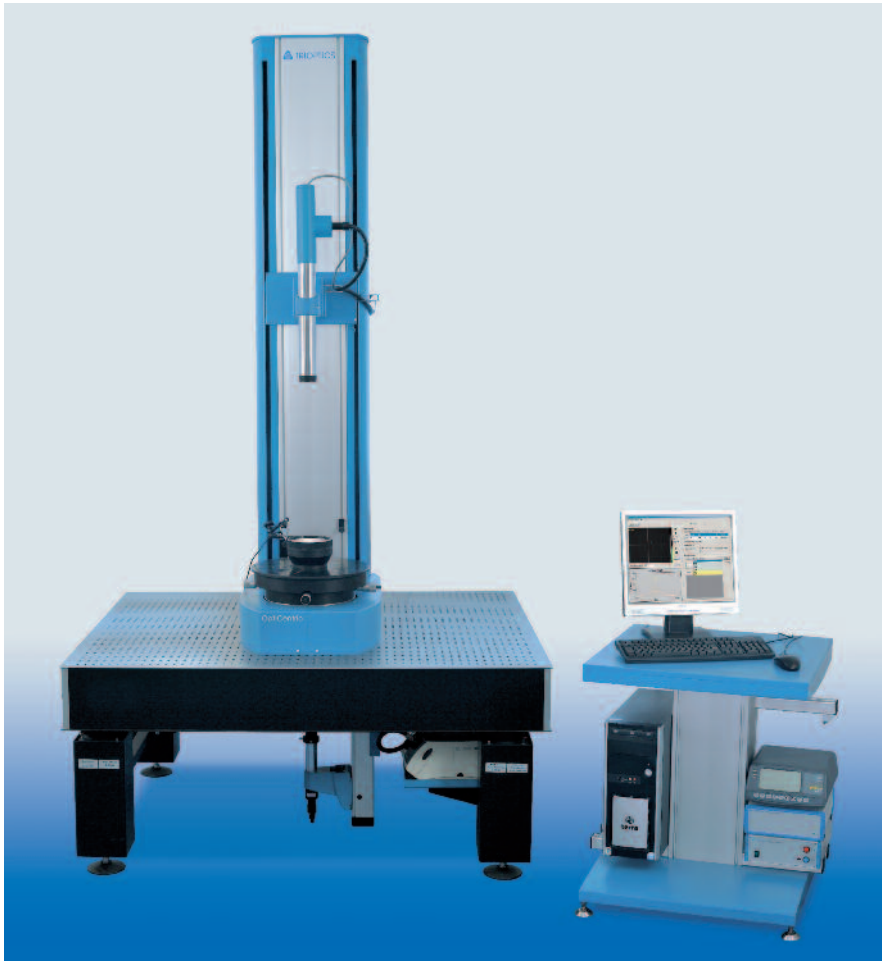
samples.
When the pre-alignment of the lens chuck or lens cell is accurately made, the ultra-precision air bearing table gives the highest possible accuracy for assembly, cementing or bonding of lenses in barrels. Using the ultra-stable and finely adjustable tilt and translation tables, not only tiny 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 also 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 UltraStable 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

## OptiCentric® MAX

The **OptiCentric® MAX** is the further development of OptiCentric® UltraStable. It was developed for the measurement and production of extreme heavy and large optics. OptiCentric® MAX 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 limited to 250 mm. With a maximum axial load of up to 500 kg and a free sample height of 1600 mm OptiCentric® MAX can measure almost every large scale optics.
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 me-

chanical 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 to 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.




Customer-specific construction for the measurement of laser rod end surfaces

As all other TRIOPTICS instruments, OptiCentric® MAX can be individually adapted to the customer requirements, e.g. increasing the travel of the measuring head stage, selecting a larger air bearing or adding equipment for cementing and bonding of lenses in mounts and thus creating a work station for a complete automated production process.

## OptiCentric® Custom

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 mod-

ule 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.

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:




OptiCentric® instrument with linear air bearing stage

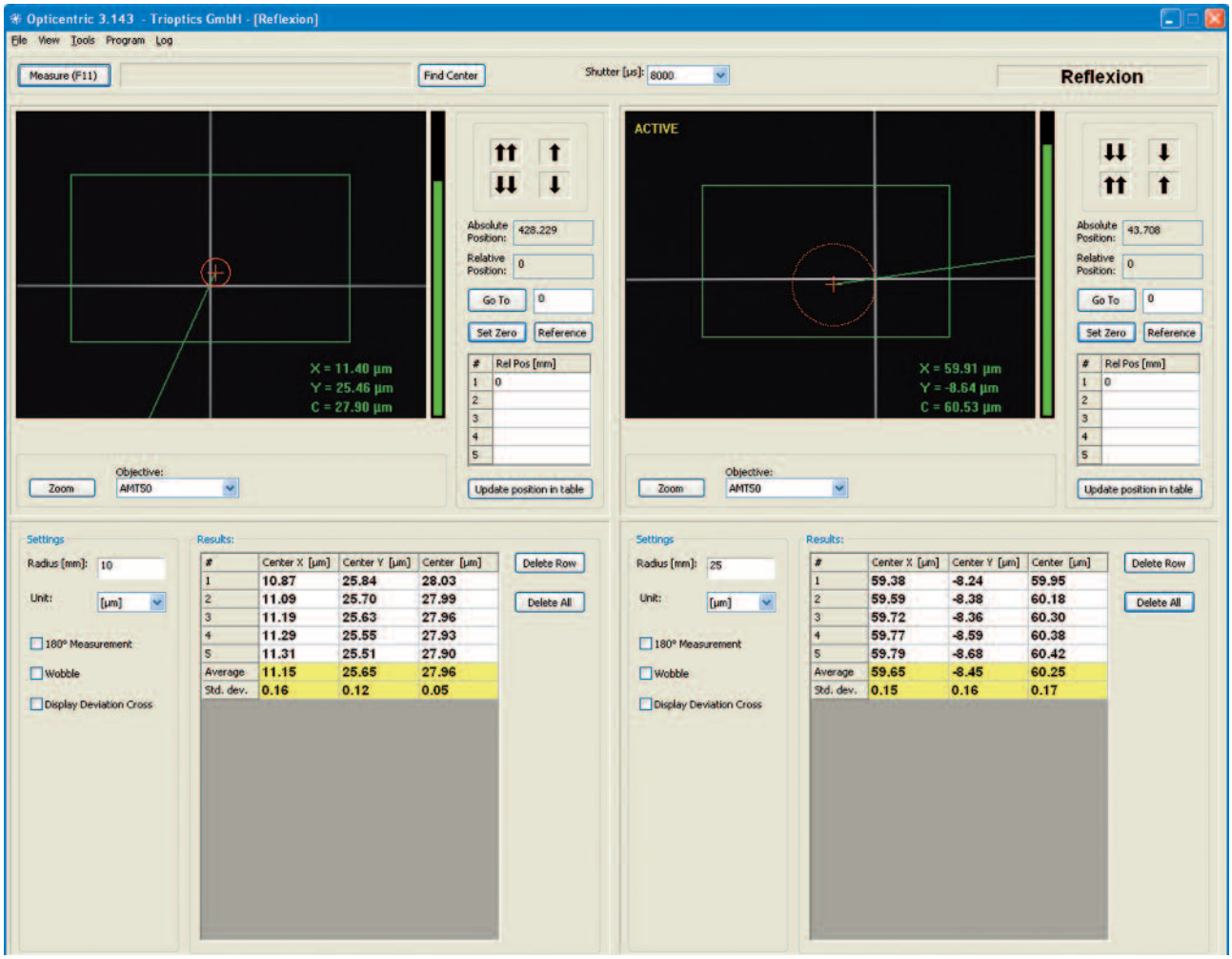
The autocollimator is initially focused on the upper surface of the sample and in a second stage into the center of curvature of the same surface. Due to the accurate autofocus feature, both positions can be detected with high sensitivity. The distance between the two positions, corresponding to the radius of curvature of the surface, is measured using precision linear encoders mounted on the instrument stand.

