TRIOPTICS

TRIOPTICS GMBH · OPTISCHE INSTRUMENTE

ImageMaster®
Universal Line
Compact Line
MTF Solutions for Laboratory and Research

ImageMaster
Compact Line
Production Line
Universal Line

ImageMaster®Universal Line
The preferred choice of R&D labs around the word

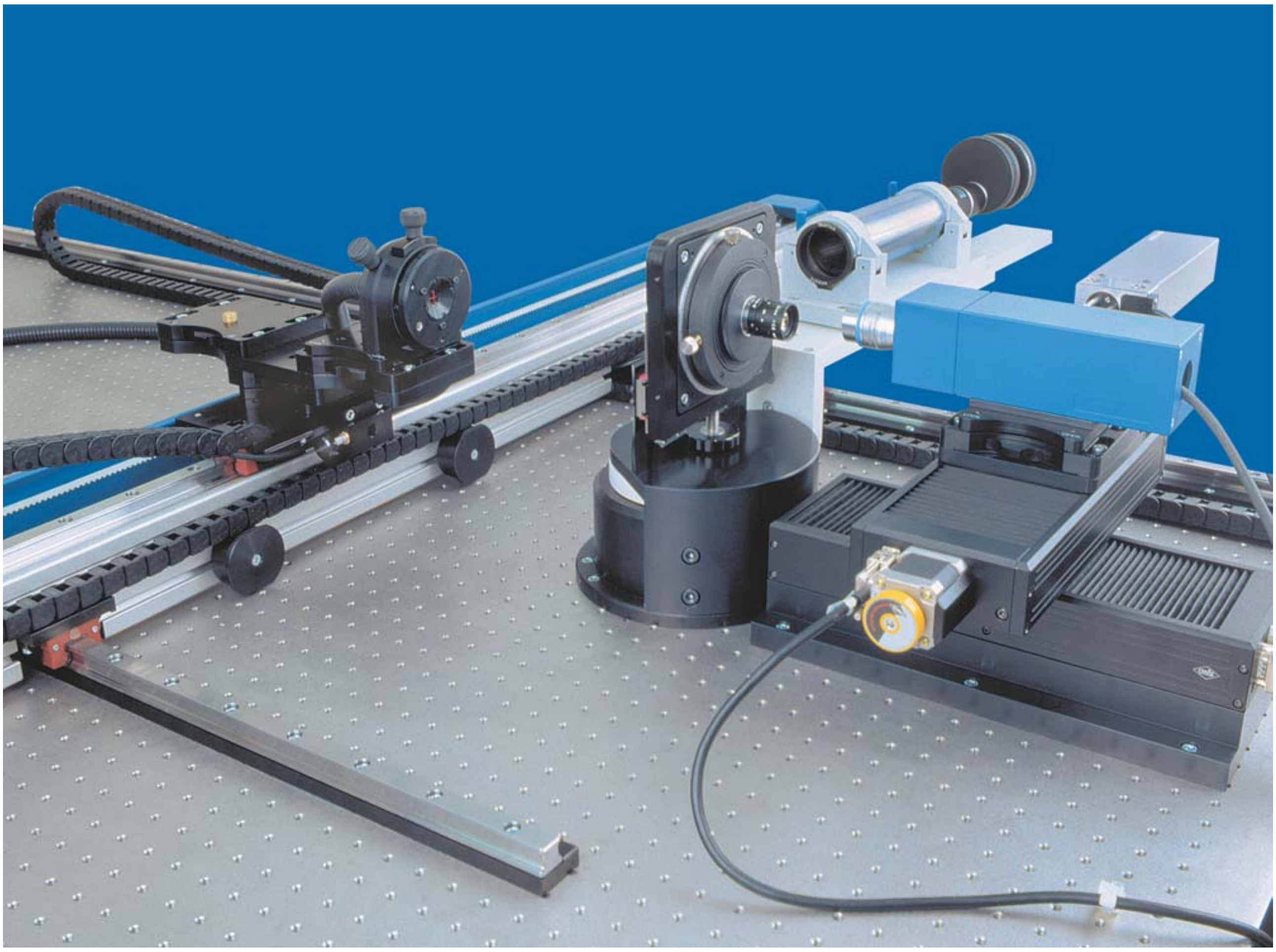
ImageMaster® Universal has been designed to measure a wide range of optical parameters related to almost all typical optical components and lens systems.

Virtually any existing lens systems ranging from high performance photographic lenses to military sighting devices can be accurately measured.

ImageMaster® Universal is modular and upgradeable to allow for custom configuration as test requirements change. The instrument can be configured for testing optical systems with:

- object at infinity
- object and image at finite conjugates
- afocal systems

ImageMaster® Universal is designed to work in different spectral ranges from UV to far IR. High quality optics include specially designed high definition lens collimators and mirror collimators with surface quality up to λ/15.



ImageMaster® Universal Finite Conjugates Set Up (Motorized Swinging Arm with Lens Collimator switched off)

