TRIOPTICS

TRIOPTICS GMBH · OPTICAL TEST EQUIPMENT

WaveSensor® & WaveMaster®

Flexible and Reliable Wavefront Measurement

Surface & Wavefront Metrology

AspheroMaster®

WaveMaster®

OptiSurf®

Contents

Page

Comprehensive Wavefront Measurement 3

Measurement Principle 5

Shack-Hartmann Sensor 5
Real Time Wavefront Analysis 6
Measurement Set ups in Transmission and Reflection 7

WaveSensor® 10

Technical Data 10
WaveSensor® Reflex Module 11

WaveSensor® and WaveMaster® Software 11

Wavefront Analysis 12
Software Extensions for WaveMaster® Instruments 13

WaveMaster® Instruments 14

WaveMaster® COMPACT 15
WaveMaster® LAB 17
WaveMaster® PRO and WaveMaster® PRO Wafer 19
WaveMaster® PRO Reflex 21
WaveMaster® IOL 23
Customized WaveMaster® Instruments 25

Accessories and Upgrades 25

Wavefront Sensors 25
Illumination 25
Telescopes 25

Overview of Applications 26

Overview of Available Configurations 27

Order Information 28

TRIOPTICS Contacts Worldwide 30

Comprehensive Wavefront Measurement

Aspheric Lens Testing Using Shack-Hartmann Sensors

Aspheric lenses are of increasing importance in today's optical industry. In a multitude of different areas of application single aspheric lenses are used to build compact imaging systems.

All of these have to be checked not only for the imaging properties of the final lens system but also for the quality of the intermediate products during assembly as well as the single lenses itself.

In most of the cases conventional methods cannot be used for this kind of testing. Although e.g. the measurement of the modulation transfer function is a well established method for fast and accurate quality inspection of entire objectives it has its limitation for non imaging systems.

In contrast to this, Shack-Hartmann sensors are able to measure a very broad range of spherical and aspherical lenses as well as partially or fully assembled objectives due to their large dynamic range. In addition the high measurement frequency allows for real time testing and analysis.

Real Time Wavefront Sensors and Turnkey Solutions

With the **WaveSensor®** series a variety of Shack-Hartmann wavefront sensors optimized for different measurement applications is available. The WaveSensor® is integrated into existing laboratory or production setups or used for in-field testing. An additional module which is attached easily to the WaveSensor® allows for the measurement of surface form in reflection.

The **WaveMaster® instruments** are Shack-Hartmann based turnkey solutions for quality assurance, research and development, and production environments. They are employed for example in laboratories, institutes or mobile phone industry.

WaveMaster® PRO, WaveMaster® COMPACT, WaveMaster® LAB,

WaveMaster® COMPACT

is ideally suited for fast quality control and simple research and development measurement tasks. The table top instrument can be adapted to different lens types with only a few steps.

WaveMaster® COMPACT

WaveMaster® LAB

has been optimized for research and development in a laboratory environment. It provides an optical bench which allows for different infinite and finite conjugate mode setups for measurement in transmission. In addition the surface profile is measured using the optional reflection module.

WaveMaster® IOL

has been optimized for the measurement of intraocular lenses in air or in situ with a model eye.

WaveMaster® PRO

has been designed for the fully automatic test of large numbers of samples in a production environment. All instruments feature a high degree of automation and ease of use.

In addition to the measurement of individual samples, wafer lenses are measured (WaveMaster® PRO Wafer).

Furthermore WaveMaster® PRO Reflex allows for fast surface profile measurement in production.

High Resolution and Accuracy

All these instruments feature high spatial resolution and accuracy (up to < λ/20). They are available with different setup options which include amongst others fi-

WaveMaster® LAB in operation

nite or infinity conjugates configuration or setup in transmission or reflection.

The comprehensive software for WaveSensor® as well as WaveMaster® works in real time and provides various ways of measuring and displaying the wavefront. It includes extended analysis features and data saving options.

Measurement Principle

Shack-Hartmann Sensor, Wavefront Analysis and Different Setups

Shack-Hartmann Sensor

The standard design of a Shack-Hartmann sensor consists of a CCD camera which is

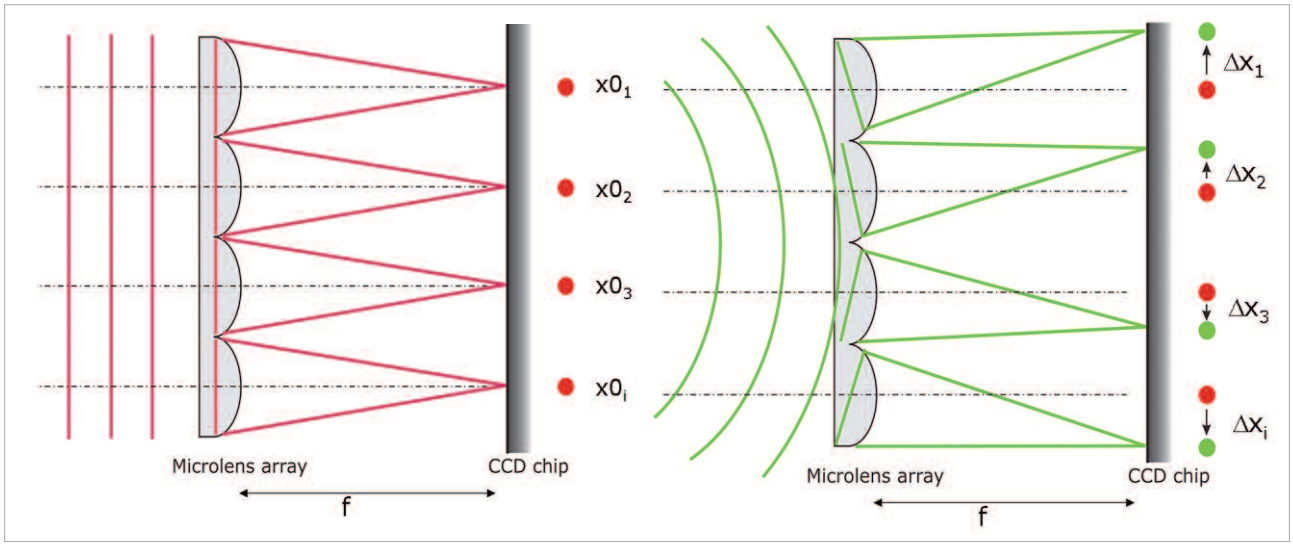


Fig.: 1 Schematic setup of a Shack-Hartmann sensor with an a) incoming plane wavefront and b) incoming diverging wavefront.

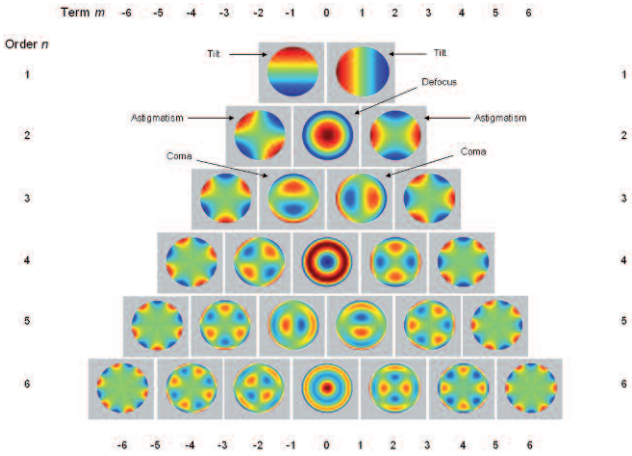
placed in the focal plane of a microlens array. An incoming wavefront is sampled by the lenses of the microlens array and the foci form a spot pattern on the camera which would be evenly spaced in case of a plane wavefront. Any aberration introduced by the sample lens leads to a curvature of the wavefront thus resulting in local wavefront tilts. These induce a measurable shift of each focus spot position (Fig. 1).

A numerical integration of the obtained slope information allows for reconstruction of the wavefront profile with high accuracy. Using state of the art computers this wavefront reconstruction is done within the CCD camera frame rate i.e. within fractions of a second even if large, high resolution arrays are used.

High Dynamic Range Compared to Interferometers

The dynamic range of a Shack-Hartmann sensor heavily depends on the routines which assign each measured spot to the corresponding microlens. A wavefront is reconstructed only when this correlation is kept. Especially in case of stronger curved wavefronts sophisticated algorithms are needed since the simple assignment of a predefined searching area in the CCD plane of the size of a microlens is not sufficient anymore. Modern techniques achieve wavefront dynamic ranges up to 1500 λ.

Due to this high dynamic range Shack-Hartmann sensors are able to measure wavefronts with strong aberrations which are not accessible with interferometers anymore. Here the lack of dynamic range is usually solved by using diffractive null optics specially made for each type of measured lens which is less flexible and much more costly.