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 multi-lens systems or complex alignment tasks.

## OptiCentric® Software

The advanced software is designed to work with Windows XP® operating systems. The software fulfils 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.




Simultaneous measurement in reflection of both lens surfaces

## Additional features of the software

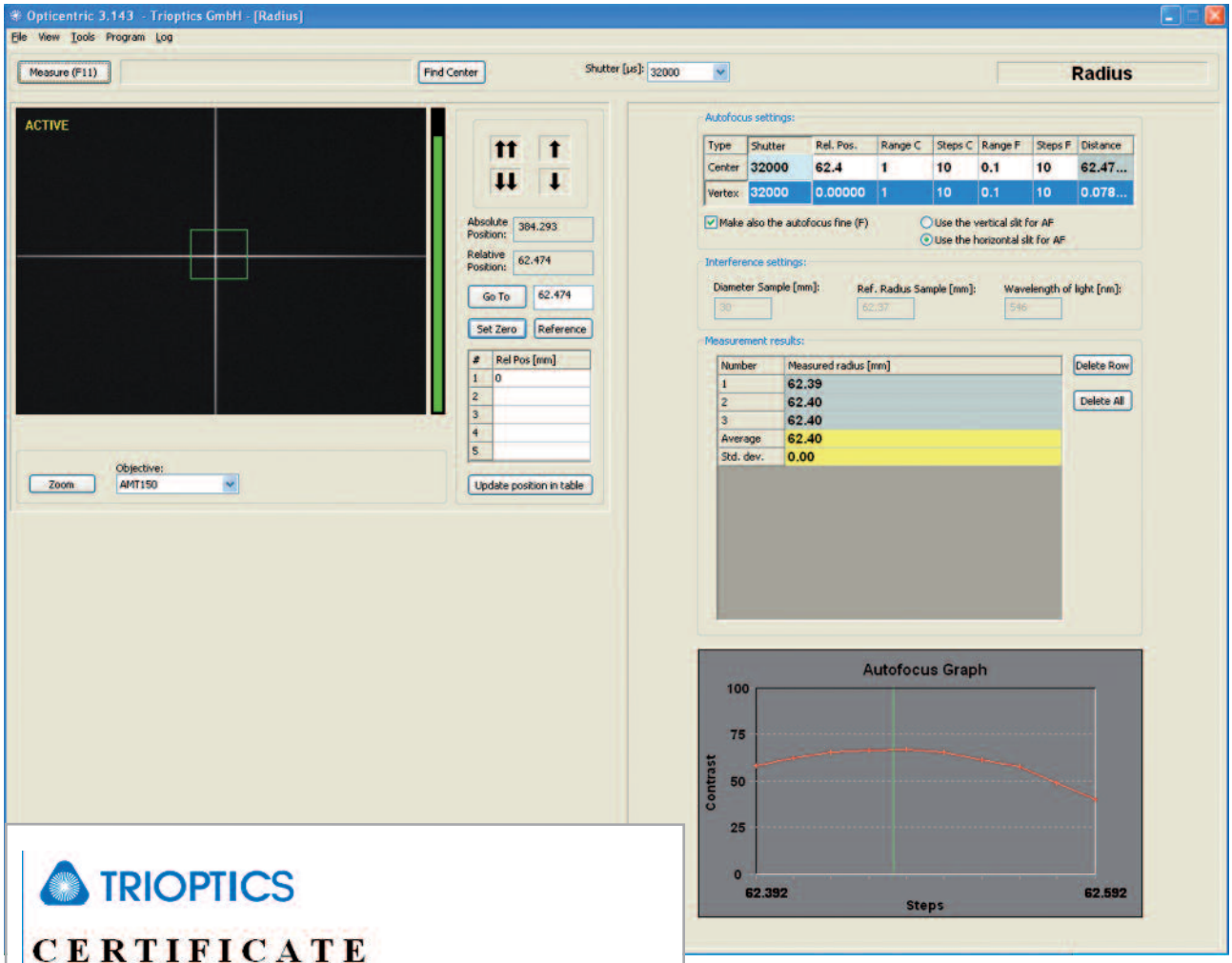
- Real time monitor display of the camera image from one or two measuring heads
- Real time, continuous display of the measurement values
- Vector display of the size and direction of the centering error
- HTML certificate output
- Computer generated tolerance circles or angle graduations for the quick 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®

This complex software module is used either for the 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.