Set up

Measuring Head

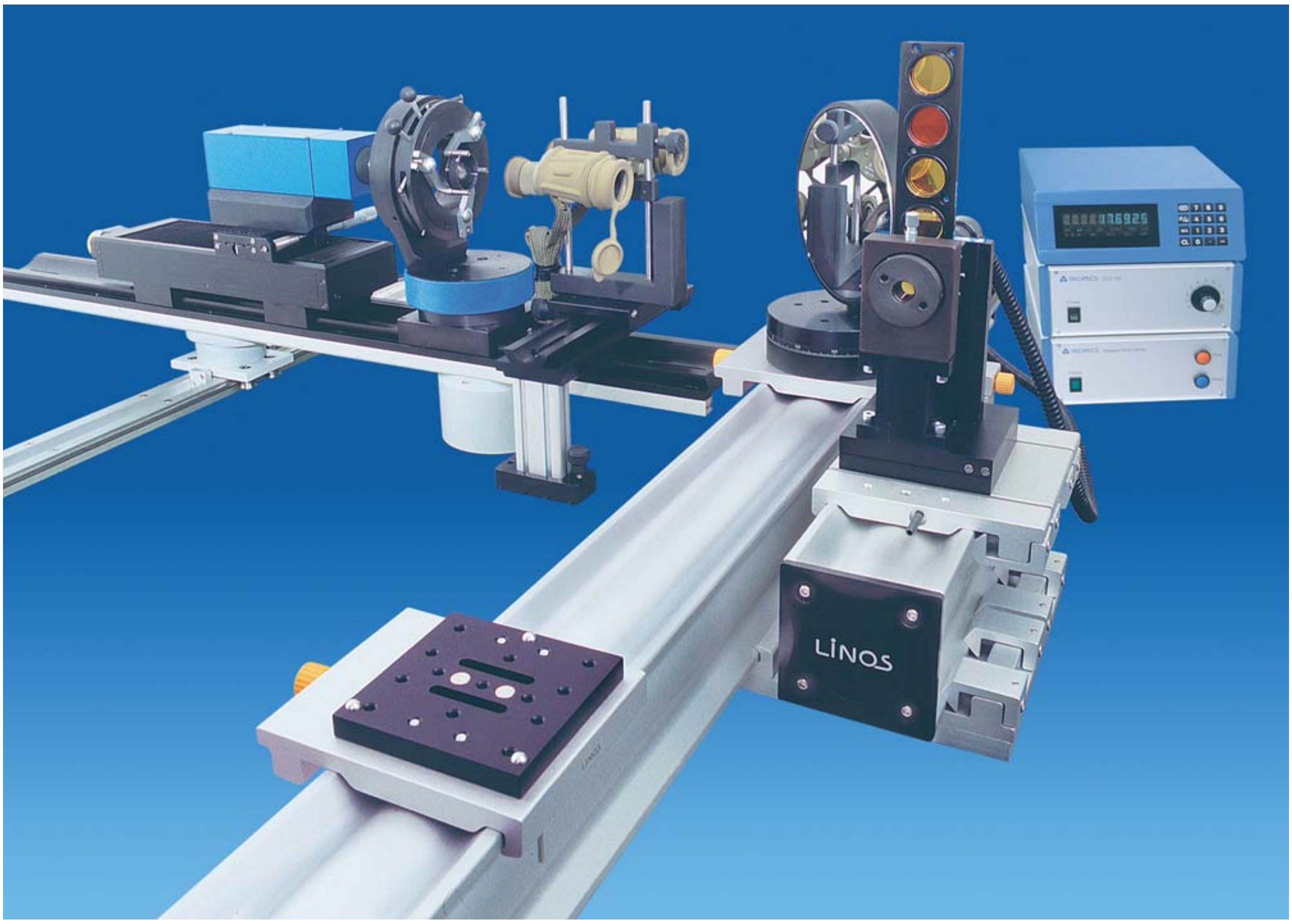
Relay Optics free of residual aberrations

The long co operation of Trioptics with world known companies as Zeiss and Leica resulted in specially selected, high performance objectives manufactured by these companies and used in Trioptics instruments as relay optics.

ImageMaster® Universal incorporates only relay optics with insignificant residual aberrations and with large numerical aperture. The selection of the relay optics is continuously improved, however, some examples often used relay optics:
Zeiss 50XNA0.7, Zeiss 50XNA0.8, Zeiss Apo 50XNA0.95, Leica PL Apo 50XNA0.9.

Selection and characterisation of the CCD-Camera

The CCD-Camera used in Trioptics MTF equipment are selected and measured in order to determine the own MTF curve of the camera. Criteria for selection are the own camera MTF, Progressive Scan CCD, optimal resolution and low noise. Examples of camera used in ImageMaster® series: Progressive Scan 8 bit 647X493 pixels, Progressive Scan 10 bit 1300x1084 pixels or for special applications Digital Camera 12 bit 1280x1024 pixels.



ImageMaster® Universal Afocal Set Up

ImageMaster® Universal Infinity Setup

Perfectly aligned optical heads

An important error source in MTF-Measurement is related to the adjustment and alignment of the measuring head. To avoid any conceivable misalignment or focus error, Trioptics developed a proprietary procedure to perfectly locate the CCD-Chip in the focal plane of the tube lens. In a second step the centration of the relay and the tube lens is optimized so that the residual errors of the relay optics are negligible. This highly accurate alignment of the optical head is an essential and distinctive feature of the ImageMaster® Series, ensuring excellent accuracy and repeatability.

Optical Bench and Stages

The geometry of the optical bench system and the quality (straightness, flatness, long term stability, etc.) are essential for a high level of accuracy in MTF measurement.

TRIOPTICS GMBH · OPTISCHE INSTRUMENTE

The ImageMaster® Series include only guide ways, linear and rotary stages made of high stiffness, corrosion resistant materials and featuring exceptional straightness and running tolerances.

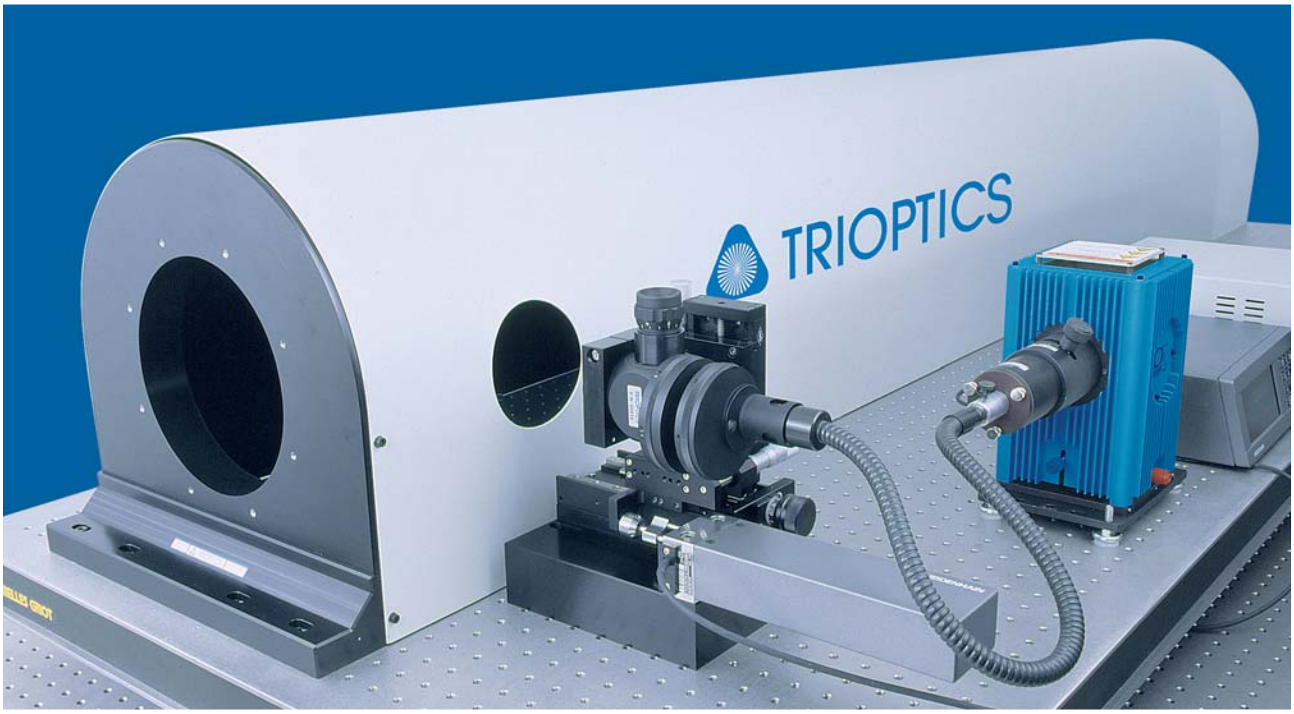
The stepper motor stages have typically a positioning accuracy of 0.2µm and superior straightness tolerances due to high precision guides with roller cross bearings.