Zernike analysis

Real Time Wavefront Analysis

Zernike Polynomials

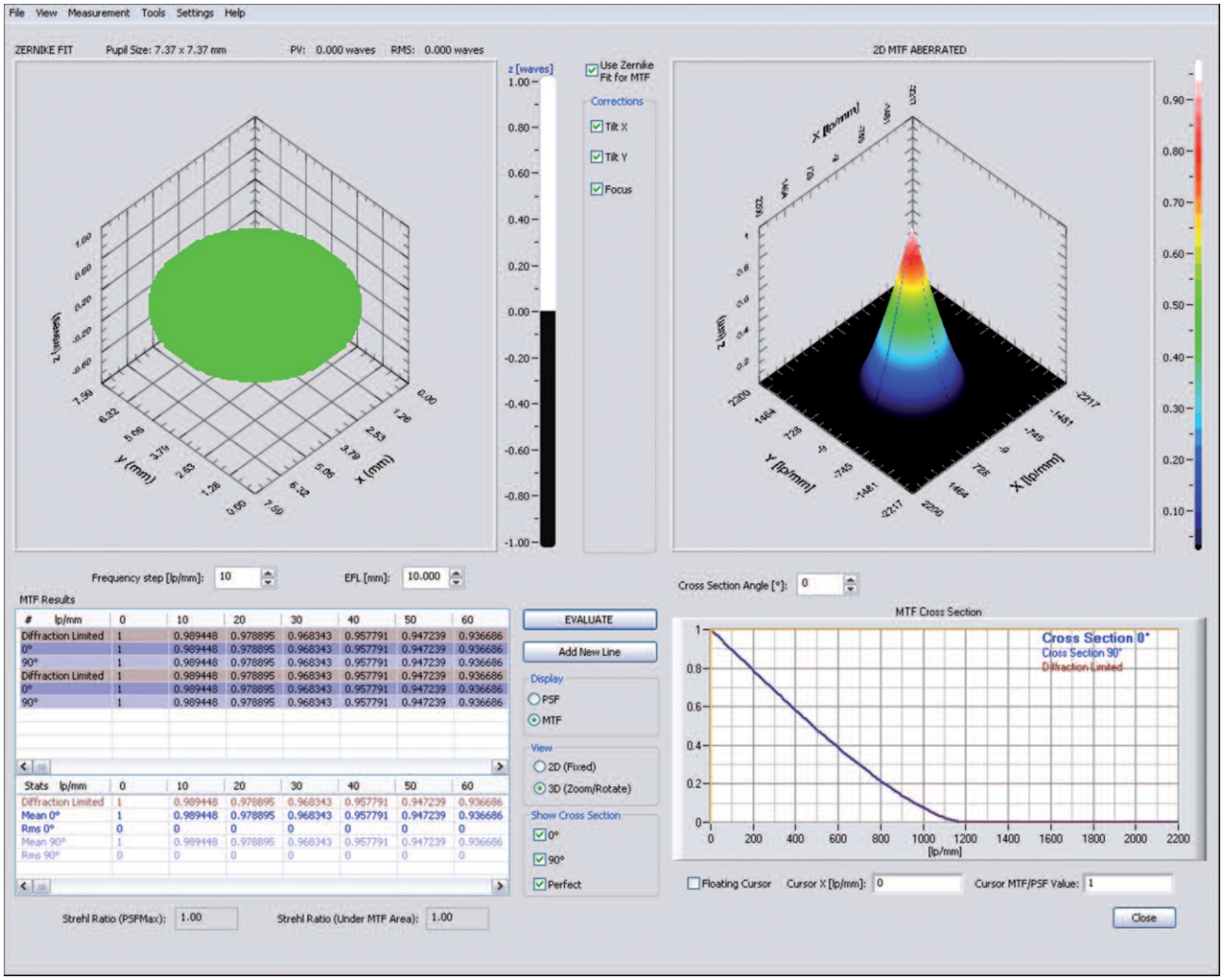
The measured wavefront is decomposed into a linear combination of Zernike polynomials which describe typical optical properties and errors of a lens or lens system as e.g. defocus, coma or astigmatism.

The polynomial decomposition gives a numerical representation of any kind of aberration of the sample. These have basically two sources: aberrations directly linked to the design of the lens, most likely spherical terms, and asymmetric contributions due to lens errors.

MTF, PSF and Strehl ratio

The effects of aberrations are also characterized by calculating the Point Spread Function (PSF), Modulation Transfer Function (MTF) or Strehl ratio of the optical system which are obtained from the wavefront. The MTF is as well known as the modulus of the Optical Transfer Function.

The wavefront measurement and its further analysis give a full spatially resolved description of the imaging characteristics of the lens under test.



MFT, PSF and Strehl ratio calculation

Measurement Setups in Transmission and Reflection

Different configurations of the setup can be chosen for measuring the wavefront. Most important for the choice of configuration is whether the optical properties - using the transmission mode - or the lens shape - using the reflection mode - shall be analyzed.

Transmission Mode

Measurement in transmission provides information about the optical properties of the lenses or lens systems combining the influence of all surfaces as well as refractive index variations in the measured wavefront.

Basic Infinite Setup

In the basic transmission setup (Fig. 2) the sample lens is illuminated with collimated light. A lens in combination with a telescope is then used to collimate the beam again and image the wavefront onto the Shack-Hartmann sensor.

In this setup the sample lens can be easily adjusted in its lateral and height position to achieve the best focus position with re-

spect to the sensor. This setup is one of WaveMaster® LAB's setups

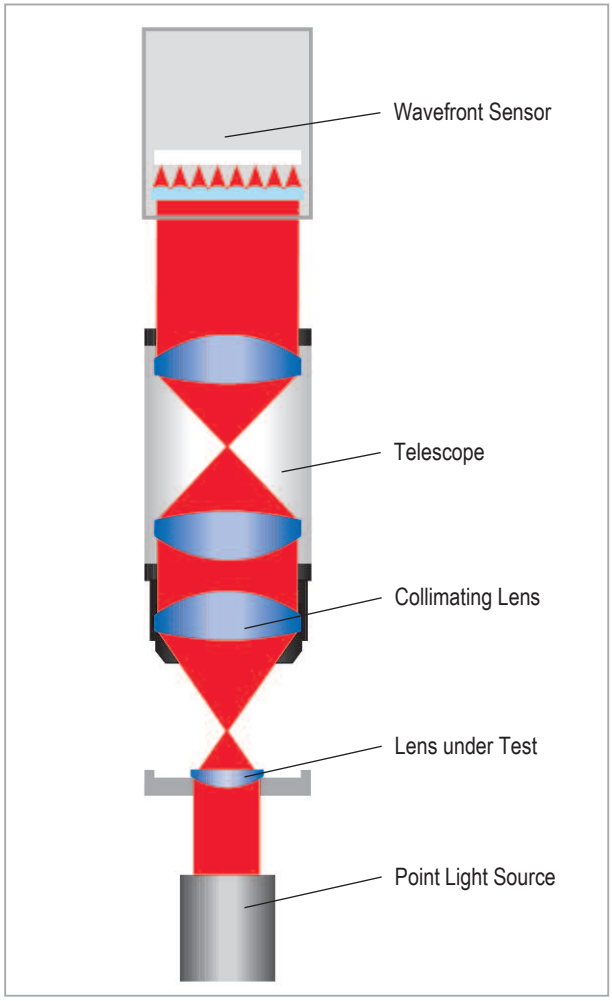


Fig. 2 Infinite setup in transmission

Reverse Infinite Setup

In this configuration (Fig. 3) the sample lens is illuminated by a point light source in the focal plane of the lens. The exit pupil of the lens is imaged onto the wavefront sensor by a telescope.

The height position of the point light source, the lateral position of the sample lens and the image plane of the Shack-Hartmann sensor are chosen separately. This gives full access to the measurement conditions.

The setup is recommended when measurement data shall be compared with theoretical data or if comparison of different lenses is required.

The reverse infinite setup is used for the instruments WaveMaster® COMPACT and WaveMaster® PRO and is one of WaveMaster® LAB's setups.

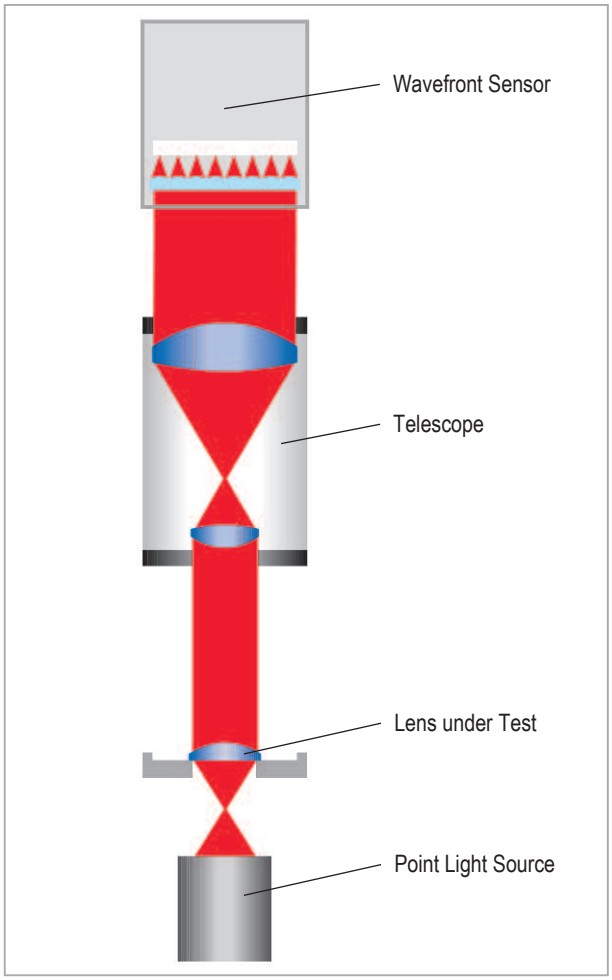


Fig. 3: Reverse infinite setup in transmission

Finite Setup

The most complex but sometimes required configuration for measurements in transmission is the so called finite setup (Fig. 4). In addition to the reverse setup, a collimating lens is added to the imaging system between sample lens and sensor.

In this configuration the lens is illuminated and tested in a configuration which is equal or close to the conditions of its dedicated application.

This expert configuration is only available with the instrument recommended for research and development, the WaveMaster® LAB.

