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Plμ 2300
Optical Imaging Profiler

Non-contact measurement
of optical surfaces

Introduction

Sensofar's PLμ 2300 is the perfect tool for the measurement of optical components. It allows three-dimensional measurements of moulds and finished optical surfaces to evaluate form and texture parameters. Using the high-end technology developed by Sensofar, PLμ 2300 is able to measure using the high repeatability of interferometrical techniques to evaluate roughness, and the high numerical aperture and Super Long Working Distance conventional objectives in confocal mode to evaluate three-dimensional data up to 71 degrees slope on smooth surfaces.

Key benefits

Non contact fast optical profiler. Avoids scratching, flexing and dumping typical of contact profilers.

PLμ 2300 is a confocal, conventional and interferometer microscope that provides Confocal, Phase Shifting and Vertical Scanning Interferometry measurement techniques. The choice of the technology being used is as easy as selecting the appropriate objective in the software.

Three dimensional topography from 4.9 x 3.7 mm2 to 91 x 68 mm2 in less than 5 seconds and 0.1 nm repeatability. Larger measurements can be done using the stitching method. Local slope up to 71 degree in smooth surfaces and samplings from 3.6 to 0.1 mm.

Figure 1: 30 mm vertical range and up to 71 degree local slope.

Fast two dimensional profiling (up to 300 mm) with Super Long Working Distance objectives in confocal mode. Up to 0.1 mm sampling and 35 degree on smooth surfaces.

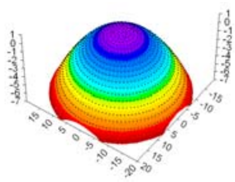
30 mm vertical range. Repeatability of 0.1 mm in the full range for non connected fields using optical gauge sensor.

Point by point Coordinate measurement of shape based on intelligent autofocus. User selected one or two dimensional trajectories can be defined in the X and Y plane. A predefined surface can be specified in order reduce acquisition time, while keeping the possibility to predict shape. Special filters can be used to define coordinate points to a roughness surface such as on the moulds.

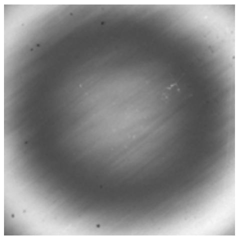
Non-contact thickness measurement of the lens up to 23.5 mm.

High thermal stability using a granite column guarantees small drift for the measurement of non-connected points. It also provides 400 mm vertical room to hold large samples.

Easy centering of the lens by leveling the base with a Tip-Tilt and interferometrical objective to find the null fringes position of the apex.



Non-contact fast 2D and 3D Coordinate measurements up to 300 x 300 mm^2.



Roughness measurement using PSI interferometrical techniques with 0.1 nm repeatability

Objectives

The PLμ 2300 can use three different types of confocal objectives. The EPI objectives are designed to have the highest numerical apertures, up to 0.95, working very close to the surface. These objectives give the highest repeatability of the system and are ideal for flat and thin samples. The ELWD and SLWD series are objectives of Extra Long Working Distance and Super Long Working Distance, up to 21 mm. They have low numerical aperture and are used in samples where the objective can collide physically. The PLμ 2300 can also use interferential objectives. The TI series are based on Michelson interferometer with an external reference mirror mounted on two tip-tilt screws. The DI series are Mirau objectives that create the interference internally by dividing the wavefront with a beamsplitter. The TI series are used for low magnification and have low numerical aperture, being objectives for the measurement of very flat and thin samples. The DI series can have up to 0.55 NA.

Confocal objectives

	Working Distance (mm)	Numerical Apperture	Field of View[1]	Spatial Sampling	Maximum Slope	rms (3σ)[2] (nm)
5X EPI	23.5	0.15	2730 x 2050	3.56	8.5º	<100
10X EPI	17.3	0.3	1260 x 946	1.64	14º	<40
20X EPI	4.5	0.45	625 x 468	0.81	21º	<20
50X EPI	1.0	0.8	273 x 205	0.35	42º	<4
100X EPI	1.0	0.9	126 x 94	0.16	51º	<2
150X EPI	0.3	0.95	91 x 68	0.10	71º	<1
20X ELWD	13.0	0.4	625 x 468	0.81	19º	<20
50X ELWD	10.1	0.55	273 x 205	0.35	27º	<8
100X ELWD	3.5	0.8	126 x 94	0.16	42º	<4
20X SLWD	24.0	0.35	625 x 468	0.81	16º	<20
50X SLWD	17.0	0.45	273 x 205	0.35	21º	<8
100X SLWD	6.5	0.7	126 x 94	0.16	35º	<4