The swinging arm relies on ultra precision bearing and Heidenhain encoders with an angular resolution of 0.36 arcsec.
The sample holder is given special attention in design and manufacturing. The stiffness and stability is essential for a repeatable location of the lens under test. The rotation of the sample in order to achieve an azimuth changing is ensured by precision bearings and precise alignment so that no focus change occurs during the rotation.

Colllimators

Trioptics is offering worldwide the largest range of collimators, autocollimators and accessories. A careful selection of the best collimators and an accurate focus alignment deliver aberration free collimators with a nearly zero departure from collimation. A certificate of calibration of infinity position can be supplied with the collimator.

Depending on the spectral range required for the MTF-Measurement, the ImageMaster® Series are equipped with refractive or mirror collimators.
The Trioptics refractive collimators are mounted in a hard chrome plated tube in order to ensure long term mechanical and thermal stability. The mirror collimators feature highest surface quality, typically λ/10 to λ/15, are made of Zerodur and mounted in a rugged, lightweight Aluminium structure. All collimators provide diffraction-limited performance on-axis.



High Quality Mirror Collimator EFL 2000mm, Aperture 200mm, Surface quality: λ/15

Principle of measurement

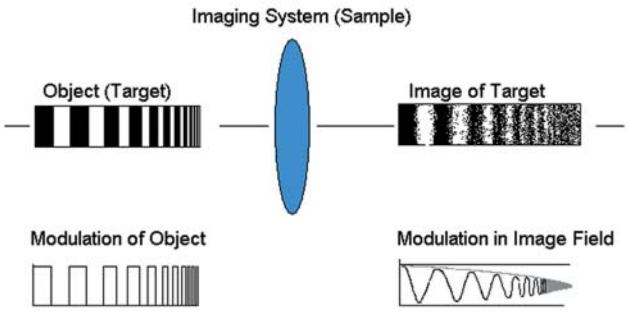
MTF-Modulation Transfer Function

The Modulation Transfer Function (MTF) is an important aid to objective evaluation of the image-forming capability of optical systems. Not only that the MTF provides a means of expressing the imaging quality of optical systems objectively, but it can be calculated from the lens design data. In this way it allows optical and systems designers to predict reliably the performance of the optical systems. The manufacturers can compare the image quality of the manufactured lenses with the design expectations.

The **Modulation Transfer Function (MTF)**, describing the resolution and performance of an optical system is the ratio of relative image contrast divided by relative object contrast

MTF = Relative Image Contrast/Relative Object Contrast (v)

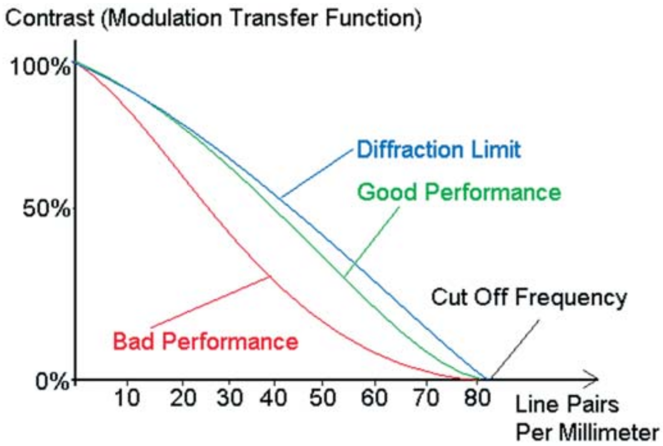
When an object (illuminated target or reticle) is observed with an optical system, the resulting image will be somewhat degraded due to aberrations and diffraction phenomena. In addition, a real lens will not fully conform with the design data. Manufacturing errors, assembly and alignment errors in the optics will deteriorate the imaging performance of the system. As a result, in the image, bright highlights will not appear as bright as they do in the object, and dark or shadowed areas will not be as black as those observed in the original patterns.
In generally an illuminated target is defined by its **spatial frequency** (number of bright and dark areas per millimetre) and the **contrast** (the apparent difference in brightness between bright and dark areas of the image). By convention, the modulation transfer function is normalised to unity at zero spatial frequency.



For low spatial frequencies, the modulation transfer function is close to 1 (or 100%). The MTF curve generally falls as spatial frequency increases. The contrast values are lower for higher spatial frequencies as shown above.

As spatial frequency increases, the MTF curve falls until it reaches zero. This is the limit of resolution for a given optical system or the so called **cutt off frequency** (figure below).

After the contrast value reaches zero, the image becomes a uniform shade of grey,



and remains as such for all higher spatial frequencies.
The modulation transfer function varies not only related to the spatial frequency but also with the position in the field of view. The MTF measurement along the axis of symmetry of the optical system is known as **on-axis measurement**.

To completely characterize the imaging performance of an optical system, the

MTF must be measured at different positions within the field of view.
The MTF measurement within the field of view is known as off-axis measurement. In order to achieve an **off-axis measurement**, the target is moved in the field of view at the desired position and the detector at the corresponding image position.

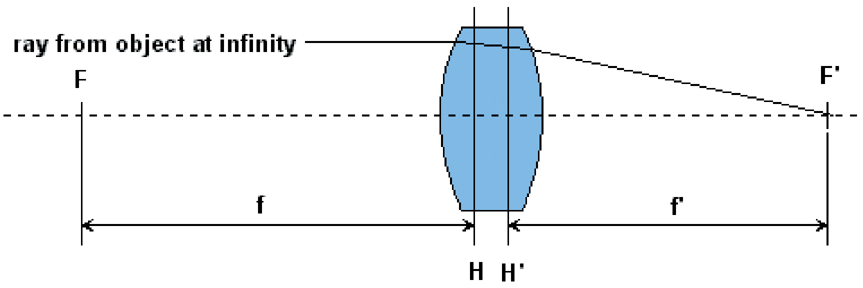
The MTF measurement can be accomplished at a single wavelength or in a spectral range covering a finite band of wavelengths. The resulting measurement data are known as **monochromatic** respectively **polychromatic** MTF values.