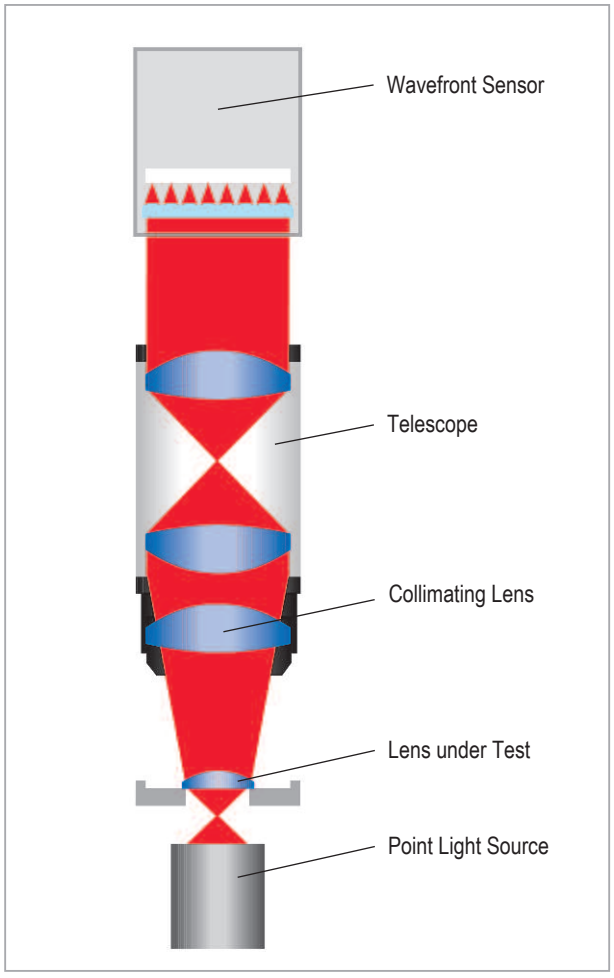


Fig. 4: Finite setup in transmission

Reflection Mode

Measurements in reflection provide information about the topography of the sample surface.

For this measurement the illumination unit with beam splitter is mounted in front of the wavefront sensor. A combination of collimating lens and telescope is used to illuminate the sample and image the reflected wavefront onto the Shack-Hartmann sensor.

The reflection setup is available as an easy to attach module for all WaveSensor® products. For production testing WaveMaster® PRO Reflex is available while for laboratory applications an optional module is added to the optical bench of WaveMaster® LAB.

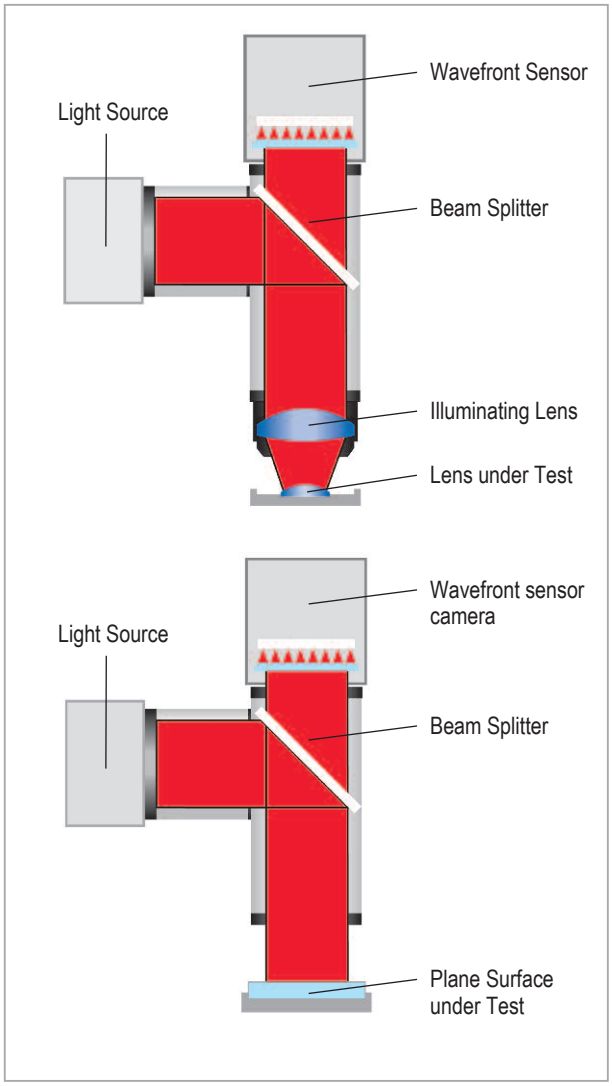


Fig. 5: Setups in reflection

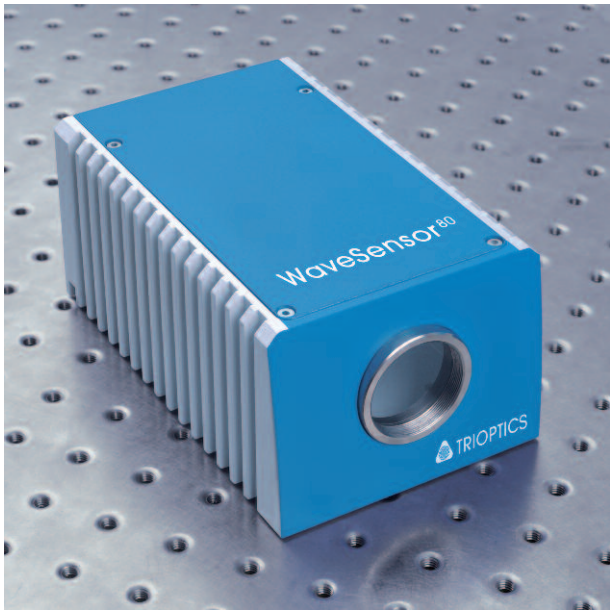
WaveSensor®

Flexible Wavefront Measurement for Use in Laboratories and Production Sites

WaveSensor® is the new Shack-Hartmann sensor developed by TRIOPTICS providing real time wavefront measurement and analysis of spherical and aspherical optics.

With WaveSensor® series a high dynamic range and accuracy are achieved.

Furthermore, WaveSensor® features a compact and robust design thus the sen-



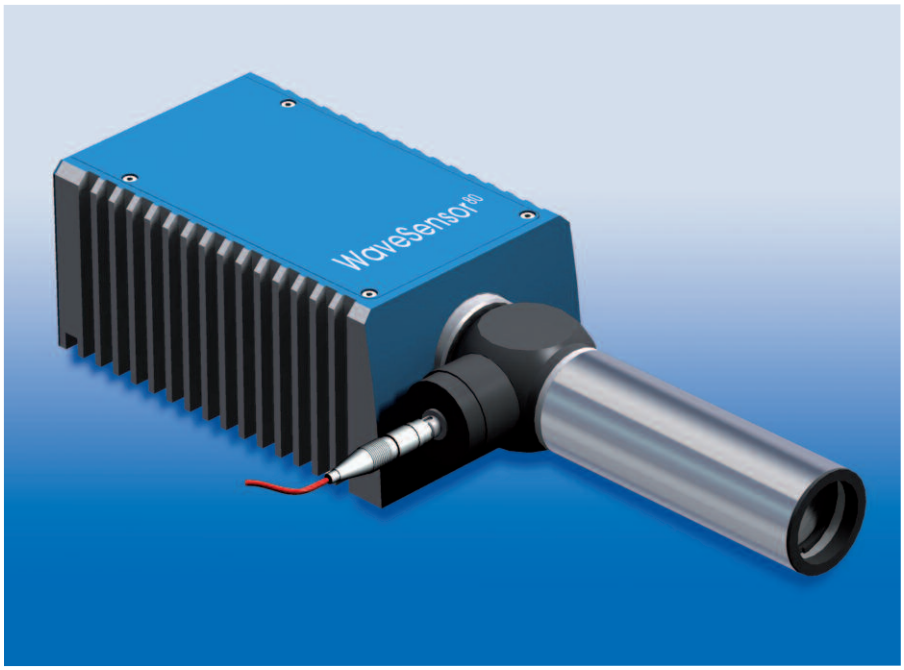
WaveSensor®

Technical Data of the WaveSensor®

	Unit	WaveSensor® 150	WaveSensor® 100	WaveSensor® 80	WaveSensor® 60
Aperture dimensions	mm	15 x 15	15 x 15	6,6 x 8,8	4,8 x 6,4
Max. number of lenslets		150 x 150	100 x 100	60 x 80	48 x 64
Focus dynamic range	λ	> 1500	> 1200	> 1000	> 800
Tilt measurement sensitivity	μrad	< 1	< 1	< 1	< 1
Repeatability (RMS)		< λ/200	< λ/200	< λ/200	< λ/200
Absolute accuracy (RMS)		< λ/20	< λ/20	< λ/20	< λ/20
Max. Measurement frequency incl. data processing	Hz	16 12	16 12	16 16	15 15
Wavelength	nm	350 - 1100			
Interface type		CL Base		IEEE 1394b	
Dimensions (H × W × D)	mm	< 74 x 100 x 144			
Weight	g	<1000	<1000	< 800	< 800

Generally, customer specific wavefront sensors can be offered

sor can be easily integrated into the customer's applications. Via CameraLink or IEEE 1394b WaveSensor® communicates with the WaveMaster® software which provides various ways of analyzing and displaying the wavefront data. Extended data saving functions allows for further external data processing of all measurement and analysis results. In addition theoretical data is loaded and compared in real time during measurements.



WaveSensor® with Reflex Module

The sensors are well proven as they are used in the WaveMaster® instruments which for example are employed in laboratories, institutes or wafer industry.

WaveSensor® Reflex Module

As a supplement of the WaveSensor® TRIOPTICS developed the Reflex Module which expands the applications of WaveSensor® to topography measurement.

The module consists of an illumination unit with collimated light source and beam splitter and an objective tube. The measurement is either done with a collimated beam using the illumination unit only or with a focused beam using the illumination unit and an additional objective lens.

The collimated illumination is employed to measure the surface and the angle of plane optics. Non planar surfaces like aspheric lenses are measured using an objective lens.

WaveSensor® and WaveMaster® Software

Real Time Wavefront Measurement

The advanced software works with all WaveSensor® and WaveMaster® instruments. The overall task of the software is the communication with the Shack-Hartmann Sensor and the analysis of the measured wavefront. In addition, the software controls the WaveMaster® instruments. Therefore, software modules depending on the specific WaveMaster® instruments are available, as for example for the production instruments.

The software package features a high ease of use, a menu-driven operator guidance and advanced data management, which allows for easy and intuitive wavefront measurement and analysis.