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

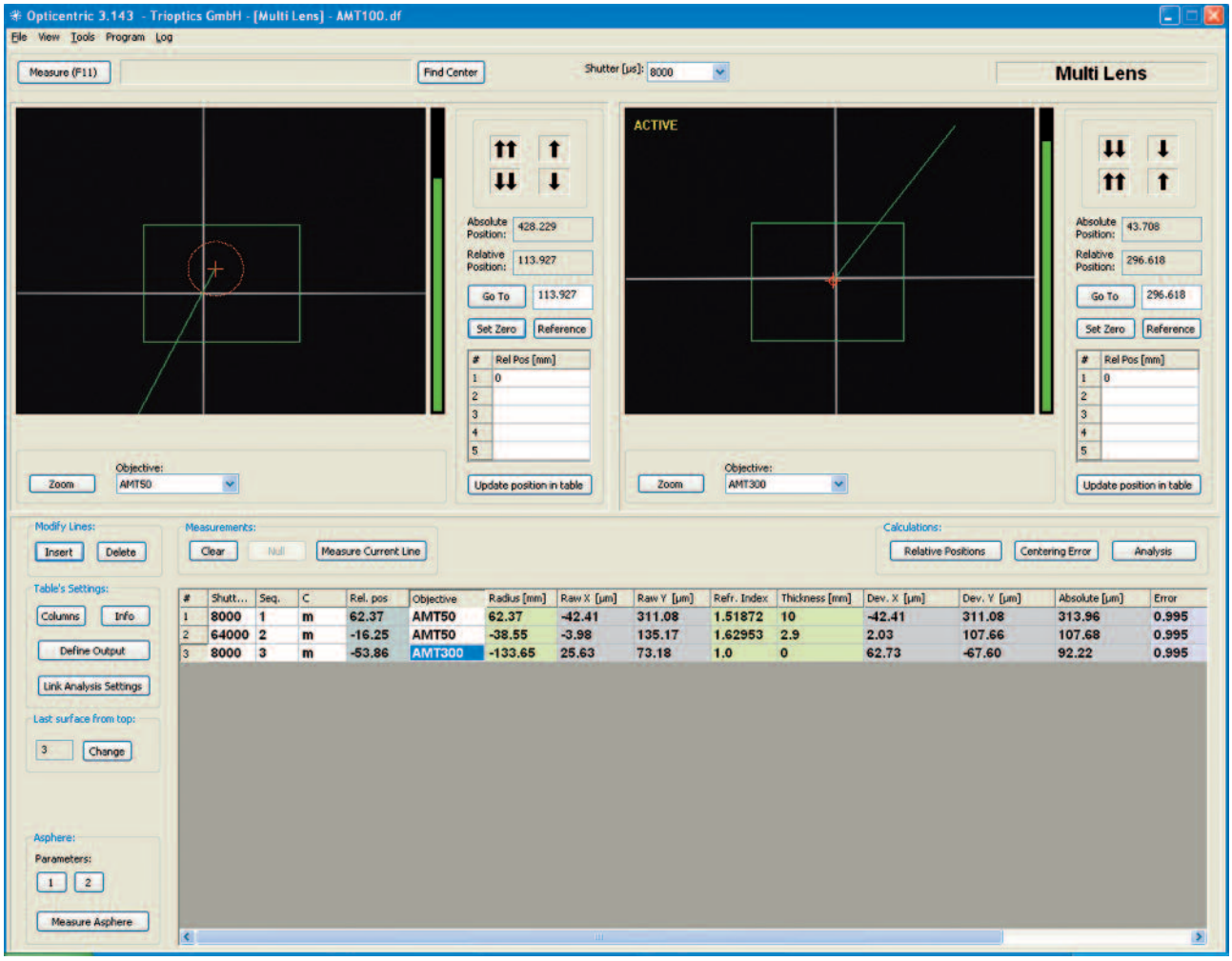
| Number | Center X [µm] | Center Y [µm] | Center [µm] |
|---|---|---|---|
| 1 | 59.38 | -8.24 | 59.95 |
| 2 | 59.59 | -8.38 | 60.18 |
| 3 | 59.72 | -8.36 | 60.30 |
| 4 | 59.77 | -8.59 | 60.38 |
| 5 | 59.79 | -8.68 | 60.42 |
| Average | 59.65 | -8.45 | 60.25 |
| Std. dev. | 0.15 | 0.16 | 0.17 |

Radius : 25.000 mm
Objective : AMT50

Measurement of radii of curvature

The MultiLens® software delivers in a constructive 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 from the CentricAna-




Dual live Image for MultiLens® checking

lyzer submodule. 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.

## 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. 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. Of course, if it is run on the same PC, the measurement data is transferred automatically between the applications.
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:

- 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.
- 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.