Interferential objectives

	Working Distance (mm)	Numerical Apperture	Field of View[1]	Spatial Sampling	Maximum Slope	rms (3σ)[2] (nm)
2.5X TI[3]	10.3	0.055	4975 x 3730	6.48	3.2º	PSI[4]: 0.1nm
5X TI[3]	9.3	0.1	2490 x 1860	3.24	5.6º	
10X DI	7.4	0.23	1245 x 943	1.62	13.1	VSI[5]: 1nm
20X DI	4.7	0.3	614 x 460	0.80	17.7º	
50X DI	3.4	0.42	245 x 184	0.32	25º	

(1) Using a CCIR 1/2 inch CCD camera (768 x 576 pixels) and 0.5X optical tube lens.
(2) Difference between two consecutive measurements on a high quality calibration mirror.
(3) TI series are mounted without a nosepiece. No other objectives can be used while using one TI objective.
(4) PSI 0.1nm rms with null fringes using PZT close-loop scanning device.
(5) VSI 1nm rms with null fringes using PZT close-loop scanning device.

Confocal objective 20X EPI

Interferential objective 5X TI

Interferential objective 50X DI

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Standard software

Using the standard software provided with PLμ 2300 it is possible to measure single profiles, extended profiles, single topographies, extended topographies and thickness. The measurement of texture and shape of optical components is easily achieved.

Extended Profiles (Shape evaluation)

For 2D form measurement, PLμ 2300 is able to acquire profiles up to 300 mm length using the extended profile option (figure 2). In this mode, a confocal objective acquires single profiles within the field of view. Then the system moves in the X direction and overlaps up to 10% of the next acquired profile. The software stitches the contiguous profiles. The maximum slope achieved by PLμ 2300 is 71 degree. Nevertheless, because of the typical shape of a lens, it is not possible to avoid physical collision with the mechanics of the objective. Sensofar offers the best solution in the market to measure up to 35 degree using a 100X Super Long Working Distance objective and lateral sampling up to 0.10 mm.

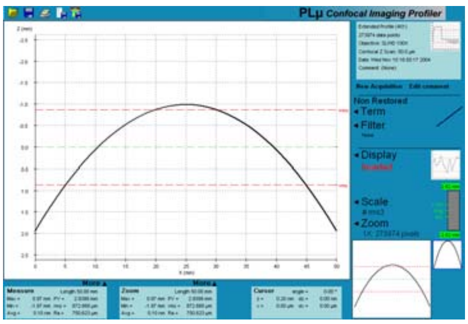


***Figure 2**: Extended profile of a lens. Using profile stitching it is possible to measure profiles up to 300 mm length.*

Single and Exteded Topography (Roughness evaluation)

For 3D roughness evaluation, PLμ 2300 is able to acquire single topographies from 91x68 mm2 up to 4.9x3.7 mm2 in few seconds. Using PSI technique it is possible to acquire single topographies with 0.1 nm repeatability. Roughness can be extracted from the measurement by the use of roughness filtering according to ISO and ASME standards. Larger fields can be acquired by the use of extended topography in which single topographies are acquired within the field of view of the objective. The system moves the sample in X and Y, overlaps up to 10% of the measurements and correlates them to avoid stage non-linearities.