Usually the modulation transfer function is used in its one-dimensional form, calculated for one azimuthal section through the image plane. The azimuth (section plane) of the object pattern when the prolongation of the slit or of the edge object passes through the reference axis is called **sagittal azimuth**. When the prolongation of the slit or of the edge of the object pattern is perpendicular to the reference axis, the azimuth is called **tangential azimuth**.

EFL

The **Effective Focal Length (EFL)** or equivalent focal length (denoted f in the figure below) is the distance from the focal points of the lens (F and F′ in the drawing) to the respective principal plane (H or H′). The EFL determines magnification and hence the image size. Because the principal planes are usually inside the lens, the direct measurement of the EFL is difficult.

However, the EFL can be measured quickly and with sufficient accuracy using the method of magnification of a double bar. Certified master lenses from NPL (National Physical Laboratory of UK) and PTB (National German Standard Institute) available



EFL Measurement

at TRIOPTICS are used for calibration. The measurement data are directly traceable to international standards.

EFL and DISTORTION

Distortion: Distortion is the percent change in magnification between the center of the field of view and the right and left off-axis positions at the edge of the real field of view. In order to determine the distortion a different method of measuring the EFL is used:

- A MTF measurement on axis (at a selected frequency) is carried out. The paraxial focal plane is determined using the MTF measurement at a frequency of interest. To achieve a high accuracy monochromatic light and MTF curve fitting are used while the aperture of the lens is reduced by a diaphragm.
- An angular field range and a number of measurement points is selected (depending on sample). The setting data are displayed in a table. The object generator will be automatically rotated to the field angles increments resulted as ratio of the selected range/number of measurement points or at specifically selected field positions.
- At each position in field the image height is measured. A table with value pairs image height/field angles is provided.
- The EFL is calculated with a formula h/tan alfa (alfa=field angle) and introduced in a curve with parameters EFL/field angle . A polynomial fitting allo-

ws for accurate determining of the paraxial focal length.

- The distortion is calculated as a ratio between paraxial and field focal length
- A graph with parameters distortion/field angle is displayed

The procedure requires a relatively large number of measurement points determined by rotation of the object generator at very precise angles and of the field stage at accurate field positions. Normally the ImageMaster® Series featuring distortion measurement are equipped with angular encoder for object generator with a resolution of 0.36 arcsec and linear encoder for field stages (typical accuracy 0.2µm). Moreover it is recommendable to motorize the object generator and the field stage.

DEPTH OF FOCUS

The depth of focus, is the extent of the region around the image plane in which the image will appear to be sharp.

The depth of focus can be determined using the "Through focus scan" and setting appropriate tolerances for the MTF. The depth of focus between the set tolerances will be measured and displayed.

A more complex measurement can be done simulating the range of object distances covered by the lens and measuring the MTF at the corresponding image distances.

FIELD CURVATURE

Field curvature is a form of optical aberration in which the focus changes from the center to the edge of the field of view. The curvature of the field is a lens aberration that causes a flat object surface to be imaged onto a curve surface rather than a plane. Field curvature varies with the square of field angle or the square of image height.
In presence of astigmatism, this problem compounds because there are two separate astigmatic focal surfaces.
To determine the field curvature a set of through focus measurements at different positions in the field is taken. The best MTF and the corresponding position in field are determined. The values are collected by an Excel routine and display in graphical and table form as position along optical axis vs. field angle or other custom graphs.

VIGNETTING

Vignetting in an optical system is the gradual reduction of the image as the off-axis angle increases. This phenomenon is resulting from limitation in the clear aperture of the elements within the system.

Vignetting is defined as the ratio of the central transmission with the transmission at the edge of the apparent field of view. Large values of vignetting are particularly objectionable with video-endoscopes and in severe cases lead to "white-out" where the central image area is saturated when the light source is adjusted for adequate edge illumination.
The vignetting is measured as a ratio of transmission in the position on axis and at the field edge. ImageMaster®-Software measures continuously the light intensity of the pattern in order to avoid saturation. In this way the necessary data are available for determining the vignetting.

ImageMaster® Compact Line
Fully automated, ultra-accurate, multifunctional MTF-Test Station

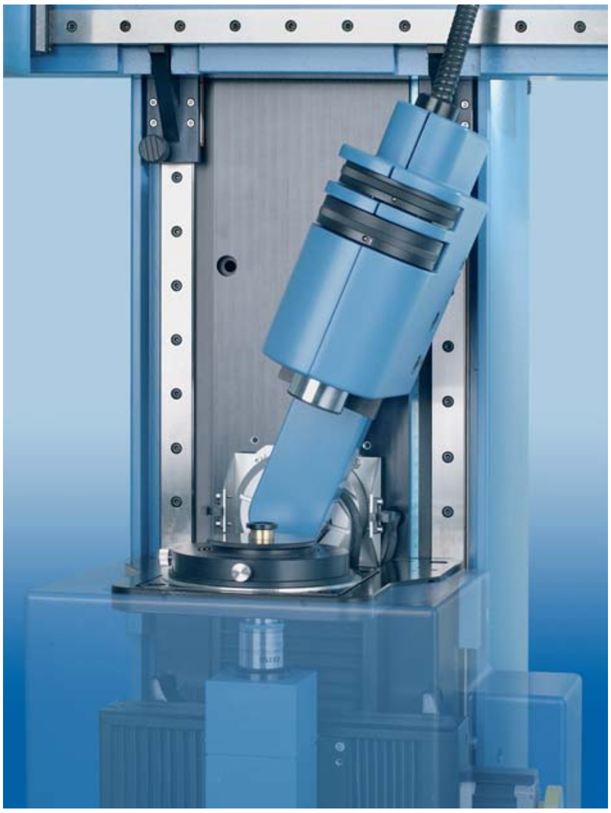
ImageMaster® HR is the top instrument of our Compact Line series. It is a modular, upgradeable instrument line able to measure a wide range of optical parameters

ImageMaster® HR Classical optical set up

related to almost all typical optical components and lens systems. Almost unlimited applications and use in laboratory, production or quality control are the outstanding features of ImageMaster® HR.

In order to ensure the most convenient and accurate positioning of the lens mounts, the ImageMaster® HR is set up vertically. Moreover, the focusing and field stages are mounted in the bottom side of the instrument. The reference mechanical surface of the sample holder is horizontal, the lenses to be measured can be simply mounted on the holder in a stable position due to the own weight.

Since the large majority of the lenses have the mechanical reference surface on the bottom side, the ImageMaster® HR offers the ideal conditions for easy, stable and accurate positioning of the lenses to be tested.