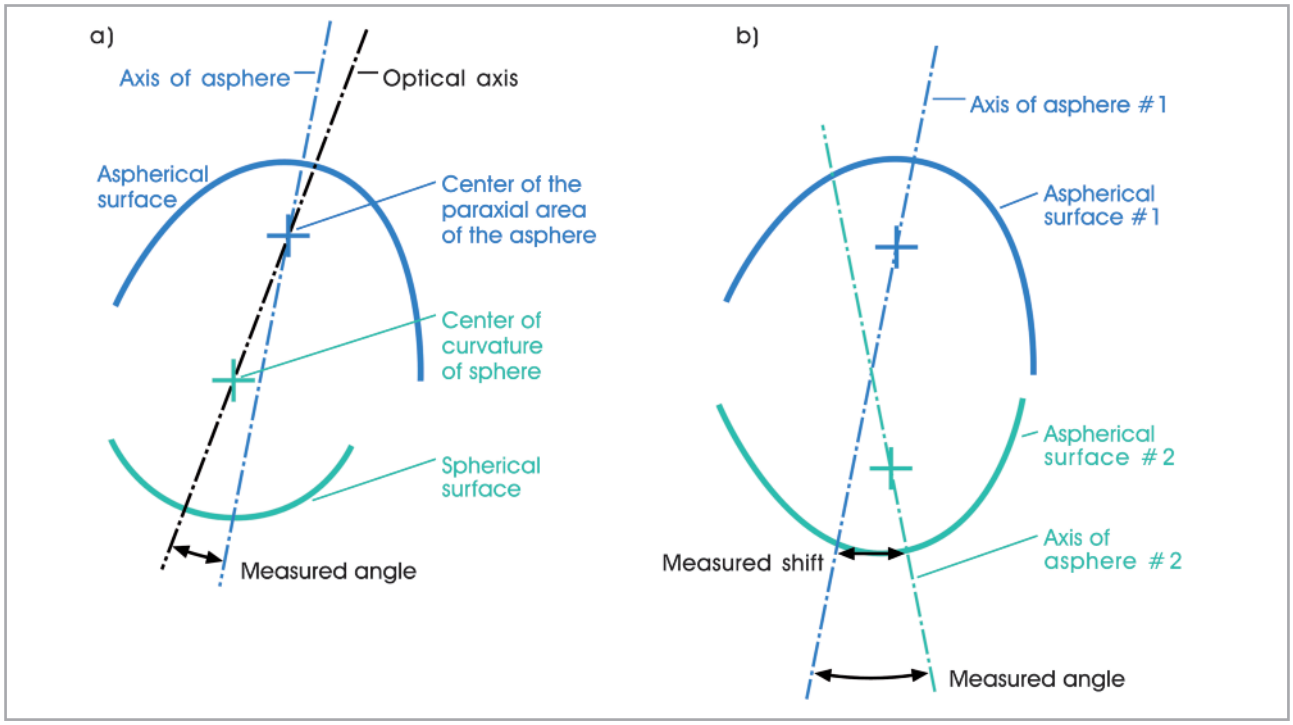



Fig. 8a: Lens with aspherical and spherical surface

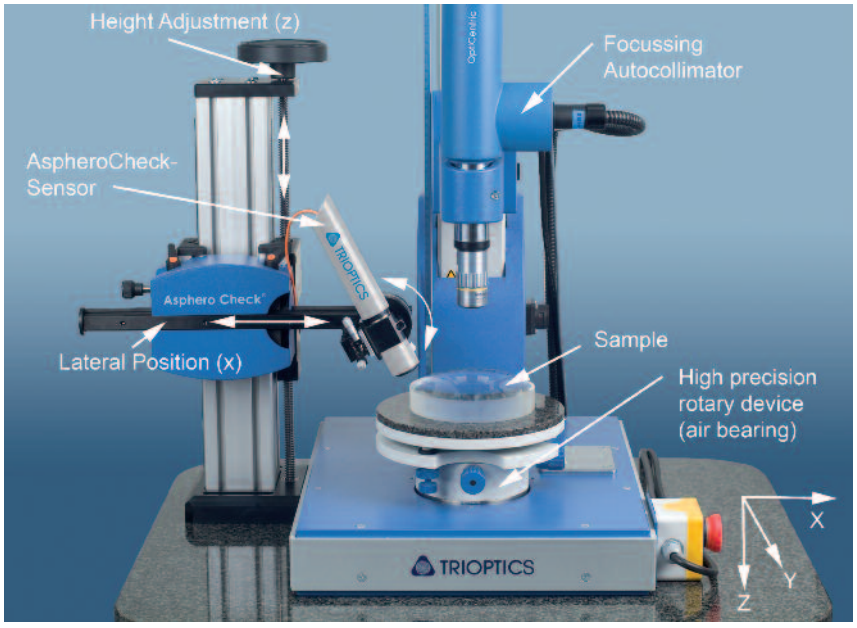
Fig. 8b: Lens with two aspherical surface

- Reference all other surfaces and optical elements relatively to any user defined optical axis
- Reference relatively to the mechanical axis

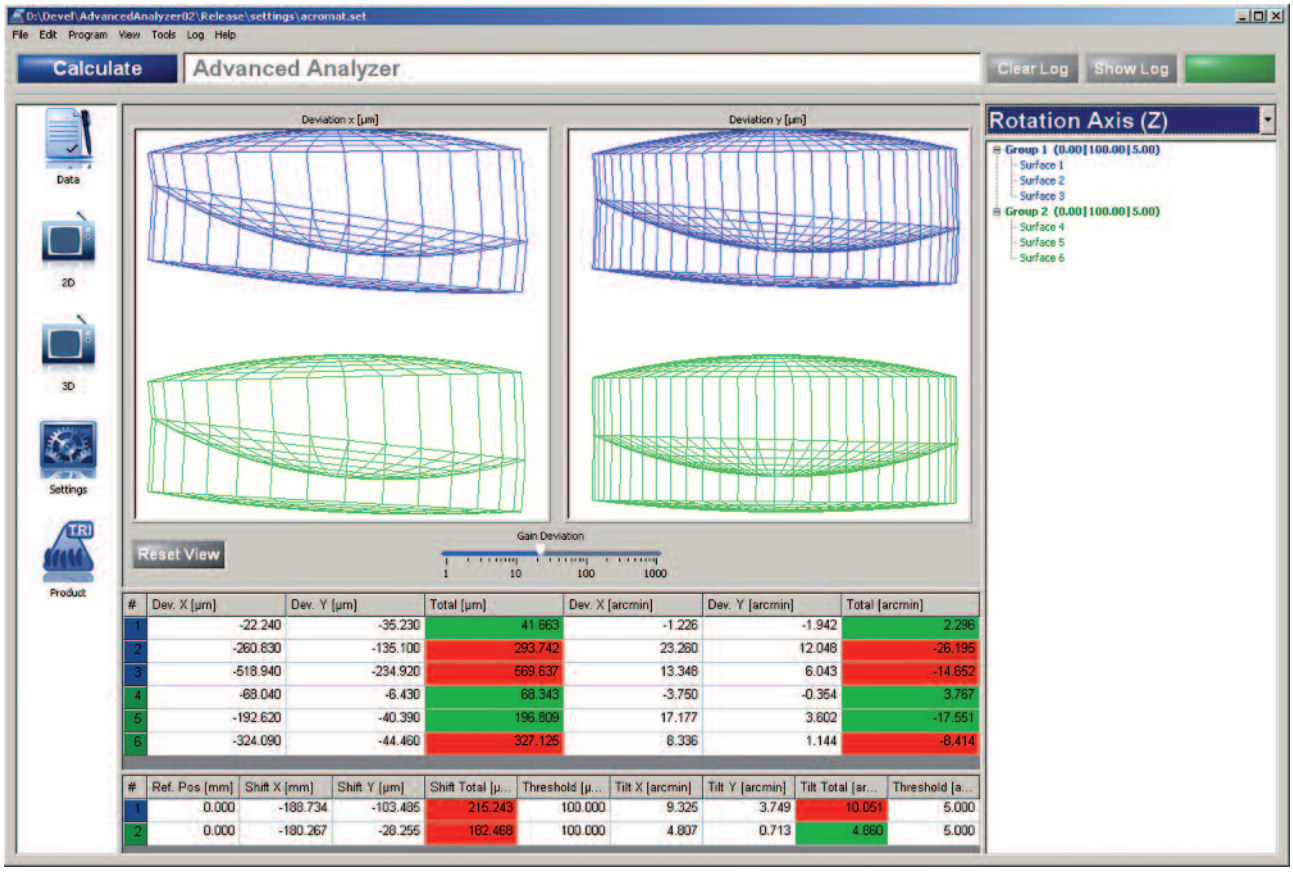
## AspheroCheck®

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.

The AspheroCheck® module consists of a high-resolution 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.




OptiCentric® AspheroCheck®




Software Advanced Analyzer

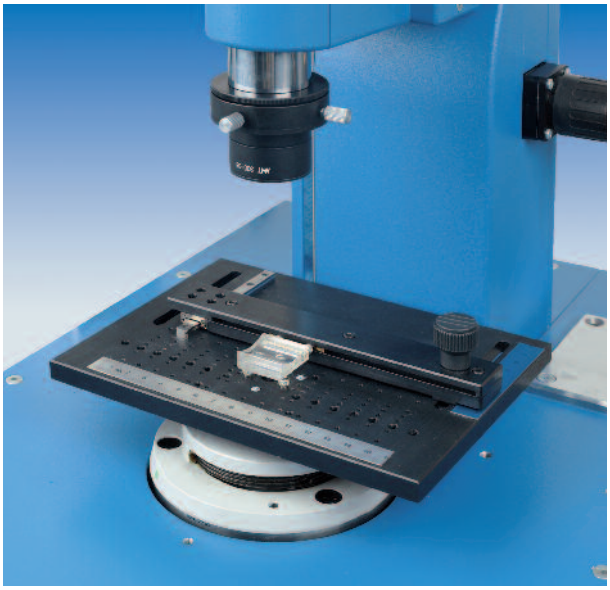
During the measurement, the AspheroCheck® sensor is moved close to the outer edge of the lens in order to capture the eccentricity of the surface during rotation. At the same time, the autocollimator determines the centering error of the surface in the paraxial area. Both values are then combined to determine the position and the tilt of the aspherical axis.