All aspects of data acquisition starting with data calculation, calibration and display of the data are under software control and fully automated. Furthermore, extended tools for live analysis are available.

In addition theoretical data can be loaded from ZEMAX and Code V and compared in real time during measurements.

Display of the Measurement Results

To evaluate the optical systems' wavefront, various ways of displaying the measurement results can be selected. Depending on the measurement task the following results are shown:

- Absolute or relative measurement
- Subtraction of background illumination
- Live display of 2D- or 3D-wavefront in µm, waves
- Live display of 2D fringes and phase
- Live display of Peak-to-Valley and RMS
- Live display of intensity
- Live display of slopes
- Live camera image
- Sample adjustment tools (tilt and position)
- Live correction of tilt and defocus
- Units of the measurement results: µm or waves

Data Saving

Of course, all sample related information and measurement results can be exported and saved in different formats:

- Slope data
- Wavefront data
- Zernike coefficient data
- Measurement certificates including measurement conditions, graphical as well as numerical display of measurement results
- COM-Port communication for external control

Wavefront Analysis

Live Zernike Analysis
Analysis of the Optical Properties

The typical optical properties and errors of a lens or lens system as e.g. defocus, coma or astigmatism are displayed in terms of Zernike polynomials.

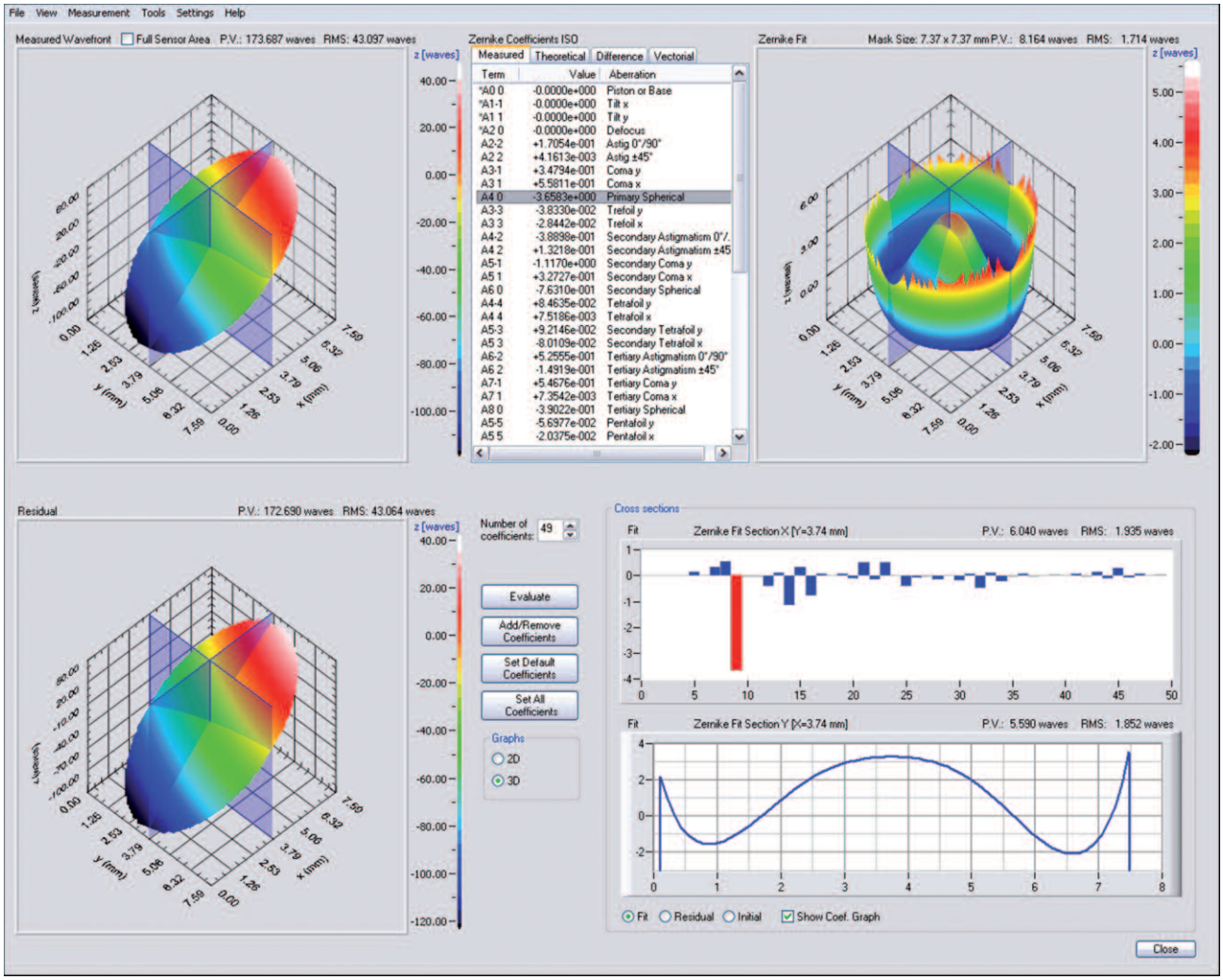
Up to 121 Zernike coefficients are fitted to the wavefront by the WaveMaster® software. The user chooses how much and which coefficients are used for the fit. A small misalignment which induces a tilt or a defocus can be suppressed without influencing the measurement result of the other Zernike coefficients. The measured wavefront is directly compared to either a reference measurement or a theoretical wavefront defined by a set of Zernike coefficients. All functions are available in real time.

- Live display of measured, fitted and residual wavefront (2D and 3D)
- Live display of cross sections
- Live numerical and graphical display of Zernike coefficients
- Free choice of coefficients included into or excluded from the analysis
- Input of theoretical wavefront data for comparison with measured wavefront
- Display of difference wavefront and difference coefficient

Live MTF Display
Imaging Quality Evaluation

Additional analysis tools are provided with the calculation of the MTF and the PSF, which both indicate the imaging quality of an optical system.

A complete two-dimensional MTF is calculated and cross sections can be chosen at selectable degrees of rotation. The calculated PSF is used to calculate the Strehl ratio automatically.



Zernike analysis window

Effective Focal Length

The effective focal length can only be measured with the WaveMaster® Instruments since an automated focus stage is needed.

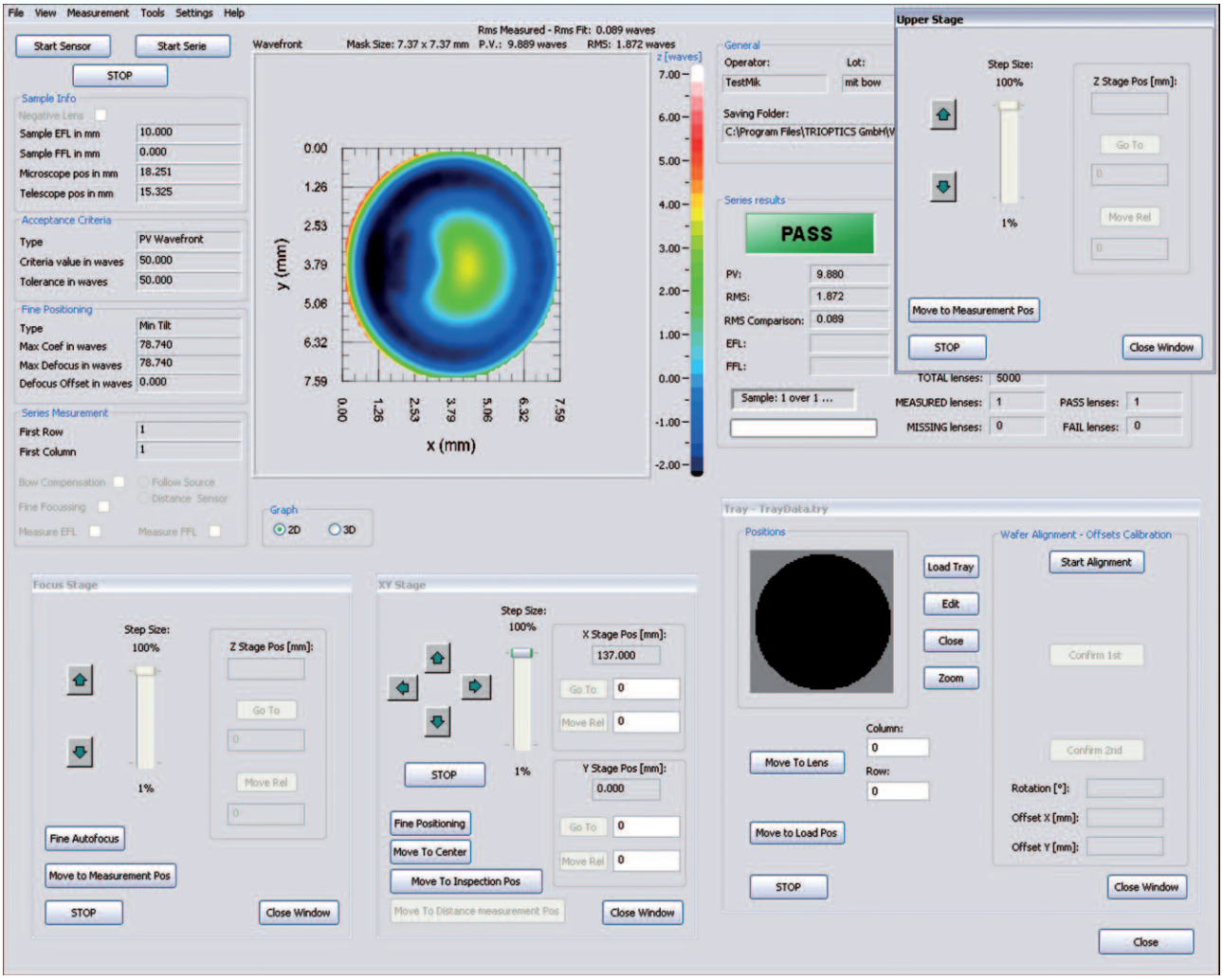
Software Extensions for WaveMaster® Instruments

The WaveMaster® instruments work fully automated thus all processes are controlled by the software. For example, the automated positioning of the sample or finding of the exit pupil is performed by the software. Therefore, an additional software package adapted to the instruments setup and measurement tasks comes with each WaveMaster® instrument.