Detail **ImageMaster® HR**

ImageMaster® HR Finite Conjugates Set Up

The motorized rotateable arm is equipped with backlash free transmission gear and an ultra-accurate rotary encoder. The rotateable arm allows for measurement of lenses at large off axis angles: +/-90° and if necessary up to 120°.

The state of the art software features advanced capabilities for detailed analysis. A motorized and software controlled reticle changer selects automatically the suitable target for the measurement intended. The high resolution (0.01MTF) and accuracy (0.02MTF) are directly traceable to PTB standards.

Features and set ups

- Vertical set up
- Automated angle setting for off axis measurements(Collimator-Swinging arm with stepper motor)
- Autofocus (Stepper motor stage)
- Automated field stage (Stepper motor stage)
- Measurement in visible spectral range
- Optional measurement in NIR range

In order to fulfil the measurement requirements of any conceivable optical system, ImageMaster® HR is designed in different mechanical and optical set ups.

Classical Set Up

In this test configuration the rotateable collimator projects a target toward the sample. The sample is imaging the target in the focal plane. This image is "picked up" by the relay lens of a telescope and then projected on the CCD-Sensor.
The instrument can be configured for testing optical systems with:

- object at infinity
- object and image at finite conjugates
- afocal systems

Reverse Imaging Set Up

In this configuration the illuminated target is placed in the image plane of the lens. The parallel beam emerging from the sample is collected by a precision telescope and focussed on the CCD.

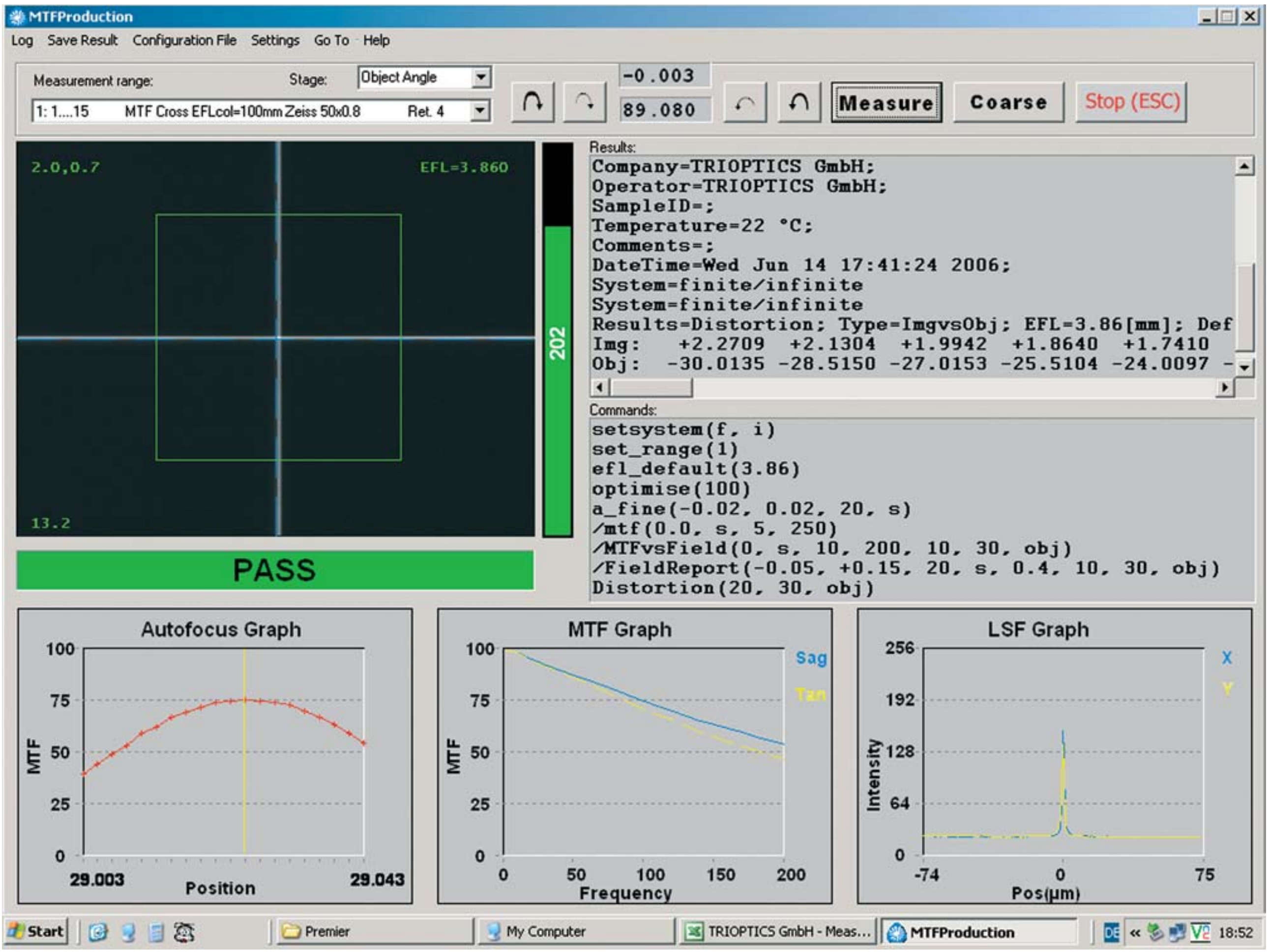
The advantage of this configuration is given by the possibility to design the illuminated target according with the measurement plan i.e. placing suitable pattern in all off-axis positions intended to be measured. In this way the function of the field stage is transferred to the illuminated target. It results a fast and conveniently priced instrument.

Other advantage is related to distortion measurement. Since the target can be manufactured with nanometer accuracy this will lead to a significant increase in the measurement accuracy of the distortion.

Software

The advanced software is designed to work under Windows XP® operating systems, includes a multitude of tools for R&D and laboratory work and offers a high level of speed and accuracy. ImageMaster® Software provides a design and research environment allowing the operator to carry out experiments, to completely characterize optical systems and finally to launch superior products faster.

Based on the long tradition and experience of TRIOPTICS in developing world class optical instruments the new software package provides Auto Focus, Through Focus Scan, Set up files, user and supervisor access to set up files, Pass or Fail features, storage of lens and batch data, data analysis over Excel etc.