The following parameters of aspherical lenses can be measured:

1) Shift and tilt of the asphere axis in relation to the reference axis of rotation.
2) 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.
3) When a lens consists of two aspherical surfaces the angle and shift of both aspherical axes are determined.

## CylinderCheck®

CylinderCheck® is a software and hardware module for the precise measurement of cen-



Cylinder lenses checked by OptiCentric®

tering errors of cylindrical surfaces. It requires a specific hardware to align the sample and perform the measurement procedures. Depending on the application, CylinderCheck® can capture various parameters of the cylindrical surface. Typical cylindrical lenses have one cylindrical surface and one plano surface.

For these samples, typically the orientation of the cylindrical axis in relation to the lens edge is measured. Additionally, it is possible to measure the angle between the cylindrical axis and the opposite plano surface. A dedicated sample holder (see picture) is required for both measurement types. CylinderCheck® also gives the azimuth angle of the cylinder axis relatively to a given edge. In addition, anamorphic lenses can be measured with this tool.

## Center Thickness

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. Same as in the MultiLens® measurement, this procedure requires the optical design data of the sample.

OptiCentric® offers two methods for this measurement. The first one uses the 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 one or two distances but can be noticeably problematic with three or more.

TRIOPTICS therefore offers an alternative method using an additional distance sensor, specifically developed for measuring distances inside optical systems. It is based on white-light interferometry and is able to measure all center thicknesses in an objective lens with an accuracy of about 1 µm.
A selection of different center thickness probes is available for the integration into the instrument. The standard white-light interferometer captures lens distances within a range of 0 to 200 mm with an accuracy of 1 µm. The high-end instrument measures lens distances with an accuracy of 0.15 µm.

## 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 and filters
- 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 OptiAngle® brochure.

# Assembly of Optics

## Automated Cementing of Lenses

For many lens manufacturers the cementing of two or three optical elements to a doublet or triplet is still a laborious process accomplished manually and prone to operator errors. The classical technology requires an accurate rotation device - whose axis serves as a reference axis - and a sample holder which must be either very accurate (and expensive) or precisely aligned to the reference axis.

The operator needs to accurately align the lens holder until the axis of the bottom lens coincides with the rotation reference axis. Once the bottom lens is aligned and the cement layer dispensed on the joint surface, the operator adjusts -mostly manually- the upper lens until the axis of the upper lens surface coincides with the reference axis. It is obvious that the accurate alignment of the bottom lens in a first step and the alignment of the upper surface in a second step is a time consuming and rather unstable process depending largely on the operator skills. Moreover, both alignments of the bottom and upper lens are carried out relatively to a reference axis and not directly to each other. Consequently, inherent inaccuracies will always go along with this technology.

The new cementing technology developed by TRIOPTICS is controlled by the software module SmartAlign®. The basic idea of this concept is to accurately measure and assess the positions of the three centers of curvature of both lenses. The measurement is done relatively to an accurate reference rotation axis in just a few seconds with submicron accuracy. In a next step the upper lens is aligned in such a way that the center of curvature of the upper surface coincides with the optical axis of the bottom lens without the need of any mechanical pre-alignment (see Fig. 8).

In the automated process, the measurement data set containing the position of the three centers of curvatures is transferred to an automatic alignment device equipped with appropriate lens manipulators. In the next few seconds the upper lens is aligned to the bottom lens with an accuracy in a range of 1 µm. The complete process cycle including measurement and alignment lasts less than 10 seconds. If required, an UV-curing device can be integrated into the automated system.

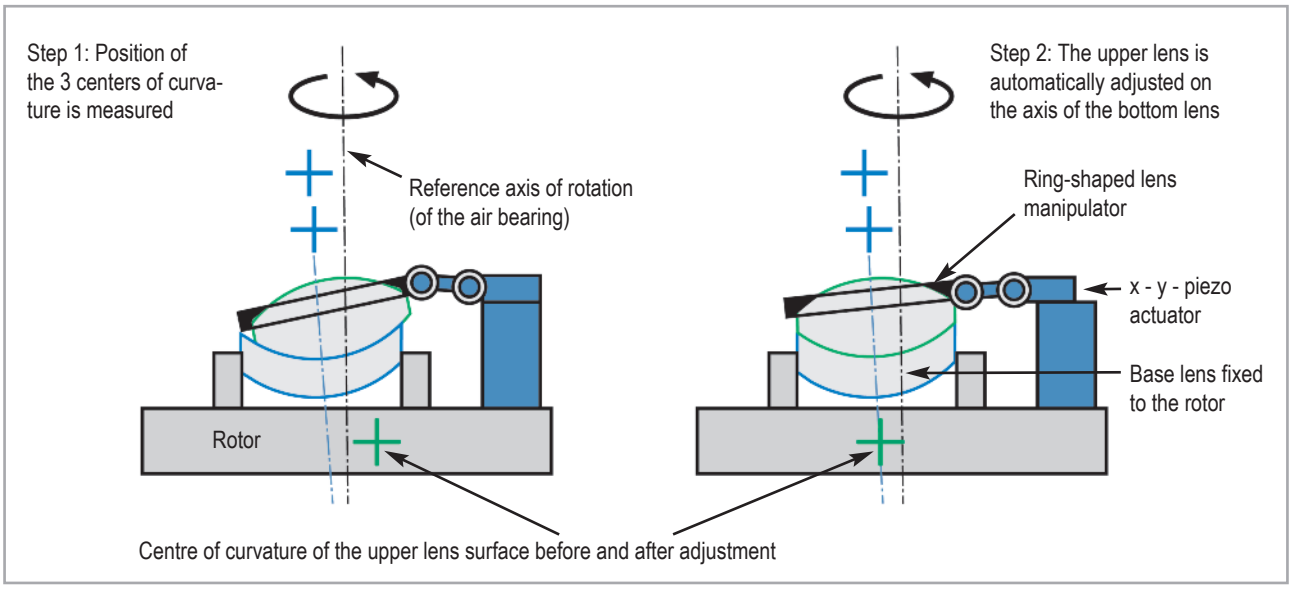



Fig. 8: The SmartAlign® technology is used for the automated adjustment of achromatic lenses in the cementing process

The SmartAlign® technology is supplied as a turnkey system under the product name OptiCentric® Cementing Station. Certainly, upgrades of existing OptiCentric® MOT instruments equipped with rotary air bearing are available.

