

ISO 11979 Intraocular Lens Testing with OptiSpheric® IOL

TRIOPTICS GmbH



Measurement of

- A. Diopter Power
- B. Resolution Efficiency
- C. MTF

TRIOPTICS OptiSpheric® System



- Market Leader for Lens Testing
- PC based Optical Bench for Laboratory and Production use
- Automatic Measurement Procedures
- Full featured Windows™ Software
- Measures
 - Effective focal Length (EFL)
 - Back Focal Length (BFL)
 - Modulation Transfer Function (MTF)
 - Radius of Curvature (R)
 - Flange Focal Length

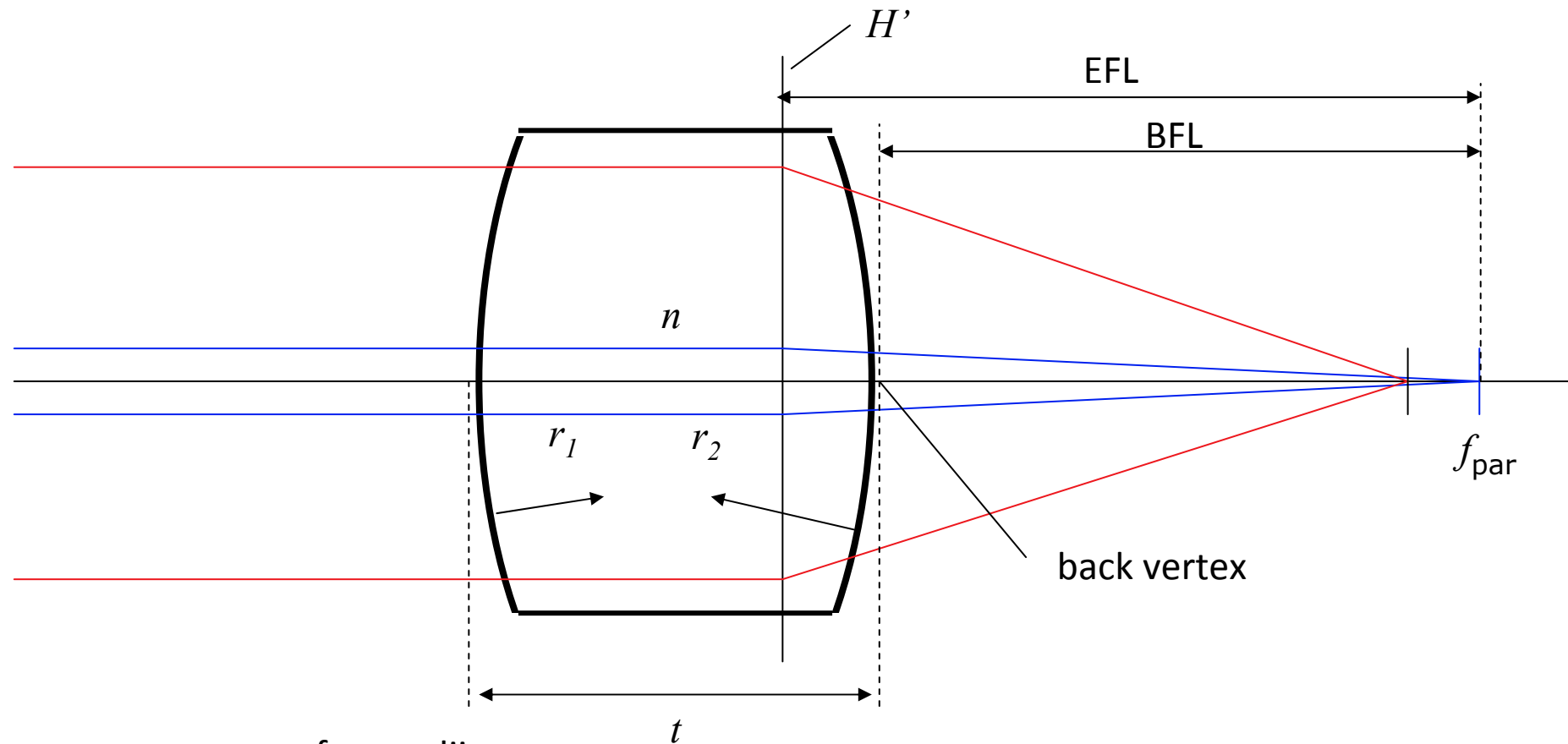
IOL Diopter Power

Definition: The Diopter Power of an IOL is defined as the reciprocal of the reduced paraxial focal length *in situ* for $\lambda=546.1$ nm.

$$D_{aq} = \frac{1000 \text{ mm}}{f_{air}} \times n_{aq} \times Q, \quad \text{where}$$
$$Q = \frac{D_{aq,nom}}{D_{air,nom}} \quad (\text{obtained from the optical design})$$

in situ means in aqueous humor (saline solution)
with $n_{aq}=1.336$ (546.1 nm) at 35°C.

IOL Lens Figure



r_1, r_2	:	surface radii
t	:	center thickness
H'	:	back principle plane
f_{par}	:	paraxial focal plane
n	:	refractive index

Measurement of Diopter Power

ISO 11979 describes 3 different methods:

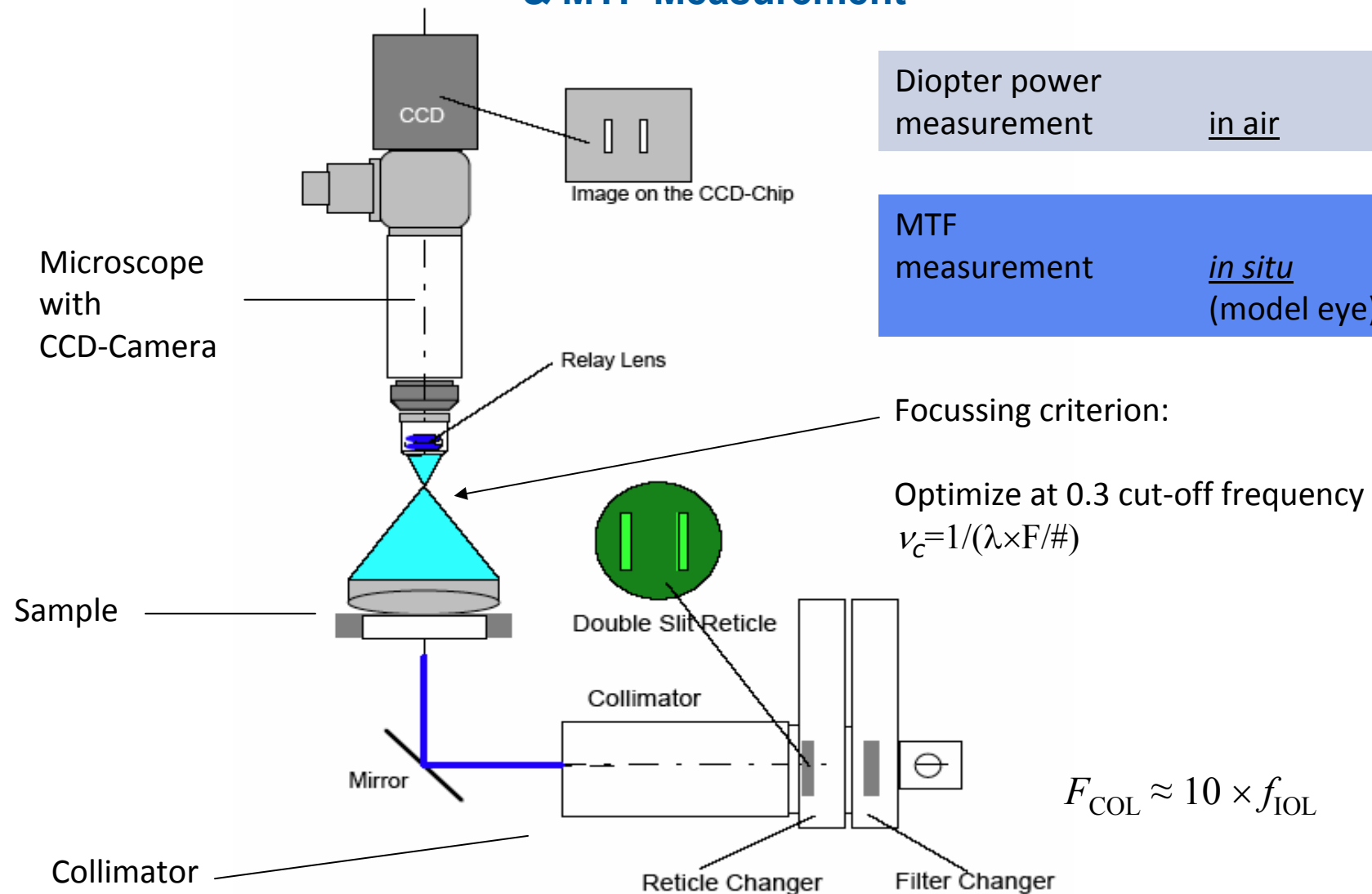
1. Calculation from measured dimensions:
 - a) radii of curvature (2)
 - b) center thickness

2. Calculation from measured BFL with *two corrections* for
 - a) distance between back vertex to back principle plane
 - b) distance between paraxial focal plane to best focal plane (correction for longitudinal spherical aberration)

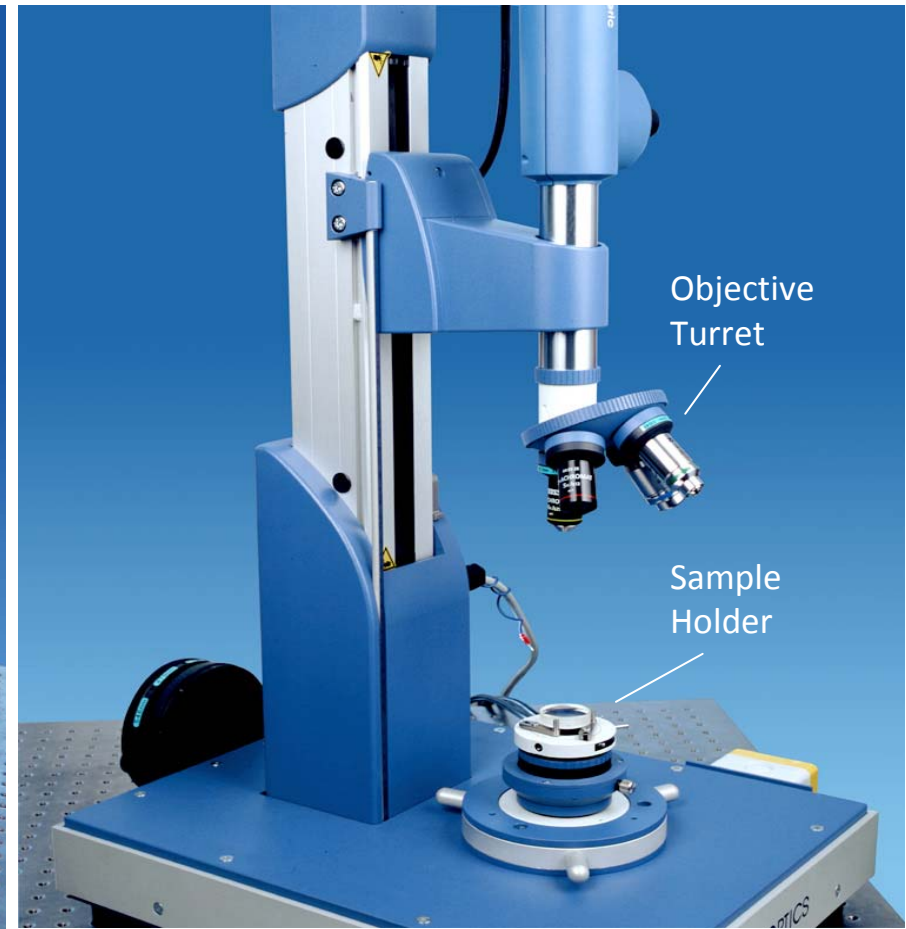
3. Calculation from measured magnification with
 - conversion factor Q to convert between media air \leftrightarrow aqueous solution

Preferred &
most accurate method

Optical Bench for Diopter Power & MTF Measurement

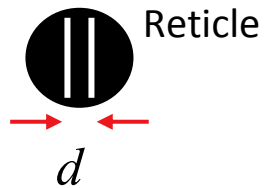
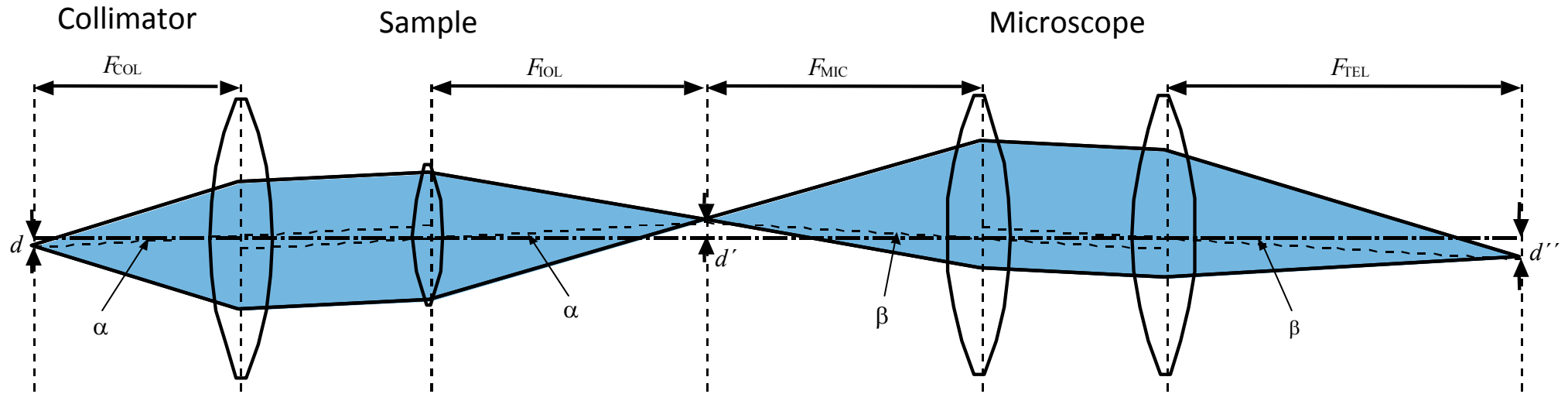