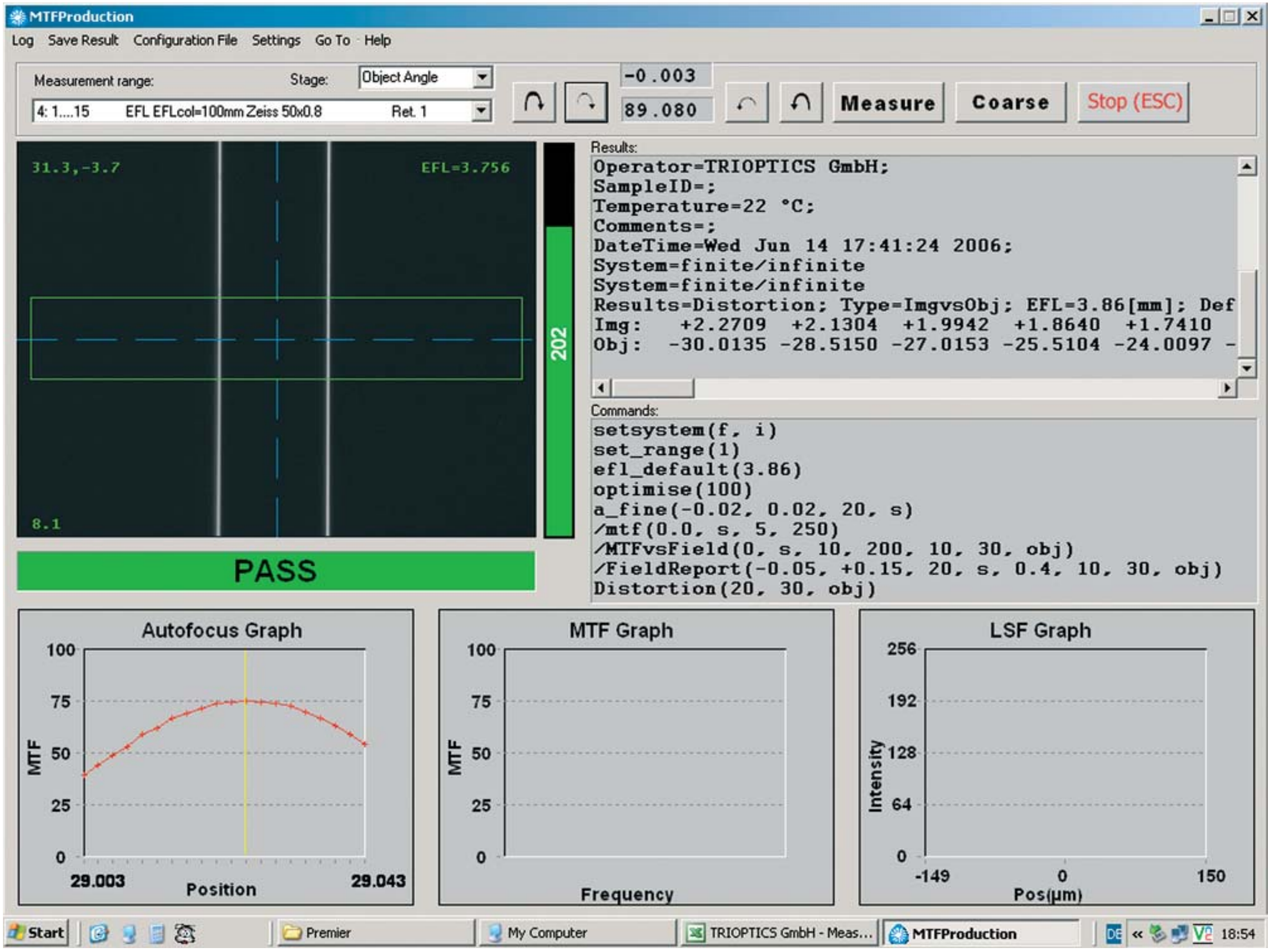


Simultaneous measurement of MTF in saggital and tangential plane

Newest feature includes script tool for custom programming of test sequences. Measurement certificate, storage of measurement data, statistical evaluation are since long standard features of our software.

ImageMaster®-Software provides unique features in order to optimize the measurement process:

- Simultaneous measurement of the EFL and MTF using special target pattern and specific software calculation
- Alternative MTF measurement using a slit or a pinhole as a target. While the slit based MTF measurement is accurate, it shows the optical performance in one azimuth only. The pinhole based MTF measurement provides information over the full lens aperture and is ideal for real time alignment during assembly of objective lenses.
- Automated selection and positioning of the suitable reticle (target) for the current application
- Set up files with the optimized process parameters with password protected access for operator and supervisor
- Script tools for custom programming and analysis –ideal for R&D laboratories
- Transfer of the main functions to a dedicated keyboard, so that even unskilled operators can provide reliable measurement results in production environment
- Extensive data processing with MS EXCEL



Measurement of EFL with **ImageMaster®** Software

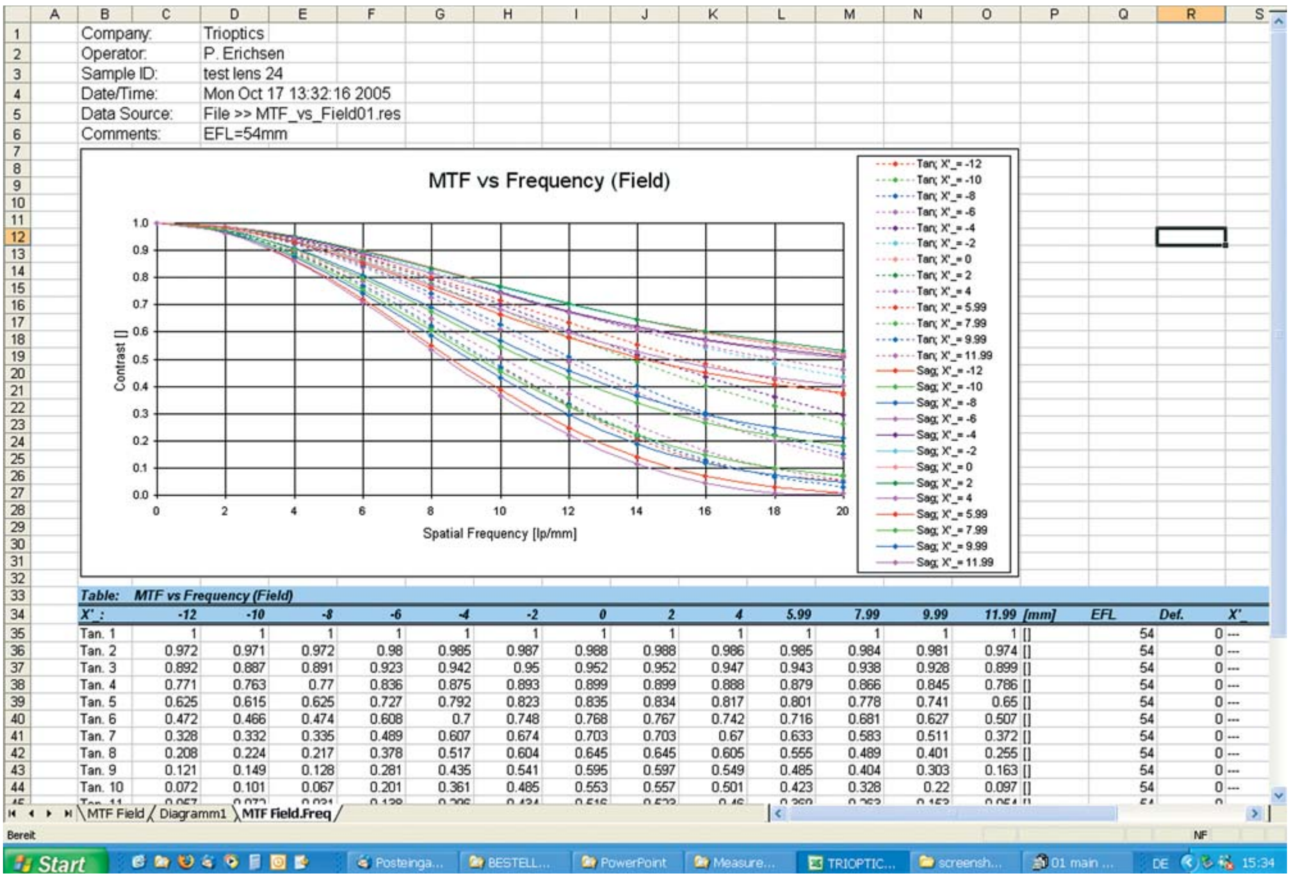
The ImageMaster® can be configured to measure the MTF in sagittal and tangential direction or to perform tests over the full lens aperture (using pinhole target). The spatial frequencies of interest can be selected prior to measurement. The real time measurement results can be compared with the calculated theoretical MTF values or with optical design files.