In conclusion, the SmartAlign® technology provides a software and technology concept for cementing of lenses with highest accuracy and repeatability and without the need of any mechanical pre-alignment. Further benefits result in the very short cycle time and the stability of the cementing process.

## Automated Bonding of Lenses into a Mount

Bonding of lenses into a cell became the technology of choice for applications requiring very precise lens alignment and where severe vibration or temperature extremes are encountered such as military systems and scientific applications.
When aligning a lens element in a cell it is necessary to adjust the optical axis of the lens to coincide with the datum axis of the lens cell. The best alignment performance is provided by the optical inspection in reflection mode. An accurate reference rotary axis e.g. provided by an air bearing is also required.

The datum axis of the cell is either measured with an accurate mechanical gauge or a non-contact optical sensor. An alternative is the use of precise hydrostatic cell holders ensuring repeatable clamping of the lens cell. Certainly the mechanical axis of the hydrostatic holder must be initially aligned until the datum axis of the holder runs true to the reference axis of the air bearing.

Finally the bonding cement is applied and allowed to set or is cured using UV-light sources.

The bonding of lenses into a cell is a laborious process requiring experience and remarkable operator skills.

For this complex part of the optics assembly process TRIOPTICS developed an automated work station known as OptiCentric® Bonding Station. The features of this work station can greatly simplify the optical assembly, reduce the risk of alignment and centering errors and increase significantly the efficiency and stability of the process.

The heart of the system is a complex and stable software integrating and automating the process of inspection, alignment, cement dispensing and curing.
A schematic representation of the basic process is presented in Fig. 9. The work piece, a cell with the lens element set inside, is clamped using either an accurate hydrostatic holder or a more simple mechanical chuck.

When using accurate (hydrostatic) holders the accuracy of the alignment of the cell to the reference axis depends on the accuracy of the holder itself. The disadvantage of this method is that the precision holder can be employed for one cell diameter. A cell holder accurate to 1-3 $\mu$m is expensive enough, the equipment for a large range of diameters becomes really unaffordable.

The SmartAlign® technology integrated in the software of the work station allows the use of inexpensive mechanical chucks. The datum axis of the cell is determined by measuring the cell with a precise non-contact optical sensor or a mechanical gauge. The datum axis of the cell is compared with the system overall reference axis (the axis of the rotary air bearing). The measured centering errors of the lens element can now be recalculated taking the datum axis of the cell as reference. The new data set is fed to an automated alignment device performing the accurate alignment of the lens elements. The complete process is shown in Fig. 9:

A) The work piece is rotated around the reference axis of the air bearing. A set of measurement data is taken. The position of the

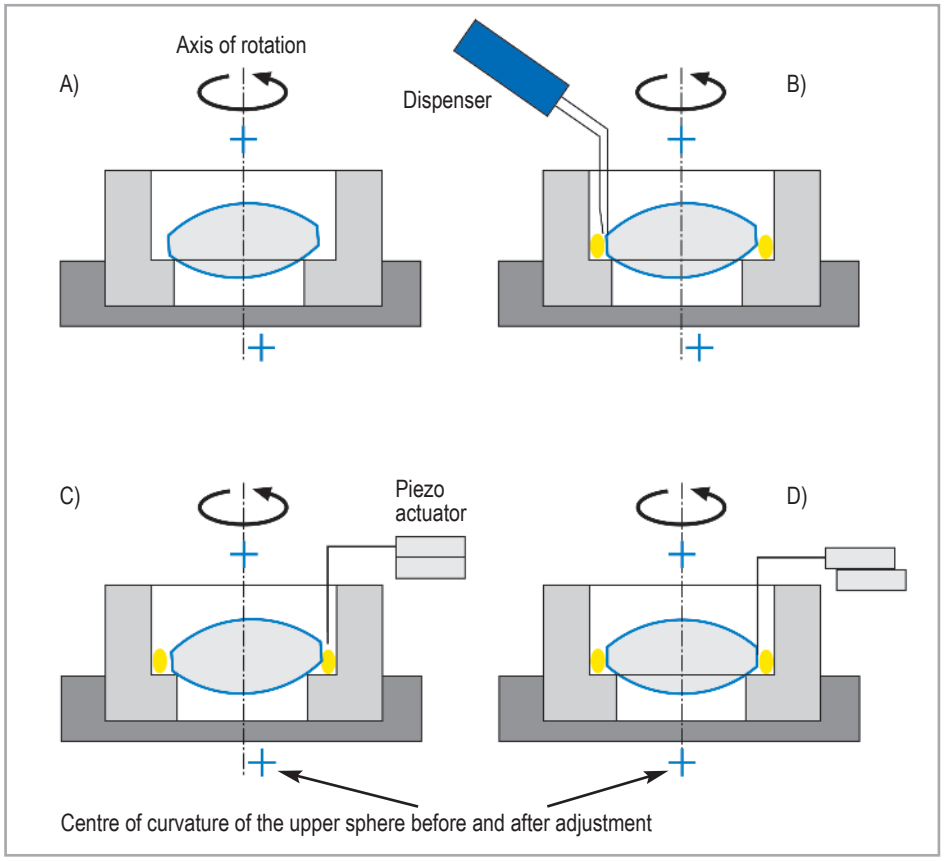



Fig. 9: Automated bonding of lenses into a mount

center of curvature of the both surfaces is assessed.

B) The dispenser is precisely positioned by means of a stepper motor stage in the space between the cell and lens element. While the sample is rotated, the dispenser needle produces a precise joint around the lens. The dispensing time is coordinated with the lens rotation.

C) and D) The data set obtained during the measurement is transferred to a piezoelectric alignment device. Using an appropriate manipulator, the device aligns the lens element to the reference axis or the datum axis of the cell.

The process is completed by the automated curing of the cement using a UV-light source integrated into the work station.