TRIOPTICS OptiSpheric®



OptiSpheric Autofocus Instrument

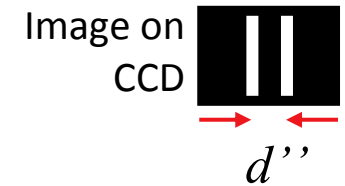
Magnification Method



$$\alpha = \frac{d}{F_{COL}} = \frac{d'}{f_{IOL}}$$

Intermediate Image

$$\beta = \frac{d'}{F_{MIC}} = \frac{d''}{F_{TEL}}$$



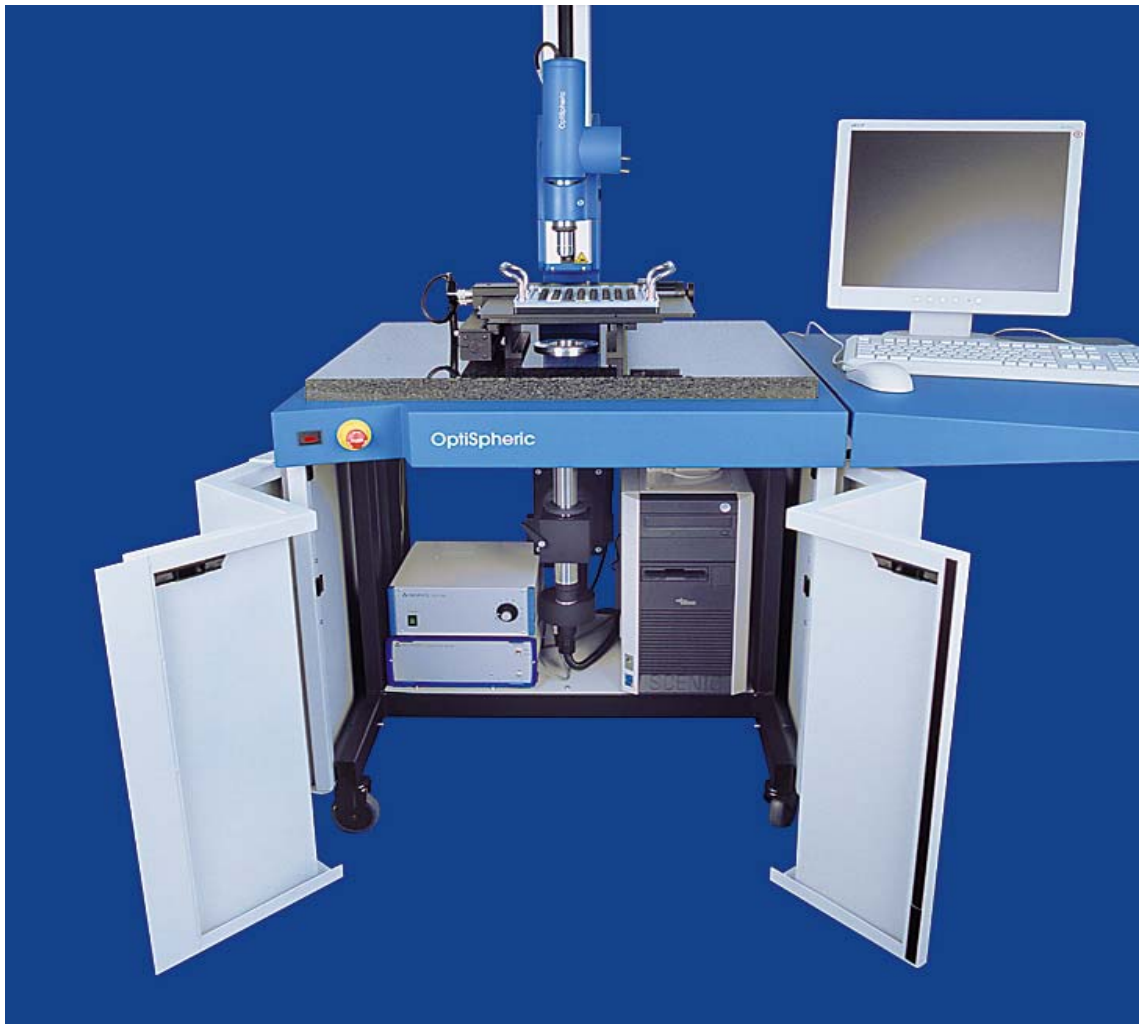
$$f_{IOL} = \frac{d'}{d} F_{COL}$$

$$= \frac{d''}{d} \frac{F_{MIC} F_{COL}}{F_{TEL}}$$

\Rightarrow

$$D_{aq} = \frac{1000 \text{ mm}}{f_{IOL}} \times n_{aq} \times Q$$

OptiSpheric® IOL



OptiSpheric IOL Tray system
for volume testing in production

Diopter Power Measurement Accuracy

Accuracy required by ISO 11979 Standard:

Diopter Power Range (D)	Tolerance (D)
0 ... \leq 15	\pm 0.3
> 15 ... \leq 25	\pm 0.4
> 25 ... \leq 30	\pm 0.5
> 30	\pm 1.0

Accuracy of TRIOPTICS OptiSpheric:

2 ... \leq 40	\pm 0.10
> 40 ... \leq 200	\pm 0.12
> 200	\pm 0.2

Measurement of Resolution Efficiency

Procedure:

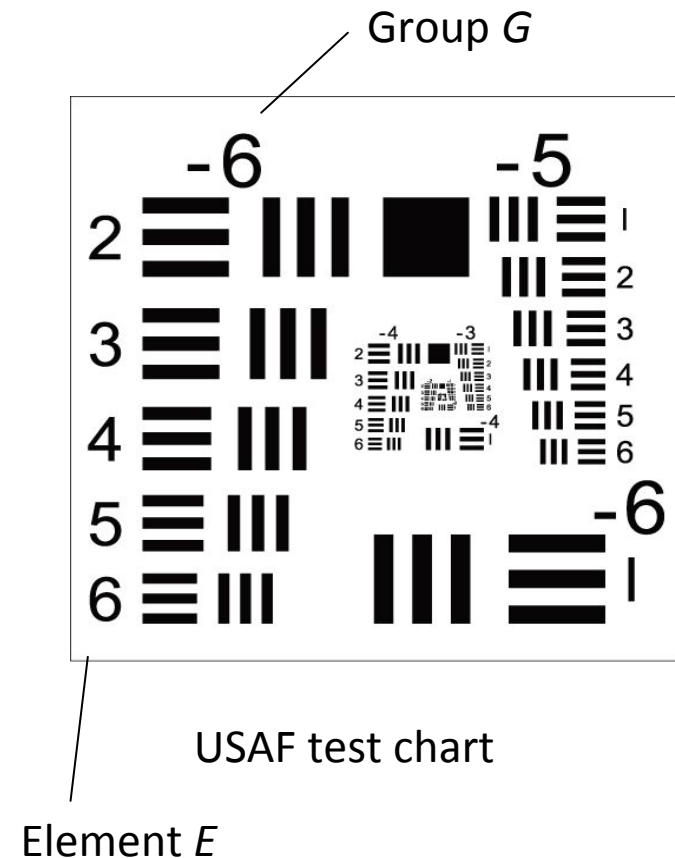
1. Examine the image of an USAF 1951 test chart in the image plane of the IOL in air, using an aperture stop of 3.0 ± 0.1 mm.
2. Determine the finest pattern (Group G , Element E) that is resolved.

Spatial frequency of the resolution limit:

$$\nu = \frac{F_{\text{COL}}}{f_{\text{IOL}}} \times 2^{G + \frac{E-1}{6}} \quad (\text{mm}^{-1})$$

F_{COL} : EFL collimator

f_{IOL} : EFL IOL



Resolution Efficiency

$$RE = \frac{\nu}{\nu_c} \times 100, \quad \text{where} \quad \nu = \frac{F_{\text{COL}}}{f_{\text{IOL}}} \times 2^{G + \frac{E-1}{6}} \quad \leftarrow \text{from USAF chart}$$

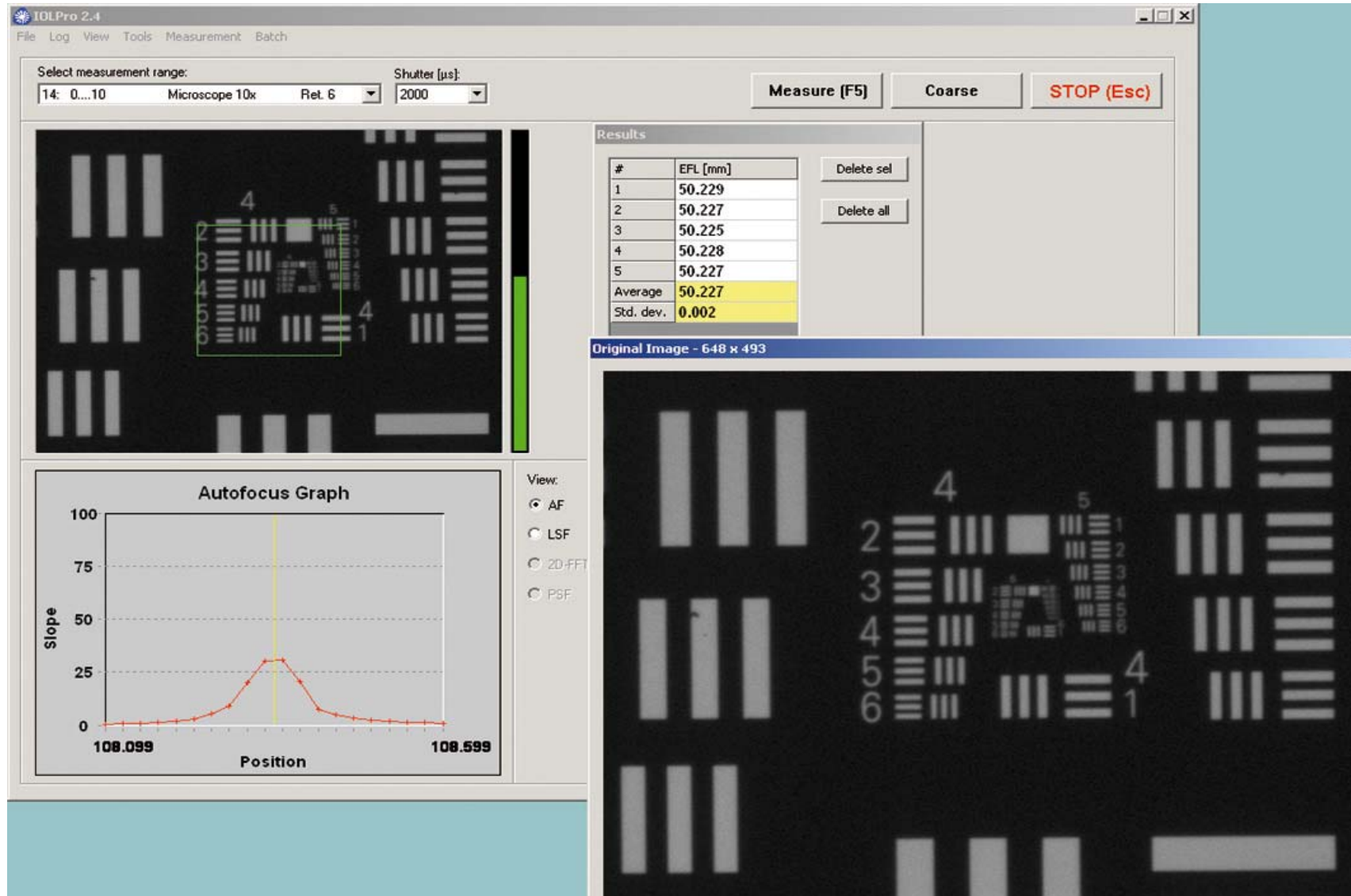
$\nu_c = \text{cut - off frequency}$ ← from diffraction limit

$$= n \times \frac{1}{\lambda \times F/\#} \quad \text{with} \quad F/\# = \frac{f_{\text{IOL}}}{3 \text{ mm}} \quad \text{and} \quad \lambda = 546.1 \text{ nm.}$$

Repeatability and Reproducibility (R&R) is about $(0.2 \dots 0.3) \times \nu_c$

RE can also be derived *objectively* from MTF measurement, by taking the human eye contrast sensitivity function (CSF) into account.