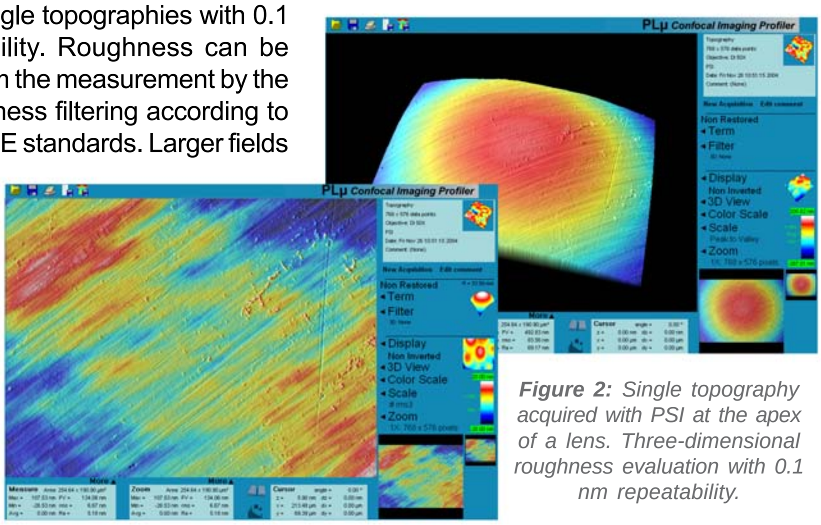


***Figure 2:** Single topography acquired with PSI at the apex of a lens. Three-dimensional roughness evaluation with 0.1 nm repeatability.*

Coordinate measurement

Sensofar three-dimensional coordinate measurement of optical surfaces allows the non-contact, fast and precise measurement of single non-connected points for the evaluation of shape parameters. It is useful for aspheric components. The user defines the XY trajectory, the Z surface predefined and the filter for each point in order to evaluate local shape. It is possible to measure polished smooth surfaces as well as rough surfaces such as moulds. Using a 100X SLWD objective it is possible to measure up to 35 degree without physical collision. Once the user has selected the acquisition parameters, the system moves point by point and executes a fast and intelligent autofocus to locate the surface. The result of the full measurement is an X, Y and Z file containing the precise measurement of the shape.

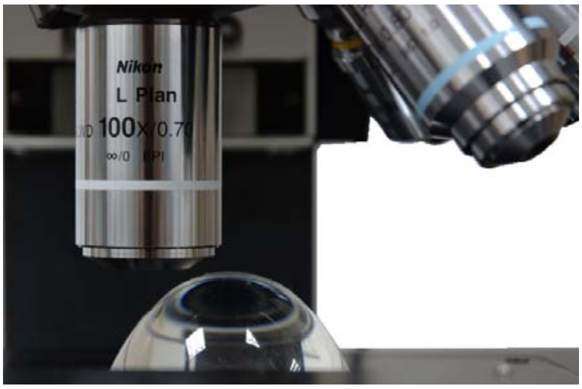


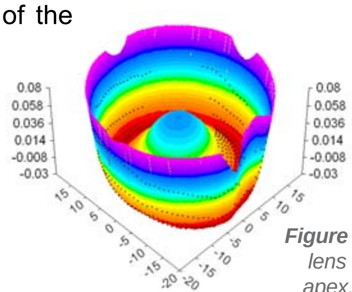
Figure 3: Measurement setup of an aspheric lens using a 100X SLWD. It is possible to measure up to 35 degree without physical collision.

Trajectory

The user defines the trajectory of the X and Y stage. It is defined as the single points that have to be measured.

Straight line. It is possible to define the length, the number of points and the direction. This is useful for fast two-dimensional measurement in any direction crossing the apex of the lens.

Arc. It is possible to define the center of curvature, the angle and the number of points.



Square grid. It is possible to define the X and Y lengths and the number of points. The grid is spacing scanned in a spiral way, minimizing the acquisition time.

Circular Grid. The same as square grid but with a circular crop.

Spiral. This is an Archimedean spiral where the user defines the diameter and the spacing between points. If the lens is centered at the apex it is easy to measure the full lens .

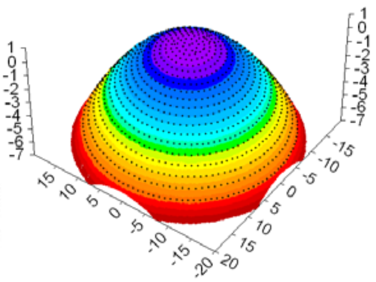


Figure 4: Coordinate measurement of an aspheric lens following an archimedian spiral from the apex. Top: measurement. Left: residuals of the measurement respect an sphere fiting.

External file. Stored file defining the X and Y points.

Predefined Surface

The user defines a theoretical Z coordinate for the given X and Y points.