The details of the different software extensions are described in the chapter of each WaveMaster® instrument.

The additional features of these software tools are:

- Fully automated alignment of the sample under test
- Fully automated positioning of the Shack-Hartmann Sensor
- Autofocus function
- FFL measurement



WaveMaster® software module for high volume production testing

- Software module for high volume production testing, including positioning system of a tray and pass/fail analysis
- Software for IOL measurement, all specific parameters for IOL measurement are implemented (dioptric power, power mapping etc.)

WaveMaster® Instruments

Turnkey Solutions for Wavefront Measurement

TRIOPTICS offers several turnkey solutions for wavefront measurement which are all optimized for their specific use in research and development, quality control or 100% production testing.

The setup and specification of each WaveMaster® instrument is adapted to the defined range of application. However, the main components of the instruments are the same:

Wavefront Sensor

A high accuracy wavefront sensor on WaveSensor® technology is installed in the measuring head. For each instrument a wavefront sensor is predefined, another wavefront sensor from the WaveSensor® family can be selected as well.

Illumination Unit

All instruments are equipped with a high quality light source with a wavelength of 635 nm or 532 nm. Further wavelengths are available as an option.
The light source allows either for collimated sample illumination with diameters up to 30 mm or for point illumination with different numerical apertures.

Motorized Stages

The high precision motorized stages of each instrument allow for accurate and automated positioning of the measuring head, autofocus function, and automated alignment of the sample under test.

Sample Holders

Part of each instrument is a high precision sample holder which facilitates the positioning process of the lens under test.

Depending on the instrument a holder for single lenses or a tray with multiple lens seats is available. For easy and precise lens alignment the holders are manually or automatically (all WaveMaster® PRO instruments) positioned in x-y direction.

Housing

The housing of each WaveMaster® instrument is vibration insensitive and prepared for applications in clean room.

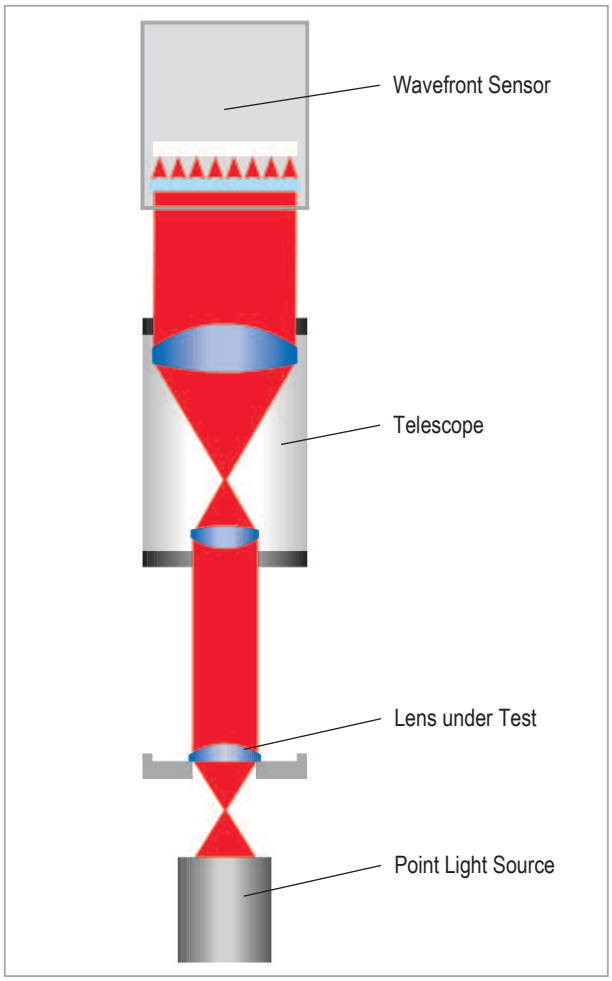
WaveMaster® COMPACT

Aspheric Lens Tester for the Quality Control

Optimized for simplicity in use and high sample throughput the WaveMaster® COMPACT is a fast and accurate tool for testing spherical and aspherical optics in quality control.

Advantages of WaveMaster® COMPACT

- Fast and easy adaption for change of different sample types, exchangeable imaging telescopes in kinematic mount
- High measurement speed enables high sample throughput
- High precision four axes alignment sample holder for submicron position adjustment.
- Alignment compensation: Only minimum amount of sample alignment necessary when measuring series of samples
- High accuracy
- Automatic focusing
- The automatic positioning of the wavefront sensor and the telescope in the exit pupil
- Real time comparison with wavefront data from master lenses or design files



Setup of WaveMaster® COMPACT

Technical Specification of WaveMaster® COMPACT

Wavefront sensor		**WaveSensor® 80**
Number of lenslets		60 × 80
Absolute accuracy (RMS)		< λ/20
Light source		
Wavelength	nm	532
Numerical aperture		0.55
Diameter/ Measurement time		
Max. sample diameter	mm	0.5 - 15
Measurement time per lens incl. sample handling and adjustment	sec	5-10

- Point light source with different numerical apertures available (up to 0.95)
- Vibration insensitive
- Comprehensive software

Operation

WaveMaster® COMPACT is employed for the wavefront measurement of single lenses in transmission. A typical field of application is sample testing of lenses in quality control departments.

In operation the sample is placed in the holder and roughly aligned using the wavefront sensor signal and the predefined set file of the lens type. In general, only a minimum amount of sample alignment is required since the software provides very good alignment error compensation.

During the measurement positioning of the imaging system as well as the light source is done automatically by the instrument.

WaveMaster® COMPACT in operation

Finally the measurement result is displayed in form of simple pass / fail criteria or as complete wavefront including analysis details.

WaveMaster® LAB

Comprehensive Wavefront Analyzer for Laboratories

In development environments WaveMaster® LAB is the accurate tool for testing spherical and aspherical optics.

WaveMaster® LAB is a stand-alone vertical optical bench. It has a flexible setup, which enables the operator to change between different configurations as well as a collimated or a point light source with several numerical apertures.

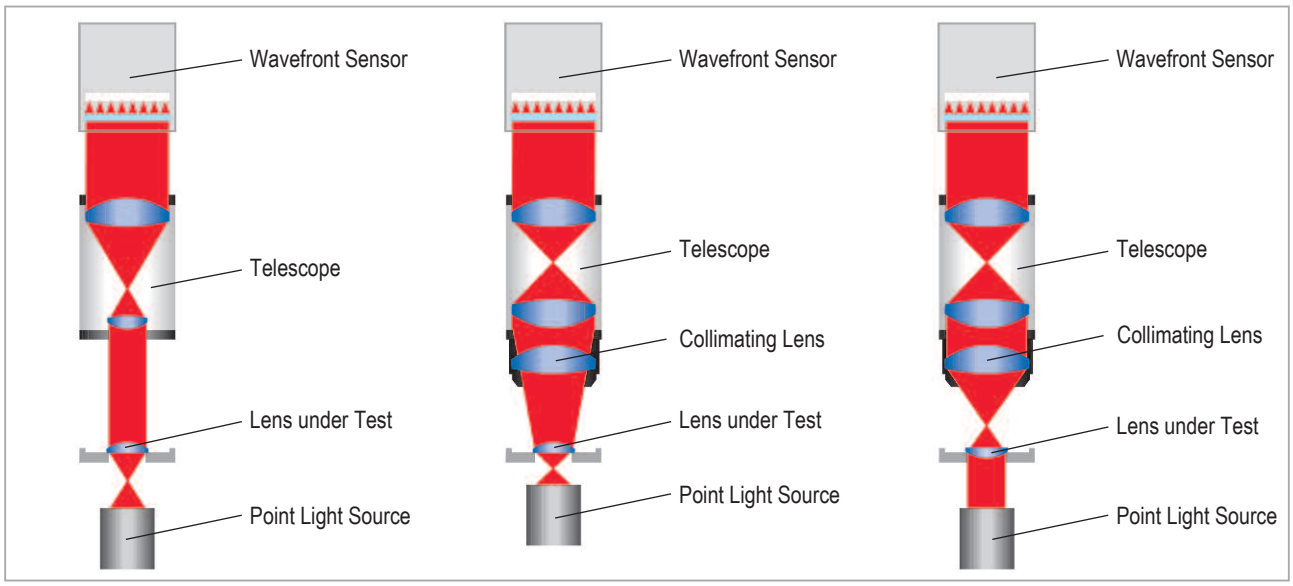
Samples are measured in finite as well as infinite configuration.

When the Illumination is set up, several telescopes permit maximum utilization of the dynamic range of the sensor. In addition WaveMaster® LAB includes miscellaneous tools e.g. for alignment of the sample or the determination of optical properties of the entire setup.

The comprehensive software allows for analysis of Zernike or MTF in each configuration. Further details on the software are presented in the chapter WaveMaster® Software.

Advantages of WaveMaster® LAB

- Flexible concept: Allows for various optical configurations on a vertical optical bench
- Fast change between measurement configurations due to kinematic mounts
- Easy exchange and alignment of samples
- Measurement in absolute or relative mode
- High measurement speed
- Extremely accurate measurements with a high spatial resolution
- Comprehensive software with a variety of analysis options
- Variety of collimated light sources with different wavelengths
- Several numerical apertures for optimum illumination of the optic under test
- Several collimating lenses, a set of telescopes for maximum utilization of the sensor's dynamic range



WaveMaster® LAB's setups

Technical Data for WaveMaster® LAB

Wavefront sensor		**WaveSensor® 150**
Max. number of lenslets		150 × 150
Absolute accuracy (RMS)		< λ/20
Light source		
Wavelength	nm	532
Numerical aperture		0.7 or collimated
Diameter/ Measurement time		
Max. sample diameter	mm	0.5 × 60
Measurement time per lens incl. sample handling and alignment	sec	5-10

Special System Components for WaveMaster® LAB

- High precision four axes alignment sample holder for submicron position alignment
- Independent alignment tool for sample tilt
- High precision linear bearings enable the setup of all components in the required position
- Stable optical axis even during change of setups
- An additional camera allows for testing further properties of the optical setup, for example system magnification or object plane position

Operation

Highest Flexibility Measuring Wavefronts

WaveMaster® LAB is a highly adaptive system which enables the user to measure the lenses in different measurement setups.