USAF Chart Test with OptiSpheric IOL



Measurement of the IOL MTF

- The IOL is measured inside a model eye
- The IOL in the model eye is measured in a standard optical bench for MTF measurement (OptiSpheric)
- The model eye is almost aberration free, thus measured aberrations are from the IOL.

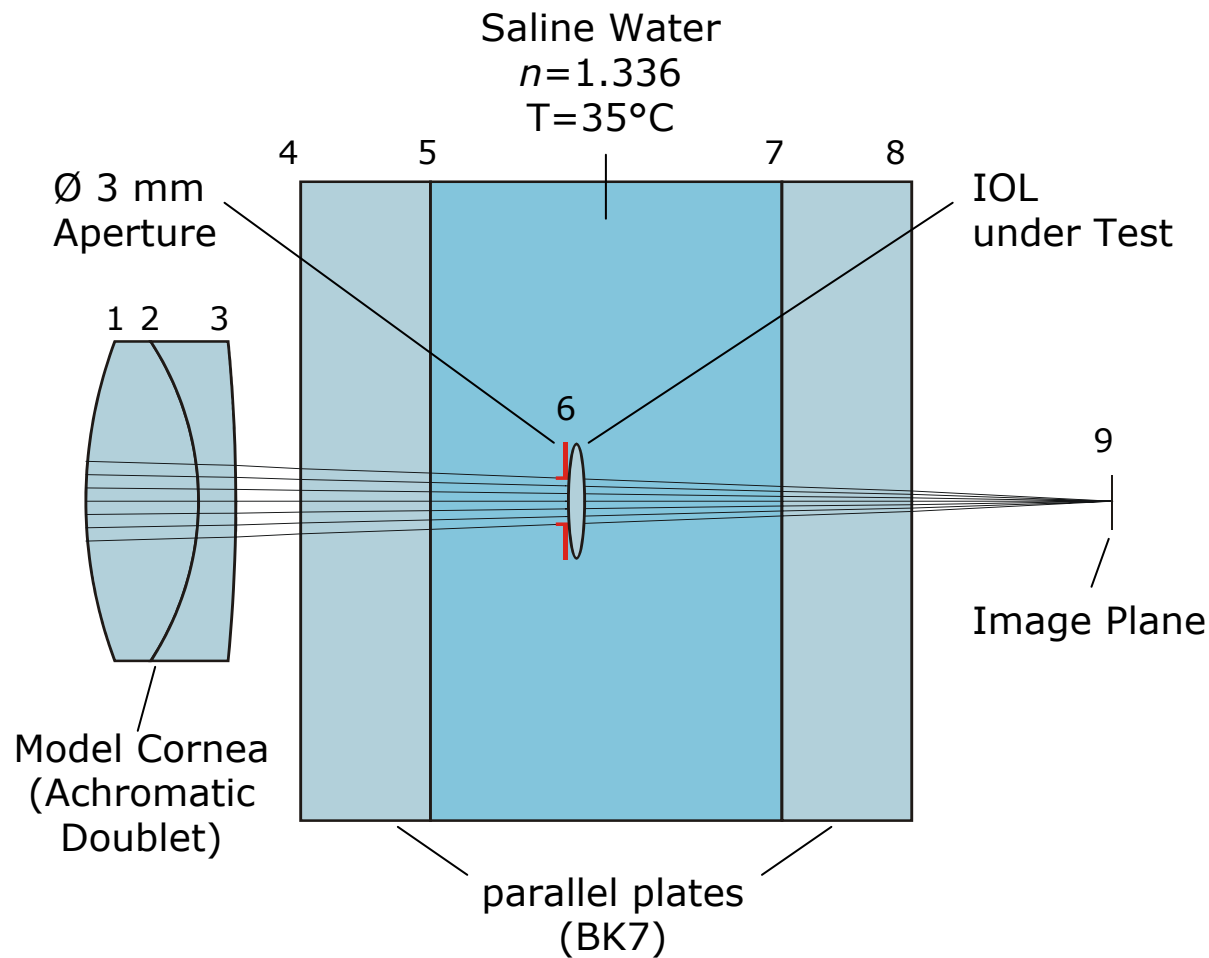
Measurement conditions:

Wavelength:	$\lambda = 546.1 \text{ nm}$
MTF optimization frequency:	100 mm^{-1}
Measurement Aperture:	3 mm
Media Refractive Index:	$n = 1.336 \pm 0.005$
Temperature: (ambient temperature applicable)	35°C



Model Eye

Model-Eye Design



Surface	Radius	Dist.	Material
1	24.590	5.21	SSK4
2	-15.580	1.72	SF8
3	-90.200	3.00	Air
4	plane	6.00	BK7
5	plane	6.25	$n=1.336$
6	plane	10.0	$n=1.336$
7	plane	6.00	BK7
8	plane	9.25	Air
9	plane		Image

Model Eye

Top side with upper window removed

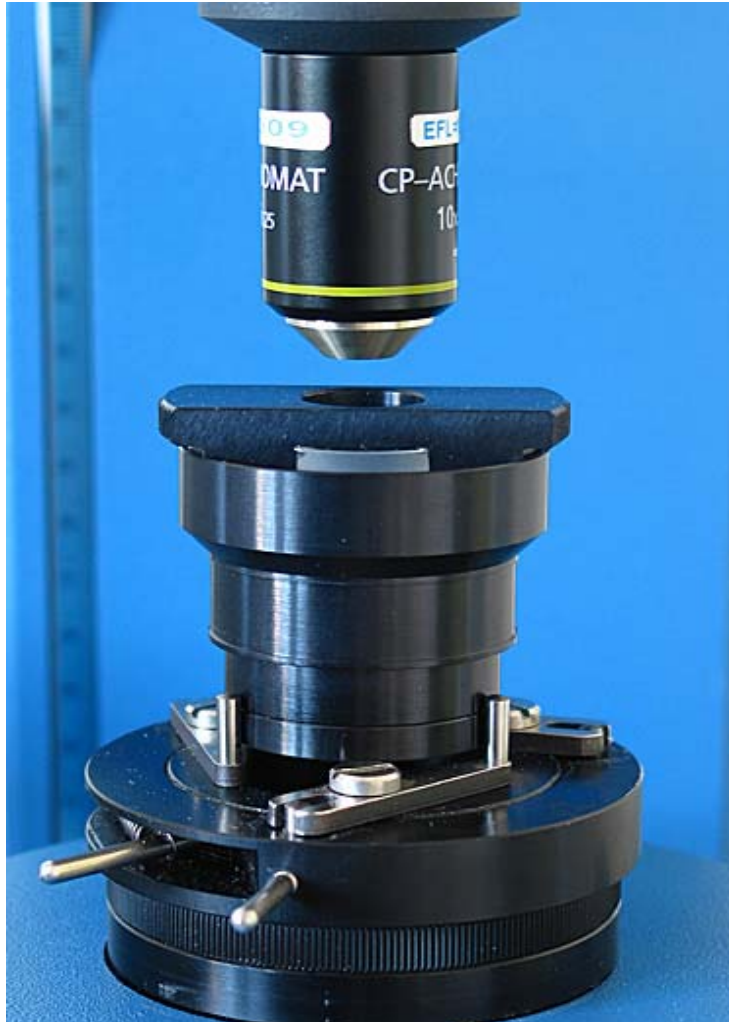


Bottom side with
achromatic doublet
(model cornea)