None. No definition. The system moves to next XY position without moving the Z actual coordinate.

Predictive calculation. It can be Flat, Convex and Concave. This is an intelligent interpolation of the surface shape to predict the Z coordinate of the current measuring point using information from the previous measured points. The user defines the confidence radius to include or exclude points used for the prediction. It allows fast approaching for the autofocus function.

Flat. Moves always on the same plane. It is useful for X and Y stage calibration with a flat mirror.

Spherical. The predefined surface is asphere. The user defines the Radius of curvature.

Aspherical. The user define the radius of curvature and conic constant.

External file. Stored file defining the X, Y and Z points. This is a useful option for complex surfaces, where the prediction is time consuming, or for repetitive measurements.

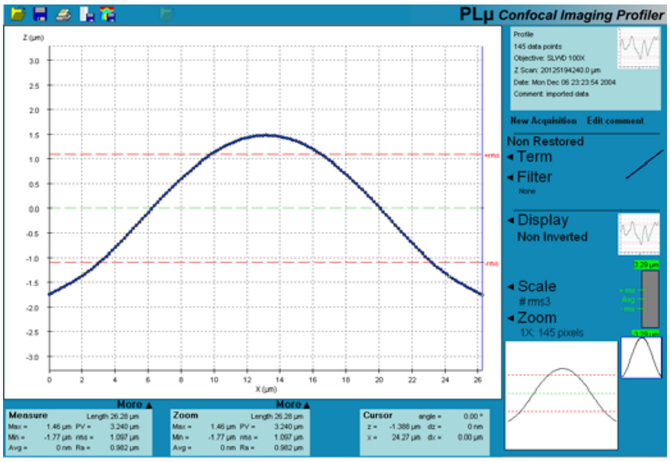


***Figure 5**: Coordinate measurement of an straight line crossing the apex of an aspheric lens.*

Results

The user defines the way the intelligent autofocus is works.

Low. This is a fast autofocus. With a single pass of the surface through the focal plane of the objective, and using a external optical gauge it is possible to acquire measured Z points with 0.1 mm repeatability in a 30 mm vertical range.

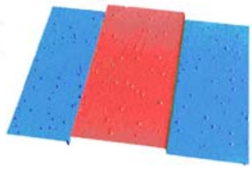
High. It first uses the low autofocus after that a multiple profile is acquired within the field of view of the objective. The result of the three-dimensional local measurement is filtered to give as a result a representative point for the centre of the field. This is useful for the shape evaluation of moulds, where a coordinate measurement of a single point for rough surface can give as a result a peak or a valley. The filters applied can be a **Plane fitting, Sphere fitting, Fit to peaks** and **Fit to valleys**.

System calibration

PLμ 2300 has three different axes: X, Y and Z. All three axes have its non-linearities and have to be calibrated.

Z Calibration

The Z Scanner is open loop by its nature. The non-linearities of the Z axis are random and can be as great as 0.1% of the scanned range. To increase the performance, Sensofar offers the option to include an external optical gauge. The system becomes linear within ± 0.1 microns within the full 30 mm range.



Step Height

XY Stage Calibration

The non-linearities of the XY stage are low frequency components. The non-linearities are highly repetitive and can be characterized and subtracted. To do this a flat high quality mirror (lambda/20) is measured in exactly the same measuring points as the sample. The result is stored and subtracted from the final measurement. Practical situations with high accurate procedures and thermal stability allow to measure lens shape within the error of the external Z optical gauge. A mirror of at least the same size of the sample is needed.

Flat reference mirror to calibrate the XY stage non-linearities.

Comparison between contact profilers and Plμ 2300

Contact Profilers	PLμ 2300
Contact by nature.	Non-contact by nature.It avoids scratching, flexing and dumping.
2D roughness evaluation.	3D roughness evaluation.
User never knows if the profile has crossed exactly the apex.	Perfect centering of the lens with interferential objectives lets profiling exactly through the apex.
Non 3D information.	3D topographies and coordinate measurements.
Need to change tip between roughness and shape measurement.	Roughness and shape can be mesured using the same objective. Changing the objective is as easy as turning the nosepiece.

Table 1: Comparison between contact profilers and PLμ 2300.

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