Before the measurement the illumination is set up and the optical elements are positioned on the optical bench.

After choosing an appropriate measurement setup the sample is placed in the holder and roughly aligned using the alignment tools provided by the instrument as well as the software. In general, only a minimum of sample alignment is re-

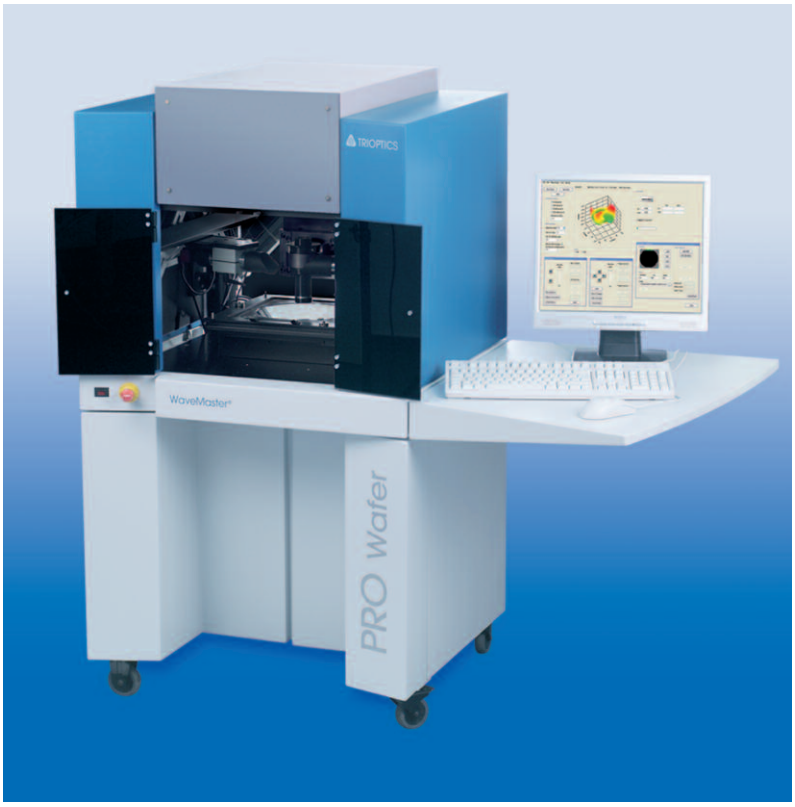
WaveMaster® LAB

quired since the software provides very good alignment error compensation.

Finally, the lens is measured and the results are analyzed with the comprehensive software.

Reflection Module

The capabilities of WaveMaster® LAB are expanded with the upgrade for measurements in reflection. This upgrade includes an additional illumination unit with a collimated light source and a beam splitter. The illumination unit is mounted in front of the wavefront sensor and allows for illumination of the upper sample surface and thus measurement of the wavefront in reflection.

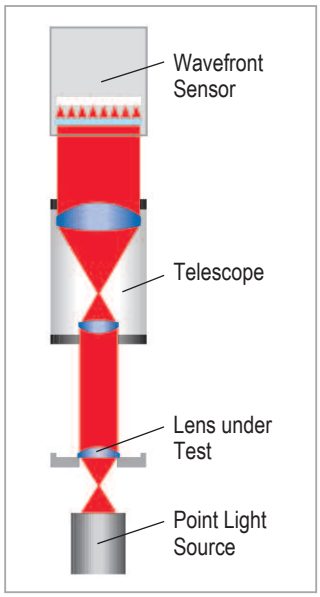


WaveMaster® PRO Wafer

WaveMaster® PRO and WaveMaster® PRO Wafer

High Volume Production Testing

WaveMaster® PRO and PRO Wafer have been designed to meet the requirements for high volume production testing of imaging systems, single lenses or lenses on wafers.



Setup of WaveMaster® PRO

The instruments provide an accurate, reliable and fast way for automatic production testing. With the combination of a fast, high accuracy wavefront sensor and special positioning algorithms a high throughput is achieved.

WaveMaster® PRO comes with a tray system in which a high number of single lenses is arranged. In contrast to WaveMaster® PRO, the WaveMaster® PRO Wafer comprises of a special tray system for wafers with a diameter of up to 12 inch and an additional tool which determines the wafer orientation in the instrument. The tray systems of both instruments allow for fully automatic positioning of the lenses during the measurement process.

WaveMaster® PRO and PRO Wafer provide lateral resolved information from design or reference data, scratches and lens impurities within a measurement time of less than three seconds for each single lens under test. This allows for direct feedback into the large volume production process.

The production software enhances the capabilities of all WaveMaster® PRO instruments proving production specific features like pass / fail classification.

Advantages of WaveMaster® PRO and PRO Wafer

- High throughput due to high measurement speed and fully automatic batch wise or wafer measurement
- High spatial resolution for extremely accurate measurements
- Point light sources with different numerical apertures (up to NA 0.95) and working distances
- Easy loading due to kinematic mount
- Automatic, high precision linear positioning
- Measurement either relative or absolute, allows for comparison with a master lens or design data
- Maximum utilization of the sensor dynamic range with a set of telescopes
- Full functionality of wavefront analysis and detailed analysis of single lenses and wafer lenses
- Production software module, for example with export of pass/fail matrix for use in adjacent production line machines
- Robust and vibration insensitive main frame
- Flange focal length measurement (FFL)
- Wafer bow compensation
- Wafer orientation measurement tool

Operation of WaveMaster® PRO and PRO Wafer

WaveMaster® PRO and PRO Wafer are easy to handle tools for quality monitoring of large numbers of single lenses and lenses on wafers in the production process or for incoming component inspection.

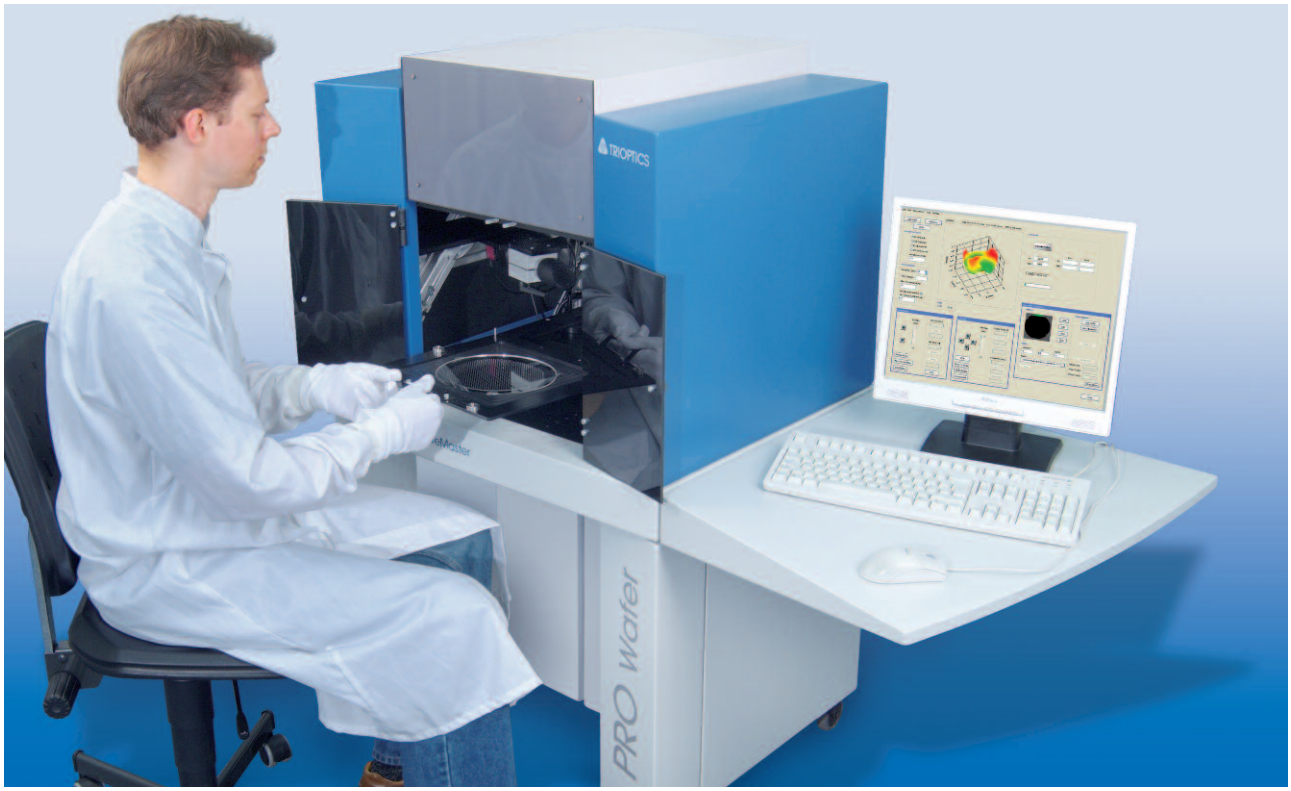
The tray with single lenses or the wafer is loaded into the instrument and positioned using a kinematic mount.

After loading the WaveMaster® PRO Wafer, the wafer orientation is determined with an integrated tool.

Finally, each one of the lenses is measured automatically. Positioning is done fully automatically by the instrument using a predefined file which contains the position of all tray seats or wafer lenses. Fine positioning is achieved using different user selectable positioning criteria. For WaveMaster® PRO Wafer the wafer bow is determined and compensated during measurement, too.