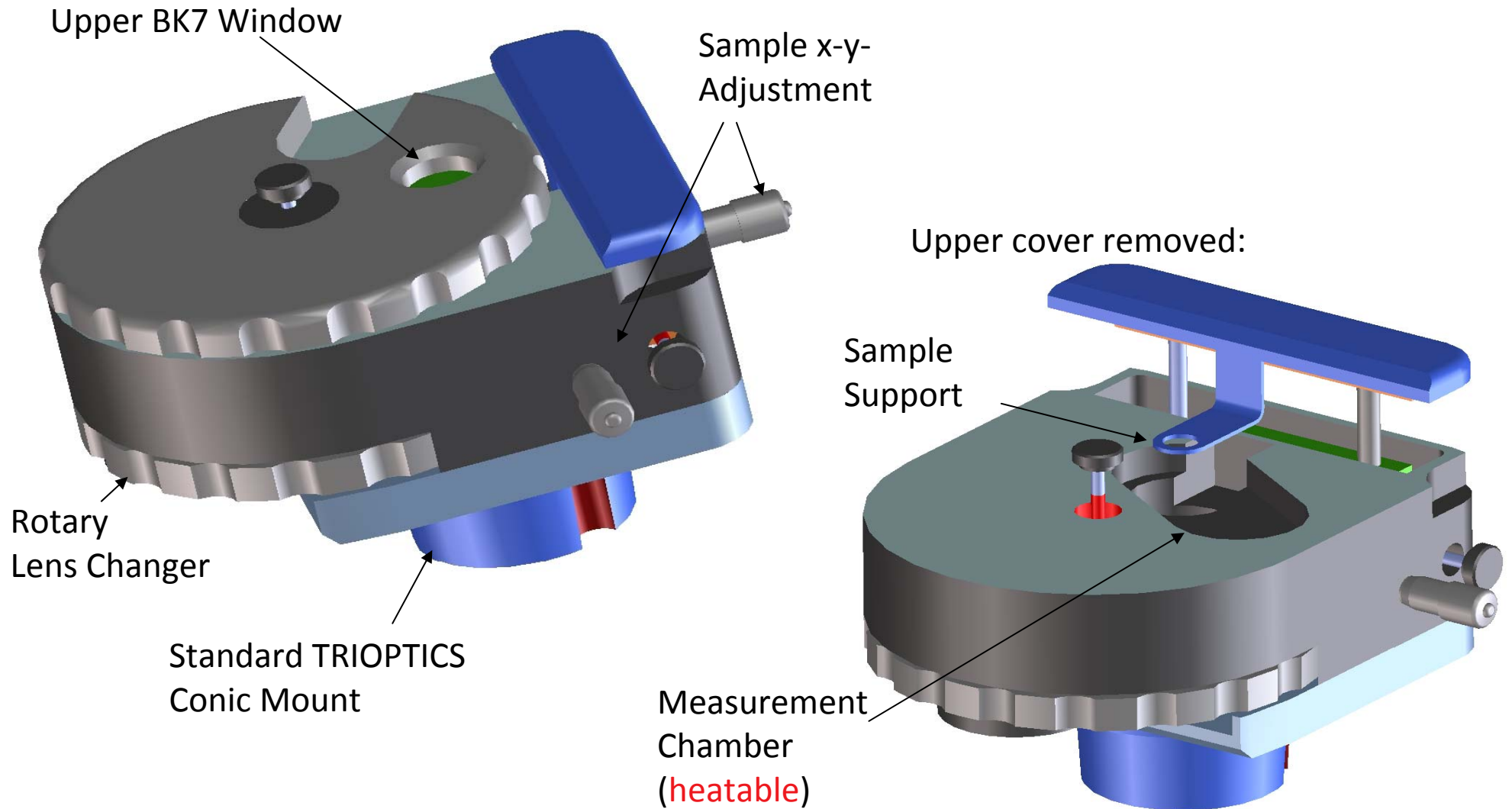


TRIOPTICS Model Eye

Measurement Situation



Model-Eye New Design

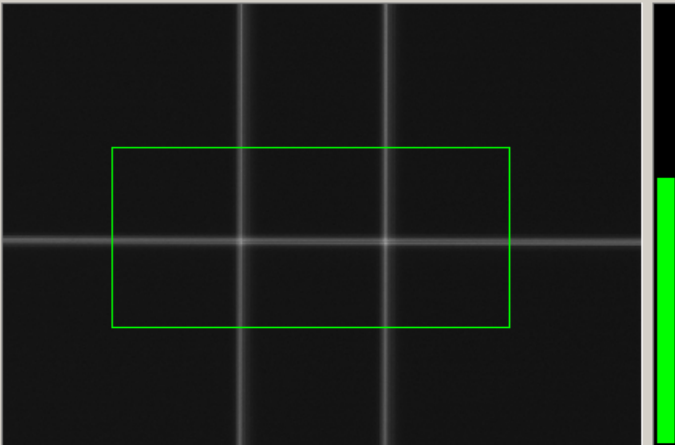


IOL PRO Software Interface

IOLPro 2.4.1
File Log View Tools Measurement Batch

Select measurement range: 4: 50...100 Mikroskop 10x Ret. 2 Shutter [μ s]:

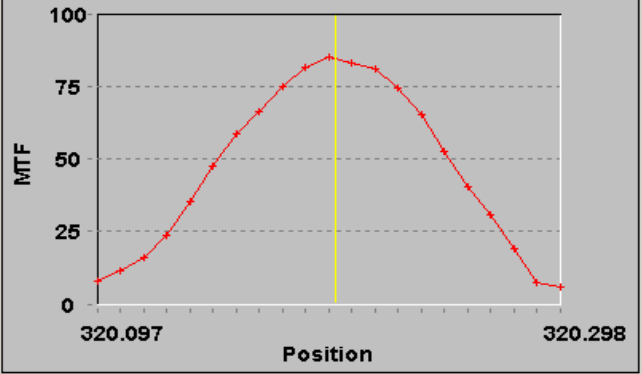
Measure (F5) Coarse STOP (Esc)



Commands - C:\Program Files\TRIOPTICS GmbH\IOLPro\silicone dpt10...1...