## Lathe Centering

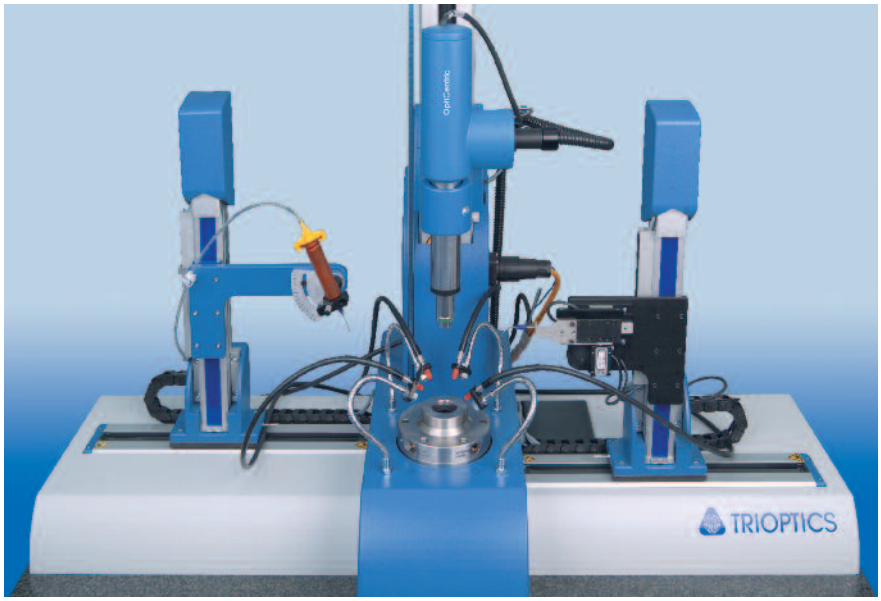
A common method of producing a precisely centered lens assembly or objective lens is based on the production of precise sub-assemblies, which are later combined into a barrel of close mechanical tolerance.

The advantage of this procedure is that the mechanical manufacturing and maintaining of the tolerances is better controlled than it is for the optical counterpart. The sub-assemblies are manufactured by lathe centering, where the optic is mounted more or less carelessly into an oversized lens cell. The cell is then adjusted in a special alignment chuck so that the optical axis coincides with the rotary axis of the lathe. Afterwards the cell is machined to the final size including the reference surfaces well aligned to the optical axis. This method is quite expensive, however it provides the highest quality and is usually applied for precision optics.

The first step of this process is to bond each individual optical element into an oversized lens cell with stress-free cement. In a second step the assembly is mounted on the chuck of the lathe and aligned with respect to the rotation axis of the turning machine.For this process two autocollimation telescopes with head lenses focused to the centers of curvature of both lens surfaces are used. As a compromise, a single autocollimator may be used that measures both surfaces sequentially in MultiLens® mode. In the third step, after

lens alignment, the edge of the cell and the flange surface are machined to their final dimensions of close tolerance. The lens cells produced in this way can now be inserted into a barrel with exact internal fit to manufacture an objective lens.

## OptiCentric® PRO




OptiCentric® Bonding Station

The **OptiCentric® PRO** line for production offers a range of fully automated cementing, bonding and lathe centering 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 cementing cycle including UV curing and manual sample handling is performed within less than 10 seconds.



OptiCentric® Cementing Station with piezo electric fine positioning stage



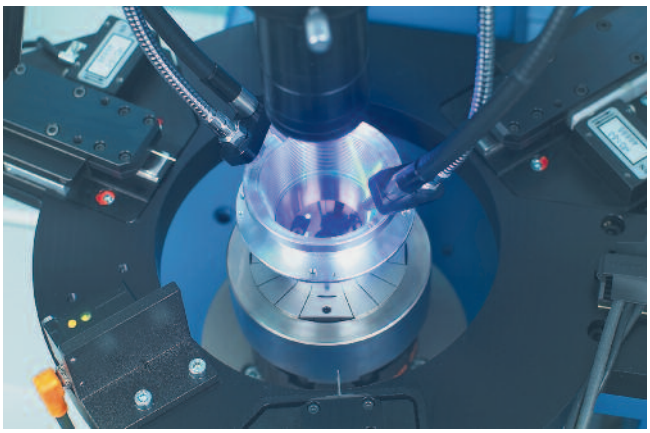

OptiCentric® Cementing Station

## 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.

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 a fine positioning of the sample lens with sub-micron 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 ro-



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




The OptiCentric® Bonding Station in operation

tation 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 scripting 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® Centering Lathe Station

The TRIOPTICS centering lathe station is based on a highly precise vertical CNC lathe and an adjustment chuck for the precise and automatic sample alignment. The alignment is done by a high-speed electromagnetic impulse drive and high end centering error recognition based on the TRIOPTICS OptiCentric® software module. The vertical lathe is designed with a compact and stiff natural granite base, high precision linear stages and a hydrostatic spindle. The automatic alignment chuck is adjusted by the impulse drives during rotation until the coincidence between the optical axis and the spindle axis is reached. The centering error of the lens is measured by an electronic autocollimator, and the measurement result is set in relation to the rotation phase of the spindle. Stroke impulses are applied at the proper rotation phase until the centering error reaches a minimum. After the lens is centered, the lens cell is CNC machined to its final size.

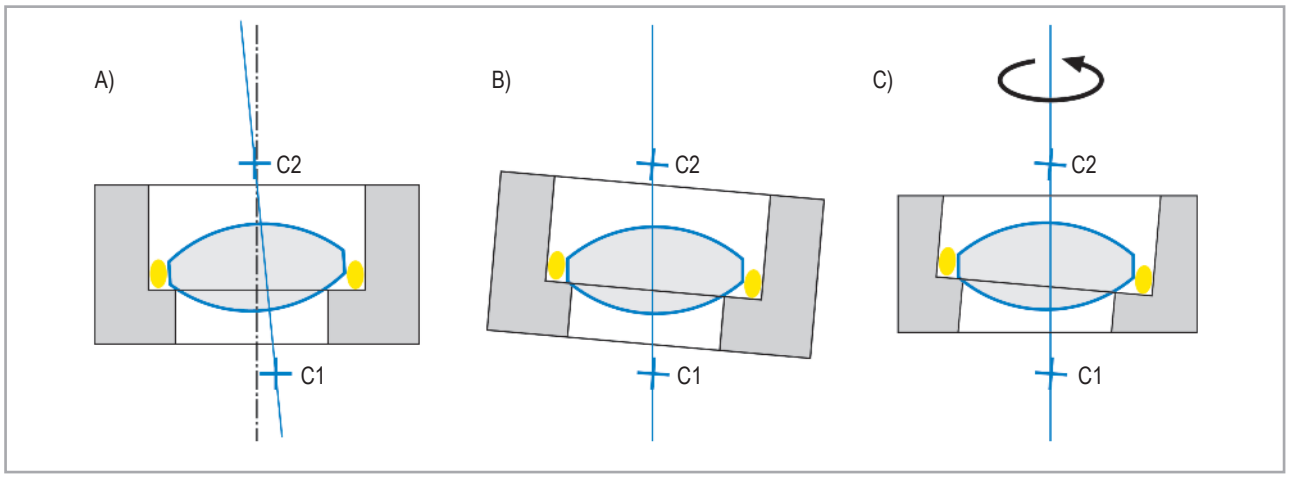



Fig. 10: Lathe Centering of lens cells

The specification of the centering lathe is:

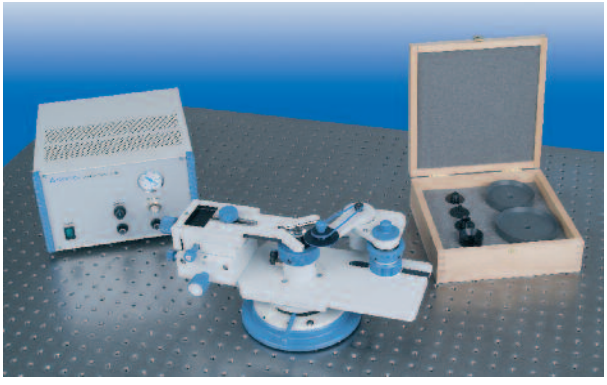
| | |
|---|---|
| Centering accuracy: | < 0.1 arcmin (tilt) |
| | < 2 µm (decenter) |
| Machining tolerances: | < 2 µm |
| Flatness of plano surfaces: | < 1 µm |
| Cylindricity of lens cell: | < 1 µm. |

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



Vacuum unit

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 using OptiCentric® MOT.

