

*Automated optical metrology of small lenses*

# *Lentino*

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*Automated wavefront sensor for the metrology of small aspherical and digital camera lenses in the diameter range 0.5mm to 20mm*



# Lentino Specifications - Hardware

KEY FEATURES	
<b>Measurement technique</b>	Wavefront sensor based on the Shack-Hartmann principle.
<b>Mounting option</b>	Can be mounted vertically or horizontally.
<b>Mounting of optical elements</b>	Optical system to be tested easily mounted on central mounting slide.  User can easily make the mounting for a specific element.
<b>Easy access to optical elements</b>	Access to the optical group is on one side of the instrument, to enable on-line alignment.
<b>Alignment technique: hardware and software</b>	<b>Hardware:</b> All optical elements mounted along the optical axis.  The carriage carrying the test system can be moved along special steel rods not to introduce tilt.  <b>Software:</b> Easy alignment of lens group via software: the software gives graphical indication of the misalignment of the optical system. This helps to quickly align the lens group.
<b>Calibration</b>	A carriage carries the calibration unit used to calibrate the collimator.  The carriage can be removed once the calibration image has been taken.  The system comes with a high-quality light source plus a pinhole calibration unit.  Using these, all the tests will be done in external illumination mode.
<b>Test in parallel light or at the focus of the lens</b>	Test in parallel light (with a collimator) or in light at the focus of the lens for a complete picture of the element.
<b>No special hardware required for running the system</b>	System can be controlled from a standard Desktop or Laptop computer running Windows 2000/XP.
<b>User friendly software</b>	Sensoft Lentino

PHYSICAL	
<b>Dimensions (L x W x H)</b>	22 x 20 x 60 cm
<b>Weight (approximate)</b>	15Kg
<b>Input voltage (for motor movement)</b>	Power supply 500mA,9V

PERFORMANCE	
<b>No of spots with standard camera</b>	23x23
<b>Maximum no. of spots (large camera)</b>	64x64
<b>Repeatability of measurements of the Zernike polynomials</b>	$\lambda/300$
<b>Measure aspherical elements with very high spherical aberration</b>	About 15% variation in LSA (longitudinal spherical aberration)
<b>Repeatability of wavefront measurements</b>	$< \lambda/200$
<b>Accuracy</b>	About $\lambda/10$
<b>Wavelength range</b>	0.35-1.1 $\mu$
<b>Dynamic range of measurements by sub-pupil (tilt subtracted, depends from combination of aberrations)</b>	$\sim \pm 50 \lambda$
<b>Acquisition speed (standard camera). Faster speeds available on request</b>	4Hz

APPLICATIONS	
<b>Elements that can be tested</b>	Lenses Group of lenses Aspheric lenses Digital camera lenses
<b>Diameter range</b>	From 0.5mm to 20mm
<b>NA range</b>	About 0.65 to 0.02
<b>Environment</b>	Laboratory or production

# Lentino Specifications - Sensoft Software

Sensoft Lentino: The modular software package that we offer with our system can:

- Fully control the hardware of Lentino
- Perform the Shack-Hartmann (SH) analysis
- Be driven by external commands, like in the production line.

## LENTINO: THE 13 STEPS FOR THE QUALITY CONTROL OF YOUR OPTICAL SYSTEM

### Step 1:

The quality of the image taken with the camera

*Automatic optimization of the SH image*

The accuracy of the analysis depends on the quality of the image taken with the camera. This is ensured by:

- Automatic control by software of the optimal exposure time
- Dark calibration acquisition and automatic subtraction where required
- Averaging of several images to improve the signal to noise ratio

### Step 2:

Control of the optical parameters of your system

*Help from the software for ensuring that the optical parameters required for the analysis are correct*

User should enter the diameter and the focal length of the optical system. The software will do the rest of the job for you and will tell you if the optical parameters specified are consistent

### Step 3:

The quality of the calibration: on-line calibration of the system.

*We do not use pre-calibrated reference images!*

The Shack-Hartmann method consist on a differential analysis between a calibration image also called "Reference" and the image of the optical system under test. Thus, the accuracy of the analysis strongly depends on the quality of the calibration image. *Our system does not come with a pre-calibrated reference image*, but allows you to take a new reference image whenever you require change an optical setup, in the same conditions of the optical system that you are testing

### Step 4:

The quality of the Shack-Hartmann spots

*Analysis of small defects of the optical element*

Our software contains a full set of tools specific for the analysis of the centroids of the spots. From this analysis, you will be able to inspect surface defects or zones in your optical system, asymmetry in your system, intensity and signal to noise distribution

### Step 5:

Inspection of zones

*How to exclude a defective zone from the analysis*

A specific zone can be selected as a sub image and the software can give in real-time the profile of the spots in that specific zone.

If the zone is considered defective and this is affecting the final analysis, it can be marked and isolated by software.

### Step 6:

Are you working in parallel light?

*Do not lose time in adjusting the test image*

We use a proprietary algorithm to collimate, in a loop, the light coming from the test element.

The procedure can also be run automatically in the motorized system

### Step 7:

Is the reference and test image aligned?