#	Command	Result
1		
2	set_range(4)	
3	set_eff(10)	
4	a_fine(.0.1, 0.1, 21, e)	320.197
5		
6	calc_eff(clb,x)	58.657 mm
7	set_dpt_formula (1000/x)	17.048
8	check_dpt (1,200)	Passed
9	set_optimise(25)	
10	a_fine(.0.1, 0.1, 21, s)	320.2
11	check_mtf (s, 25, 50)	85.57

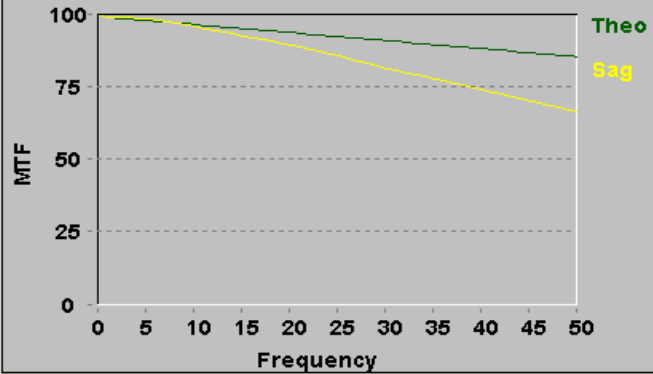
Autofocus Graph



View:

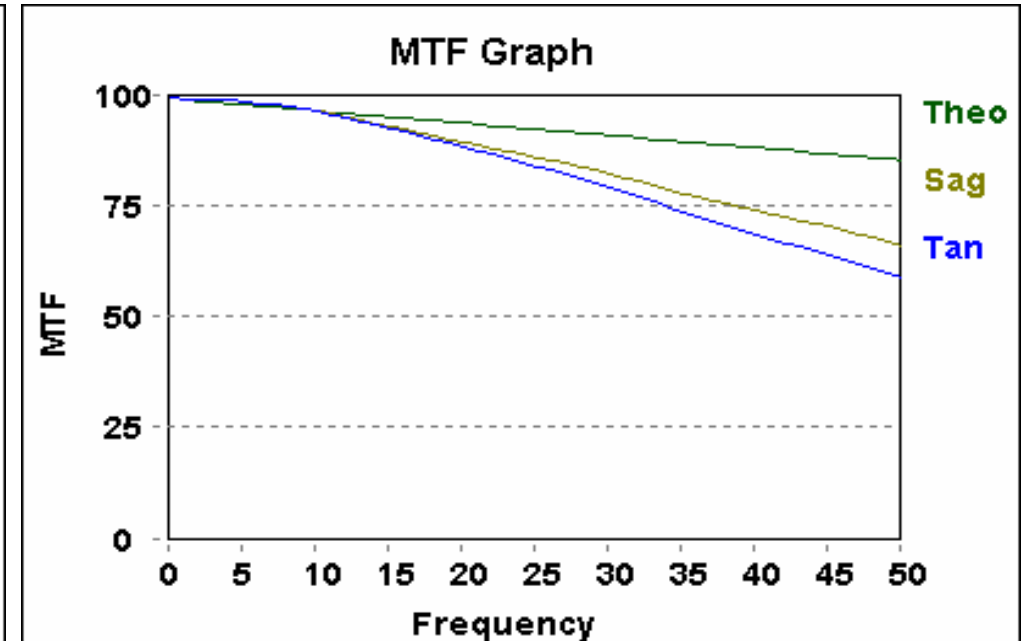
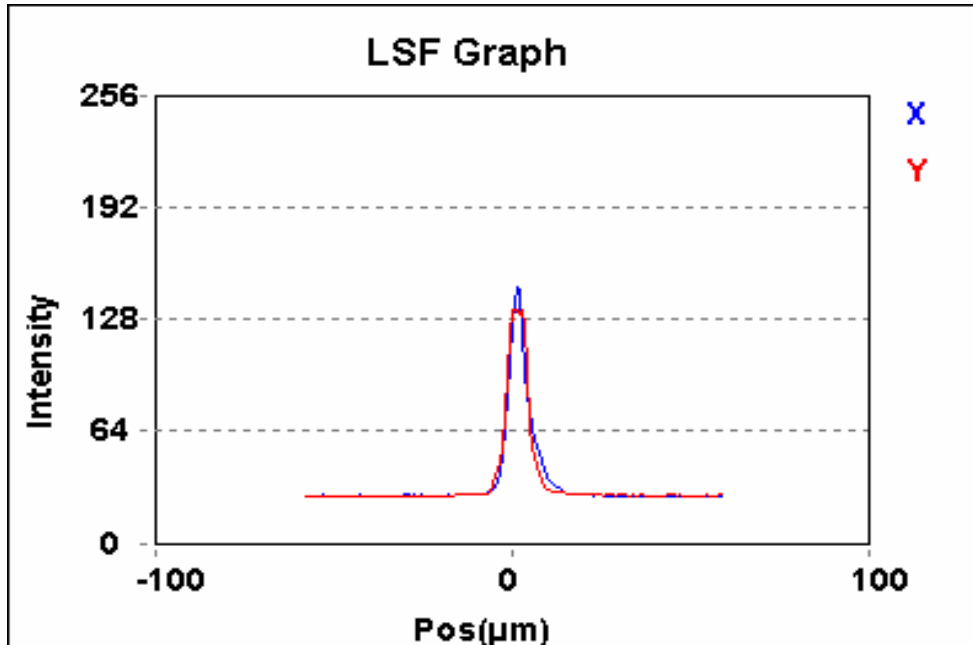
- AF
- LSF
- 2D-FFT
- P9F

MTF Graph



Start IOLPro My Computer IOLPro 2.4.1 help - Microsoft I... help - Microsoft I... help - Microsoft I... << 14:34