### Extension of Measurement Range

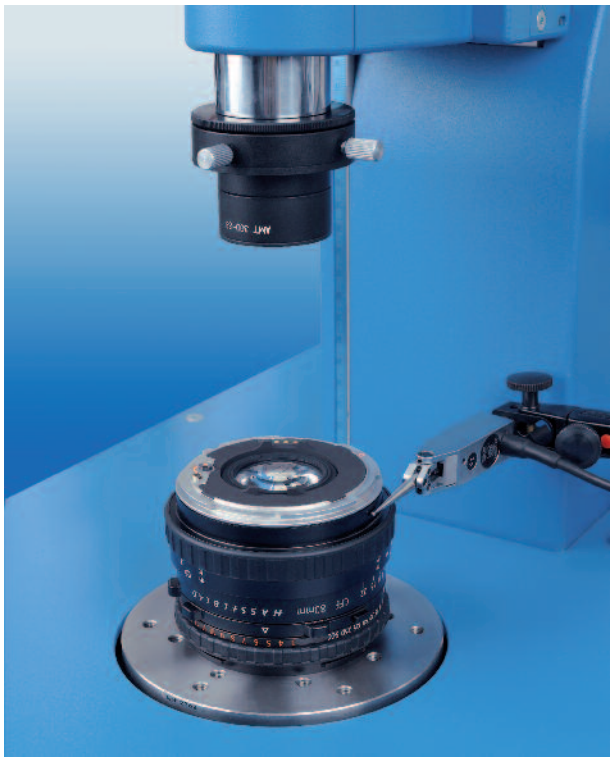
Measuring range of the OptiCentric® system is limited by the size of the upper surface radius when measuring in reflection mode or the effective focal length when measuring in transmission mode. TRIOPTICS provides a set of additional head lenses to extend the range of radius and focal length up to +/- 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 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.

## 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 assemblied 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 features ■
Option □

| Application | OptiCentric® MAN | OptiCentric® SMART | OptiCentric® MOT 100 | OptiCentric® MOT 300 Ultra Stable® | OptiCentric® Bonding | OptiCentric® Cementing | OptiCentric® Lathe Centering |
|---|---|---|---|---|---|---|---|
| Use in mass production | ■ | ■ | □ | □ | ■ | ■ | ■ |
| Measurement in reflection mode | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Measurement in transmission mode | ■ | | ■ | ■ | ■ | ■ | ■ |
| Measurement of single lenses | ■ | ■ | ■ | ■ | | ■ | |
| Measurement of objective lenses | | | ■ | ■ | ■ | ■ | |
| | | | | | | | |
| Cementing manual / automated | □/– | □/– | □/– | □/– | □/– | □/■ | –/– |
| Bonding manual / automated | □/– | □/– | □/– | □/– | □/■ | □/– | –/– |
| Lathe Centering | | | | | | | ■ |




OptiCentric® Bonding Station

# Overview of Available Configurations

Standard features ■
Option □

| | OptiCentric® MAN | OptiCentric® SMART | OptiCentric® MOT 100 | OptiCentric® MOT 300 Ultra Stable® | OptiCentric® Bonding | OptiCentric® Cementing | OptiCentric® Lathe Centering |
|---|---|---|---|---|---|---|---|
| **Illumination** | | | | | | | |
| 150 W cold-light source | ■ | | ■ | ■ | ■ | ■ | ■ |
| 250 W cold-light source | □ | | □ | □ | □ | □ | □ |
| 20 W halogen lamp (NIR) | □ | | □ | □ | □ | □ | □ |
| 100 or 300 mW LED | □ | ■ | □ | □ | □ | □ | □ |
| **Bearings** | | | | | | | |
| Air bearing AB 100 (sample diameter 0.5-225 mm) | | | □ | | □ | □ | |
| Air bearing AB 300 (sample diameter 0.5-600 mm) | | | □ | □ | | | |
| 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 | □ | □ | □ | □ | □ | □ | □ |
| **Measurement data** | | | | | | | |
| Visual reading on eye piece scale | □ | | | | | | |
| Visual reading on monitor | □ | | | | | | |
| PC + Software evaluation | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Measurement head linear stage** | | | | | | | |
| Manual positioning | ■ | | | | | | |
| Automated positioning, PC controlled | | ■ | ■ | ■ | ■ | ■ | ■ |
| **OptiCentric® extension** | | | | | | | |
| MultiLens® / Analyser | | □ | □ | □ | □ | □ | |
| AspheroCheck® | | | □ | □ | | □ | □ |
| CylinderCheck® | | □ | □ | □ | | □ | |
| SmartAlign® | | | □ | □ | □ | □ | □ |
| Central thickness / high accuracy radius measurement | | | □ | □ | | | |
| Plano optics (OptiAngle®) | □ | □ | □ | □ | | □ | |
| OptiSpheric® | | | □ | □ | | | |

# 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 UltraStable * | |
| OptiCentric® MOT 300 UltraStable / Single Head | 4-401-08 + 4-305-49 |
| OptiCentric® MOT 300 UltraStable / Dual Head | 4-405-60 + 4-305-49 |
| OptiCentric® MAX | |
| OptiCentric® MAX | 4-143-00 |
| OptiCentric® SMART | |
| OptiCentric® SMART / Single Head | 4-139-00 |
| OptiCentric® SMART / Dual Head | 4-139-00 + 4-141-00 |

* 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 |
| Center Thickness 450 mm | 4-400-86 |
| OptiSpheric® | 4-600-380 |
| OptiAngle® | 4-600-240 |

| Accessories | Order Numbers |
|---|---|
| Motorized lens rotation device with vacuum Chuck | 4-300-40 |
| Extension of measurement range | 4-400-200 |
| Alignment tool set | 4-500-92 |
| Manual revolving turret | 4-300-140 |
| Precision, motorized and software controlled revolving turret | 4-300-146 + 4-300-079 |
| Complete device for calibration check | 4-300-51 |

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