Technical data WaveMaster® PRO and PRO Wafer

Wavefront sensor		**WaveSensor® 150**
Number of lenslets		150 × 150
Absolute accuracy (RMS)		< λ/20
Light source		
Wavelength	nm	532
Numerical aperture		0.55
Diameter/ Measurement time		
Max. sample diameter	mm	0.5 - 15 mm, PRO / 12 inch, PRO Wafer
Measurement time per lens incl. sample handling and alignment	sec	1-3



WaveMaster® PRO Wafer in operation

The results are displayed in such a way that the user is able to single out any failed lens immediately.

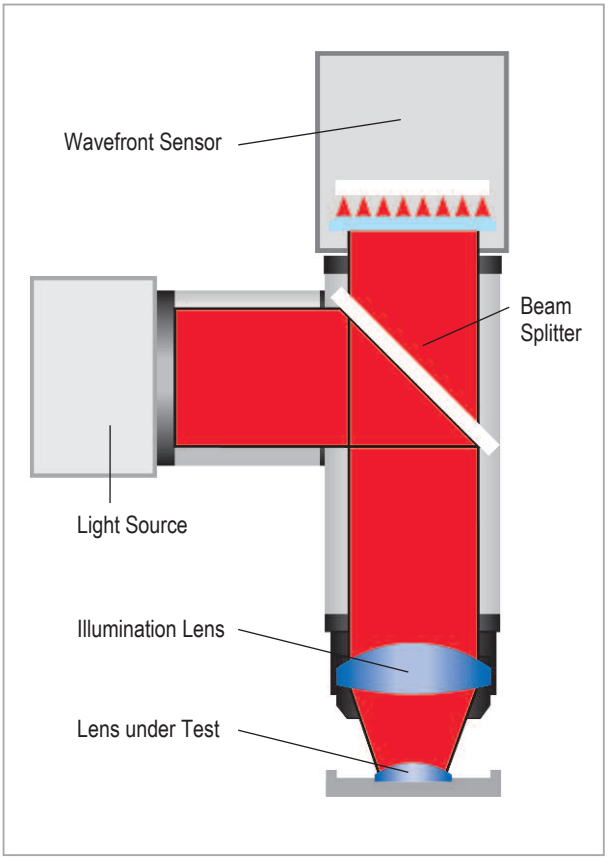
WaveMaster® PRO Reflex

High Volume Measurement of Lens Shapes

WaveMaster® PRO Reflex measures the topography of lenses in production environments.

Like all WaveMaster® PRO instruments, WaveMaster® PRO Reflex is fully automated and provides a high throughput, which is achieved with the fast and accurate wavefront sensor, a software controlled autofocus and precise positioning algorithms adapted to a tray system which allows for batch-wise testing of lenses.

The measurement results reach an accuracy of < λ/10 and they provide lateral resolved information about deviations from the lens shape.



Setup of WaveMaster® PRO Reflex

Technical data WaveMaster® PRO Reflex

Wavefront sensor		**WaveSensor® 150**
Max. number of lenslets		150 × 150
Absolute accuracy (RMS)		< λ/20
Light source		
Wavelength	nm	635
Numerical aperture		up to 0.95
Diameter/ Measurement time		
Max. sample diameter	mm	< 10, depending on lens parameters
Measurement time per lens incl. sample handling and alignment	sec	1-3

The software provides different user defined pass and fail criteria for separating lenses fulfilling the pre-defined quality requirements and those missing them.

The measurement results are presented in a matrix which immediately gives information about the quality of each single lens together with its position in the batch.

Advantages of WaveMaster® PRO Reflex

- Fully automatic topography measurement of large numbers of lenses
- Extremely accurate measurements and high spatial resolution.
- High measurement speed
- Easy loading due to kinematic mount
- Automatic high precision linear focusing stage
- Robust and vibration insensitive frame
- Full functionality of wavefront analysis and detailed analysis of single lenses available
- Export of pass/fail matrix for use in production line machines
- WaveMaster® software with additional production module

Operation WaveMaster® PRO Reflex

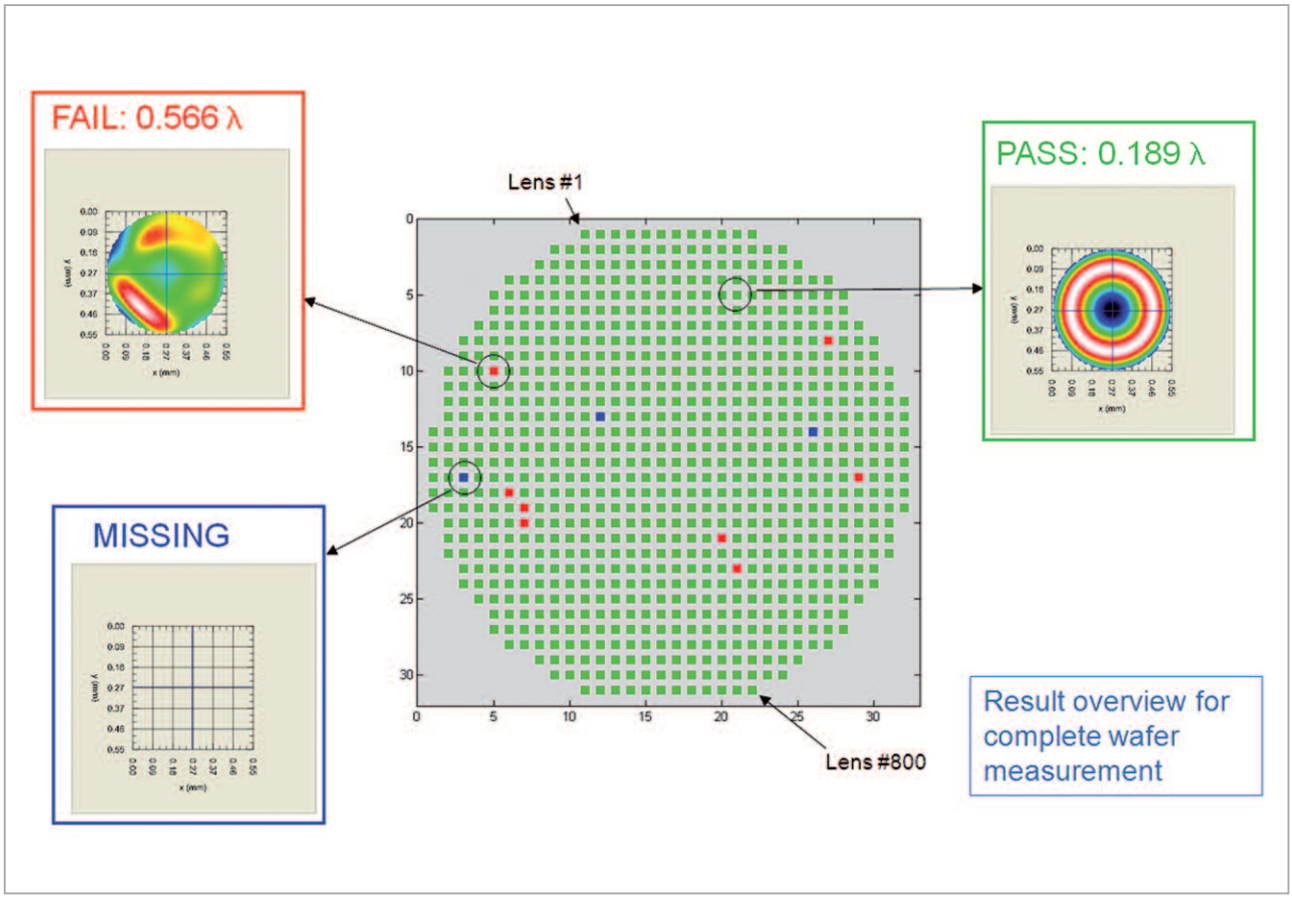
WaveMaster® PRO Reflex works in reflection mode to determine the lens shape. Before the measurement, the lenses are arranged on a tray system which is aligned in the instrument with the help of a kinematic mount. During the measurement process each single lens on the tray is positioned automatically.

Eventually, the software provides a matrix with the measurement result. It clearly shows which lenses meet the quality demands and which do not. Of course, all results can be exported for later analysis.

Software Extension for WaveMaster® PRO, PRO Wafer and PRO Reflex

High volume production requires a fast, reliable and fully automated measurement process. The WaveMaster® PRO software module controls the whole measurement of a batch starting with positioning of the tray before each measurement and analyzing the measurement result after each measurement.

During the series measurement real time analysis of each lens is done. Every single lens is classified directly according to the selected pass/fail criteria which are selected from a large variety of different criteria including the RMS wavefront error, the residual wavefront after comparing to a master lens or the MTF are used for distinguishing between good and poor lenses.



Pass and fail classification

While the wafer or lens is measured, the wavefront of each single lens, its position in the batch and its pass and fail classification are displayed live, all other measurement results are saved into a file. These can be used to extract customized sets of parameters important for the production process e.g. specific lens aberrations or pitch errors.

WaveMaster® IOL

WaveMaster® IOL provides real time analysis of monofocal and multifocal intraocular lenses (IOL) by measuring and analyzing the wavefront with high speed and accuracy.

The wavefront mapping enables the analysis of most complicated lenses with spherical, aspheric or toric shape. Among many other parameters WaveMaster® IOL provides results for dioptric power as well as high resolution power mapping of the complete lens aperture. Lower and higher orders of lens aberrations, Modulation Transfer Function (MTF) and Point Spread Function (PSF) and Effective Focal Length (EFL) can be measured as well.

Various wavefront sensors with different spatial resolutions and available accessories allow for using WaveMaster® IOL in different environments like production sites or research and development laboratories.

In combination with a temperature stabilized model eye all types of IOLs are characterized in situ according to EN/ISO 11979. It is also possible to simply measure the lenses in air.