1D MTF Evaluation

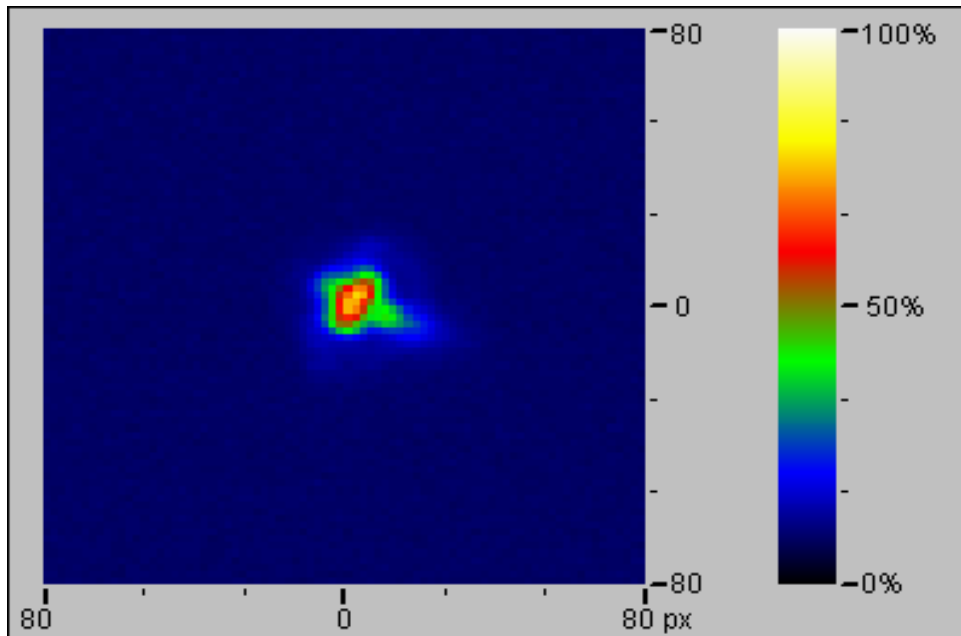


Linespread Function

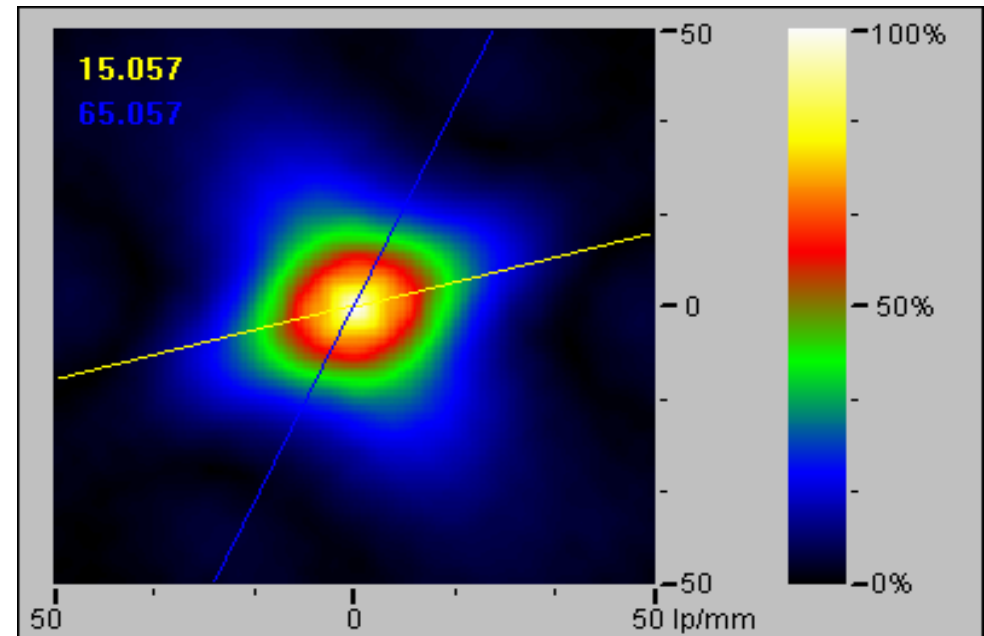
MTF Graph for both **tangential** and **sagittal** direction, compared to diffraction limit (Theo).

OptiSpheric MTF measurement accuracy: 2% ($\lambda=546$ nm, 0...300 lp/mm)

2D MTF Evaluation



PSF




2D FFT of PSF,
axis of astigmatism indicated

Instrument Software Features

- Real-time 2D camera image
- Real-time MTF evaluation
- Fast Autofocus procedure
- Graphical through-focus scan display
- Password protected user modes
- Instrument control by flexible scripting language
- User defined pass/fail threshold values
- Measurement certificates output including graphics
- Easy to use in the production environment, flexible for the laboratory
- Tray systems with automatic sample centering routine
- (many more) ...

HTML Certificate Output

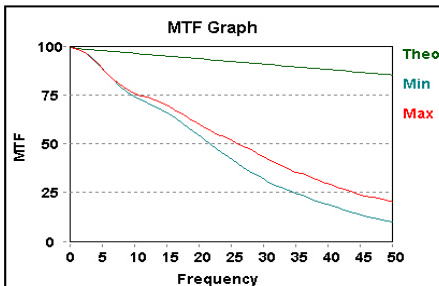
Trioptics Protocol file:///Q:/IOL/Screenshots/Certificate2.htm1



CERTIFICATE

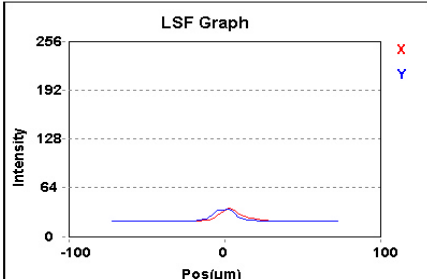
Company : Trioptics
 Operator : EduardS
 Serial No. : 123 ## FGTE 90
 Temperature : 100
 Comments : Test
 Time/Date : 14:49:55 06/23/05
 Measured With : **TRIOPTICS** - IOLPro 2.4.1

Comm and	Results
Set range	50...100 mm Mikroskop 10x Ret. 2
Set EFL	10 mm
Focus Pos	320.197 mm
EFL	58.6572 mm
Diopter	17.048
Diopter check (1.0, 200.0)	17.0482
Set optimise MTF	25 1/mm
Focus Pos	320.2 mm
MTF check (Sag, 25 1/mm, 50)	85.57
Result	Passed

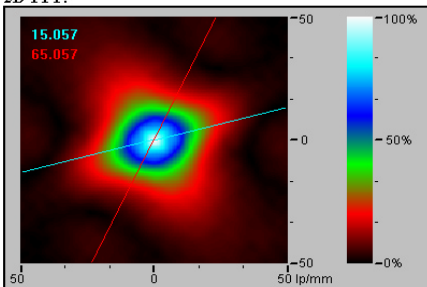


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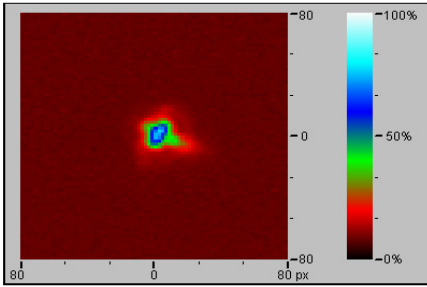
Trioptics Protocol file:///Q:/IOL/Screenshots/Certificate2.htm1



2D-FFT:



PSF:



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Accessories



Motorized Reticle Changer
incl. Control Electronics

XY-Adjustment

Sample Holders



Thank You four Your Attention!



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