GRAPHICAL REPRESENTATION OF DIFFERENT MEASUREMENT DATA

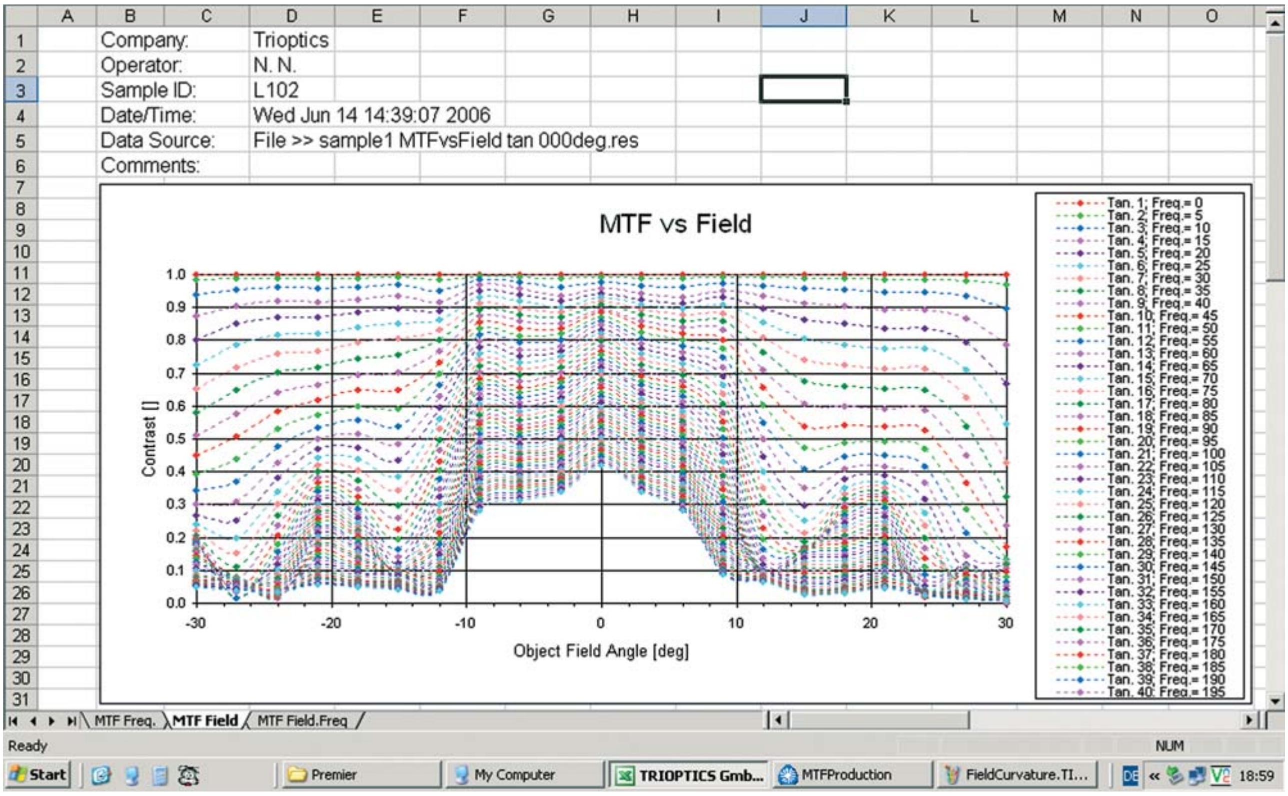
The software package of ImageMaster® Series includes an automated communication with Excel which standardly provides graphs for:

MTF vs. Spatial Frequency vs. Image Height
MTF vs. Spatial Frequency
MTF vs. Spatial Frequency vs. Wavelength
MTF vs. Defocus
EFL vs. Image Height