WaveMaster® IOL with model eye

The software is adapted for IOL measurement and delivers all IOL specific parameters like dioptric power or power mapping. It includes extended analysis features and data saving options. In addition, theoretical data can be loaded and compared with measurements in real time.

For ultra-fast measurement of IOLs in high volume production, an automated tray system with multiple lens seats and attachable model eye is available.

More detailed information about wavefront measurement on IOLs is presented in the brochure "WaveMaster® IOL".

WaveMaster® IOL brochure

Customized WaveMaster® Instruments

Besides the standard WaveMaster® instruments, customer specific wavefront turnkey solutions are developed, which rely on the technology and software of the WaveMaster® series.

Accessories and Upgrades

The wavefront instruments are characterized by a flexible design which allows for the adaption of the instruments to specific demands of an application. With the help of the following accessories and upgrades the function of the WaveMaster® systems are extended.

Wavefront Sensors

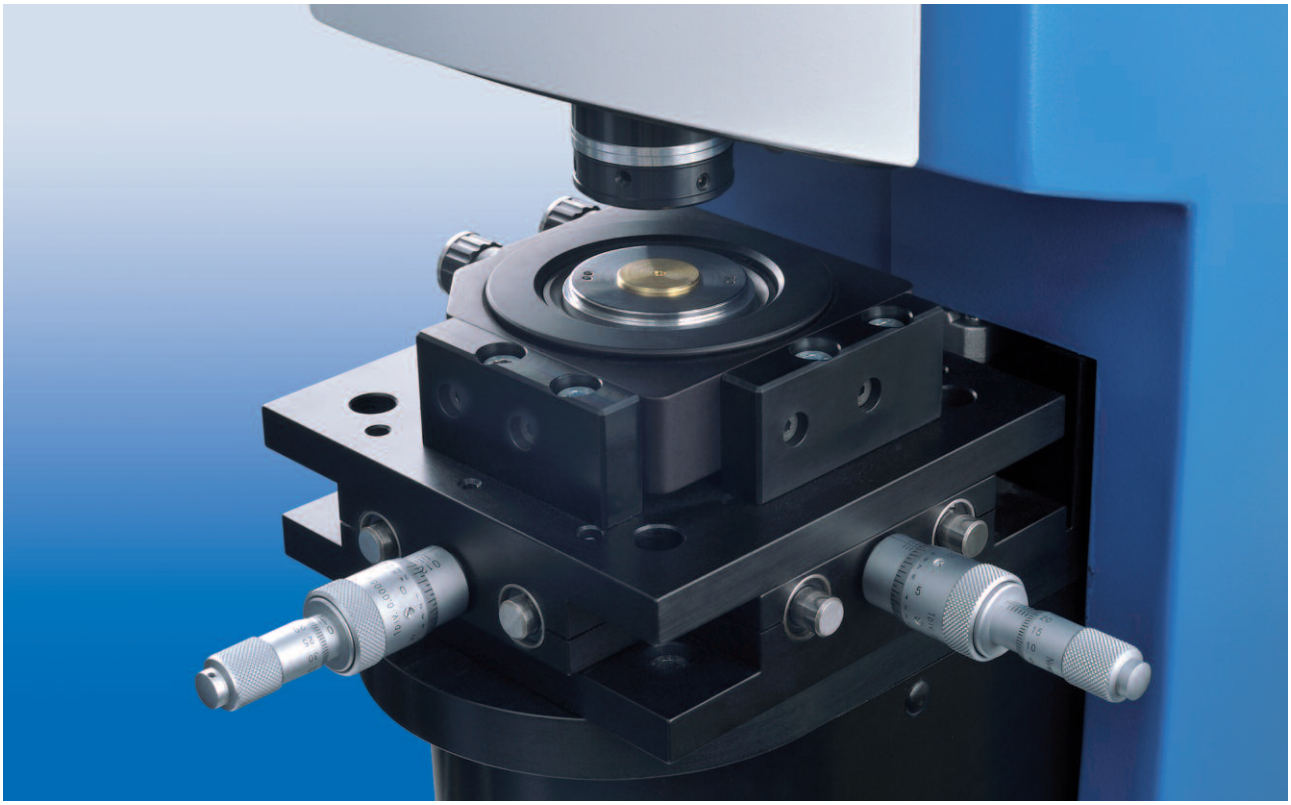
When higher dynamic range or accuracy is required the wavefront sensors of the WaveMaster® instruments can be exchanged. All available WaveSensor® devices can be implemented into the WaveMaster® instruments as an upgrade. Further wavefront sensors are offered on request.

Illumination

Light sources with different wavelengths as well as numerical apertures are available. Switching between numerical apertures is simplified due to kinematic mounts.

Telescopes

For maximum utilization of the sensor dynamic range and thus the lateral resolution a set of telescopes is available. Depending on sample diameter and wavefront sensor dimensions the optimum magnification has to be selected. The kinematic mount allows for easy exchange of the telescopes.



WaveMaster®COMPACT sample holder

Overview of Applications

Standard feature ■
Option □

	WaveMaster® COMPACT	WaveMaster® LAB	WaveMaster® PRO	WaveMaster® PRO Reflex	WaveMaster® PRO Wafer	WaveSensor®	WaveMaster® IOL
Field of Application							
Research and development	□	■				■	□
Testing of lens systems	■	■	■	■	■	■	■
Testing of intraocular lenses							■
High volume lens testing			■	■	■		
Measurement Parameter							
Wavefront Shape (PV, RMS)	■	■	■	■	■	■	■
Zernike coefficients of the wavefront	■	■	■		■	■	■
Point Spread Function (PSF)	■	■	■		■	■	■
Modulation Transfer Function (MTF)	■	■	■		■	■	■
Strehl ratio	■	■	■		■	■	■
Lens Topography		□		■		□	
Dioptric Power							■
Power Mapping							■
Effective Focal Length	■	■	■		■		■
Flange Focal Length			□		□		
Size of the Sample							
Sample diameter of the lens: 0.5 to 15 mm	■	■	■	■	■	■	■
Sample diameter of the lens: 0.5 to 60 mm		■					
Max. wafer diameter: 12 inch				■	■		

Overview of Available Configurations

Standard feature ■
Option □

	WaveMaster® COMPACT	WaveMaster® LAB	WaveMaster® PRO	WaveMaster® PRO Reflex	WaveMaster® PRO Wafer	WaveSensor®	WaveMaster® IOL
Wavefront Sensor							
WaveSensor® 150	□	□	□	■	□	■	□
WaveSensor® 100	□	□	□	□	□	■	□
WaveSensor® 80	■	■	■	□	■	■	■
WaveSensor® 60	□	□	□	□	□	■	□
Automatisation							
Motorized adjustment of the light source	■	■	■	■	■		■
Manual adjustment of the sensor head	□	■					
Motorized adjustment of the sensor head	■		■	■	■		
Configuration							
Infinite measurement in transmission with a collimated light source		■					
Infinite measurement in transmission with a point light source	■	■	■		■		■
Finite measurement in transmission with a point light source		■					
Measurement in reflection with a point light source		□		■		□	
Illumination							
532 nm	■	■	■		■	■	■
635 nm	□	□	□	■	□	□	□
further on request	□	□	□		□	□	□
Numerical Aperture of the Light Source							
NA 0.28	□	□	□	*	□		■
NA 0.55	■	□	■	*	■		
NA 0.70	□	■	□	*	□		
NA 0.90	□	□	□	*	□		
NA 0.95	□	□	□	*	□		
Exchangeable Telescopes							
Exchangeable Telescopes	■	■	■	■	■		■
Special Features							
Additional inspection camera for measuring characteristics of optical set up		■					
Alignment tool (tilt of the sample)		■					
Wafer alignment tool				■	■		
Model Eye							□
Wafer bow compensation					□		
FFL measurement			□		□		

* on request

Order Information

WaveSensor® and WaveMaster® Instruments and Upgrades

Instrument	Order Numbers
WaveSensor®	
WaveSensor® 150	6-105-150
WaveSensor® 100	6-105-100
WaveSensor® 80	6-105-80
WaveSensor® 60	6-105-60
WaveSensor® Reflex Modul	on request
WaveMaster® COMPACT	
WaveMaster® COMPACT	6-100-02
WaveMaster® LAB	
WaveMaster® LAB	6-101-02
WaveMaster® LAB Reflex Modul	on request
WaveMaster® PRO	
WaveMaster® PRO	6-106-03
WaveMaster® PRO Wafer	6-102-02
WaveMaster® PRO Reflex	6-102-04
Upgrade FFL and wafer bow measurement	6-202-03
WaveMaster® IOL	
WaveMaster® IOL	6-100-04
Model Eye acc. ISO 11979	0-101-03
Temperature controller for Model Eye	on request
Upgrades for all instruments	
Upgrade high resolution Shack-Hartmann Sensor (WaveSensor® 150)	6-200-150
Upgrade high resolution Shack-Hartmann Sensor (WaveSensor® 100)	6-200-100

Numerical Aperture Upgrades

Standard or long working distance, depending on application

	Order Numbers
NA 0.55, long working distance	9-110-905
NA 0.7	9-110-903
NA 0.70, long working distance	9-110-908
NA 0.8	9-110-902
NA 0.9	9-110-910
NA 0.90, long working distance	9-110-909
NA 0.95	9-110-901

Telescopes

	Order Numbers
Telescopes VIS Standard magnifications: 1x, 2x, 3.3x, 4x, 5x, 6x, 7.5x, 2.2x, 0.65x, 0.22x	6-100-013...022
Other magnifications	on request
Telescopes NUV Standard magnifications: 1x, 2x, 3.3x, 4x, 5x, 6x, 7.5x Optimized for one wavelength	6-200-12...18

Further telescopes on request

Illumination

	Order Numbers
Light source 405 nm	6-200-11
Light source 543 nm	6-200-22
Light source 635 nm	6-200-09
Light source 1064 nm	on request
Light source 780 nm	on request
Light source 365 nm	on request
Light source 532 nm	on request

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