*Do not lose time in adjusting the test image*

Be guided by the software in this crucial step for a quick alignment

### Step 8:

Check the mounting of the optical elements

*Is your mounting destroying the optical quality?*

It is easy to destroy the final optical quality of your optical system if the components are not mounted correctly

Several graphical images and indications of the points where the mounting stresses your optics allow you to optimize the mounting for your system

### Step 9:

Aberrations of the optical system

*Many options*

Low order and higher order aberrations up to Zernike 70 terms

Choice among 4 types of (3 Zernike and Seidel) polynomials for output

The output is given as a text file or as an Excel file where aberrations and parameters from wavefront reconstruction are reported

### Step 10:

Wavefront reconstruction, P-V, rms

*Look at the wavefront due to individual aberrations or a combination of aberrations*

Our software can reconstruct the wavefront with the possibility of mathematically subtracting the contribution of the aberration coefficient(s) selected by the user

P-V (peak-to-valley) and rms can be specified in nm or in units of waves

We give also the possibility to check in an on-line loop the repeatability of the analysis

### Step 11:

MTF, PSF, Spot diagram, Encircled Energy distribution, Strehl ratio

These are some of the parameters given as output from our analysis. Many of them are also given in graphical form

### Step 12:

Take the guesswork out of alignment

*Be guided by the software as to the direction and magnitude of decentering/tilt to get the correct alignment and spacing*

The software gives you the amount of the correction to be applied for correcting misalignment if you are testing a composite optical system

The computation is based on an empirical calibration that can be determined using any ray-tracing program

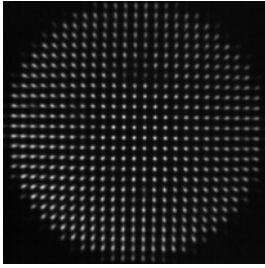
### Step 13:

Focal length of the system

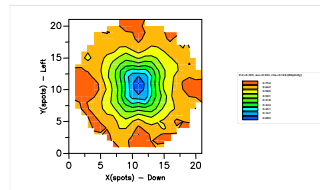
With Lentino, the effective focal length of the optical system can be determined. This procedure is automatic in the motorized version

## LENTINO IN YOUR PRODUCTION LINE

Lentino can be easily adapted to the production line. In fact, the system is able work in a close-loop with the manufacturing machine. An optional software module contains the tasks for the communication of operative commands and results between the systems. The communication protocol can be easily adapted to any specific request.



Shack-Hartmann image of an aspheric lens



Asymmetric intensity distribution of lens

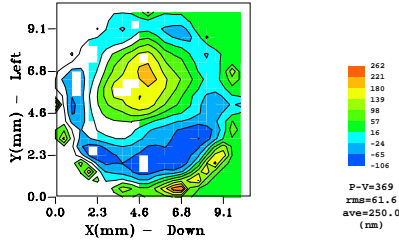
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Mr. Test0001	2002-09-08	12:40:28	4074 sec.	731	30
Mr. Test0001	2002-09-08	11:30:31	574 sec.	803	30

Abs.	x	CX(mm)	CY(mm)	err	Cloned	err	angle	err
Def	0	2		19.2	33.2	7.01	4.80	
Tilt	1	-3.4	-28.0	28.2	29.7	3.49	1.56	-96.8
SAG	0	4		79.8	7.6	56.49	5.37	
Axial	2	40.0	24.1	46.7	25.1	17.04	5.45	31.3
TComa	3	7.8	7.4	10.8	10.8	4.82	7.05	45.0
GAst	4	4.0	-3.3	5.2	11.0	3.46	7.75	-39.0
SAG	0	6		58.6	4.3			

Wavefront (values in nm)	Max.	Min.	Ave	Rms	P-V	Stdev
Residual	62.1	-70.2	-67.4	31.3	132.2	0.840
Actual	506.7	-201.7	-325.9	116.2	708.4	0.899
Potential	172.8	-296.4	-37.3	84.2	409.1	0.291

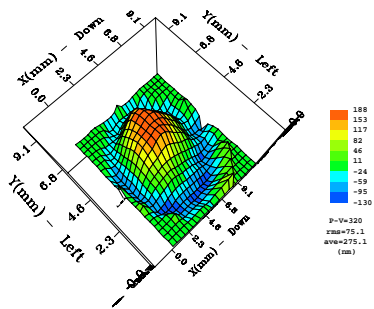


Contour of wavefront, tilt subtracted

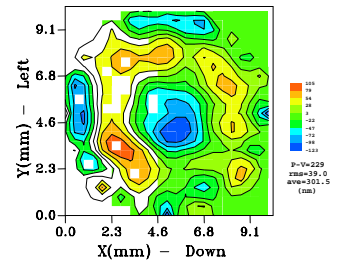
Image	PN21	PN22	PN23
Date	2011/2003	2011/2003	2011/2003
Time	10:53:44	10:58:07	11:14:26
Coef	Angle	Coef	Angle
Defocus	-10	448.3	198.6
Tilt	1995.9	-39.4	2043.6
Coma	53.3	-5	13.1
3rd order Spherical	1.3		-12.4
Asigmatism	10.3	-50.7	58.2
Triangular Coma	31.4	-9	30.2
Quadratic Astigmatism	26.1	-2.5	7.2
DOVA1	4.27		4.34
PV(A)	388.1		341.4
DOVA2	4.86		3.60
PV(F)	246.9		310.5
DOVA3	4.36		3.86
PV(R)	348.9		370.5

Output from analysis in Excel format

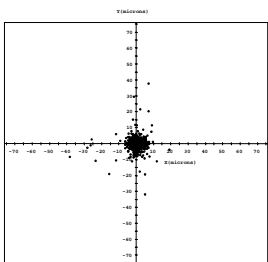
Output from analysis: aberrations and wavefront



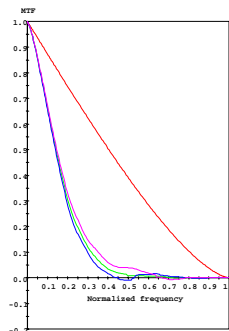
3D of wavefront, tilt subtracted



Contour of wavefront, user selected low-order aberrations subtracted



Spot diagram



MTF