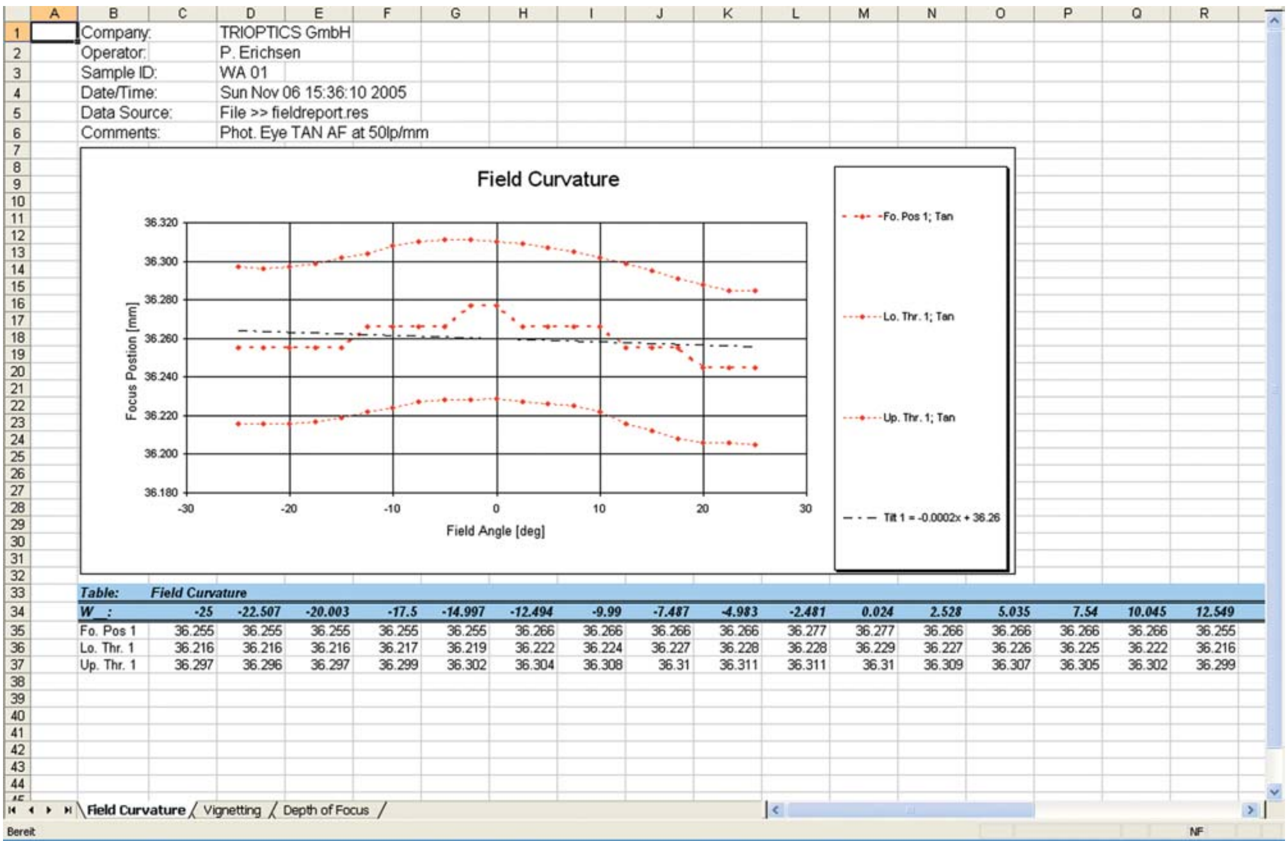
Further graphs or data tables can be easily programmed according to customer requirements.



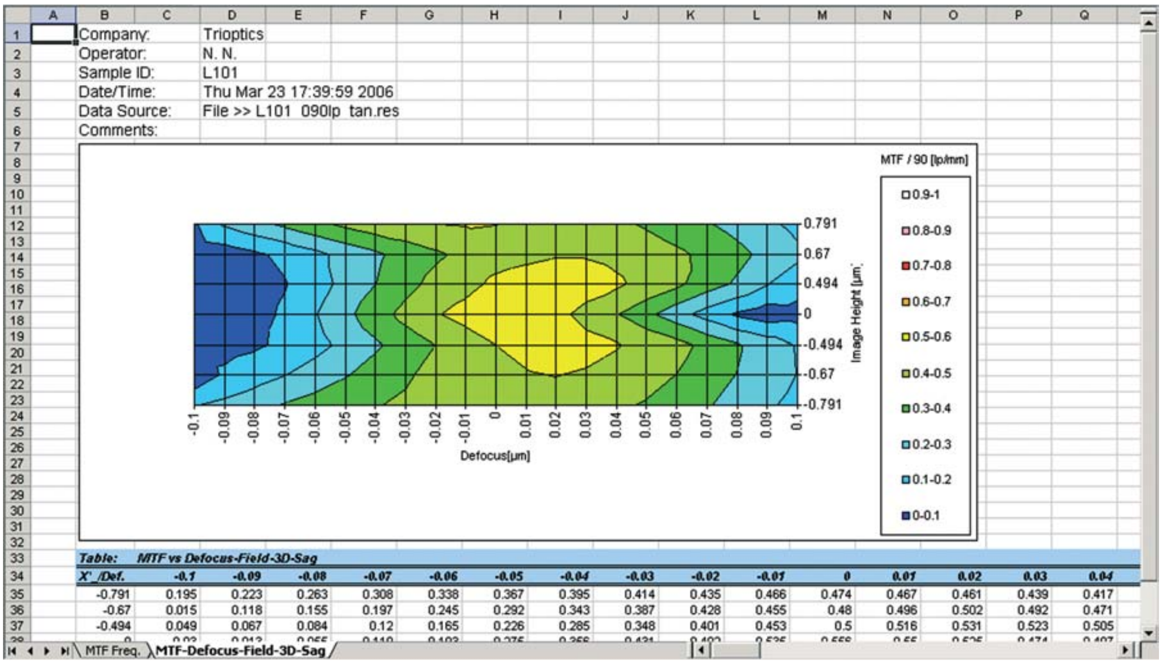
MTF versus Frequency (Field)



MTF versus Field



Field curvature



MTF versus Field and Focus

Specifications

PARAMETER TO BE MEASURED:

MTF in following configurations:

- Infinity conjugate
- Finite conjugates
- Afocal systems
- MTF on-axis, MTF off-axis, off-axis angle +/90°

Further optical parameters:

- EFL(Effective Focal Length)
- FFL (Flange Focal Length)
- PTF(Phase Transfer Function)
- Distortion
- Astigmatism
- Field curvature
- Chromatic aberrations
- Relative Transmission
- Vignetting
- FOW (Field of view)
- Chef Ray Angle

Spectral range:

- VIS (Visible range)
- NIR (Near infrared)
- SWIR (1-3µm)
- IR (Infrared) 3-5µm and 8-12µm

SYSTEM SPECIFICATIONS

- Accuracy MTF: +/-0.02 MTF (directly traceable to international standards)
- Repeatability MTF: +/-0.01 MTF
- Azimuth measurements over 360°
- Spatial frequency: 0-1500 lpm, 0-60c/mm
- Lens focal length range: 0.5-1200mm
- Max. clear aperture: up to 450mm
- Measuring process: manual or fully automated

ImageMaster® PRO4
High Speed Universal Production MTF-Tester

Leadership in testing mobile phone and digital camera lenses

ImageMaster® PRO 4 is the leading instrument for testing mobile phone and digital camera lenses. It is recognized as the industry standard providing highest accuracy and reliability. The calibration of the instrument is directly traceable to international standards.

Please contact the TRIOPTICS representatives for more detailed information.

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