

High quantity wavefront measurement of miniature aspheric optics on wafer level

I. Erichsen¹, M. Cherrier², A. Ruprecht¹, S. Krey¹

¹Trioptics GmbH, Hafenstr. 35 – 39, D-22880 Wedel, Germany

²Trioptics France, 27 bd du 11 Novembre 1918, Batiment CEI, BP 2132, 69603 Villeurbanne cedex, France
i.erichsen@trioptics.com

With the recently emerged large volume production of miniature aspheric lenses a new fast fully automatic high resolution wavefront measurement instrument has been developed which is able to measure highly aspheric optics directly in production.

Introduction

The massive introduction of digital cameras in cell phones has lead industrials to produce increasingly higher quantities of lenses for camera objectives. This evolution implies major innovation in terms of in-line testing of lenses meeting demanding quality results as well as fitting high speed constraints.

The ultra-fast wavefront analyzer presented in this paper has such potential since it can test complete trays or wafers with large quantities of lenses with less than 3 seconds per lens keeping high dynamic and accuracy performances.

The technology is based on the Shack-Hartmann sensor which provides real time wavefront measurements and analysis of spherical and aspherical optics over the full aperture. The very high dynamic range of the employed sensor allows for measurement of not only completely assembled objectives but also single lenses in earlier production stages. The system provides fully automated characterisation of lens wavefronts in transmission as well as a large panel of usual analysis such as Zernike coefficients calculations and Zernike fits display, 2D MTF, point spread function and Strehl-Ratio, all presented in an integrated software.

The new technology of mass fabricated miniature or micro-lenses on wafers give reason to new developments in in-line wavefront measurement equipment. Automatic alignment procedures ensure the optimum and repeatable positioning of each lens under test.

This system also offers a production quality feedback by making statistical analysis of series measurements.

Measurement Principle

A Shack-Hartmann sensor consists of a microlens array placed in front of a camera. The distance between both elements is chosen such that camera chip is in the focal plane of the microlenses (see Fig. 1).

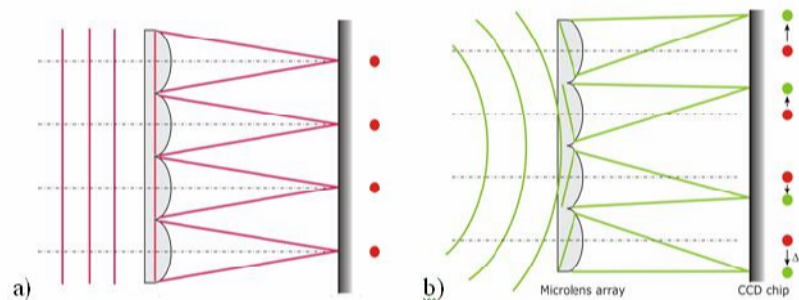


Fig. 1. Schematic setup of a Shack-Hartmann sensor with a) incoming plane wavefront and b) incoming aberrated wavefront

The wavefront is sampled by the pupils of the microlens array and the foci form an evenly spaced grid on the camera if the Shack-Hartmann sensor is illuminated with a plane wavefront. These spot positions are used as initial reference.

Any aberration introduced by the sample lens leads to a curvature of the wavefront thus resulting in a small local tilt within each microlens pupil. This induces a measurable shift of the focus position on the camera and the so obtained slope information can be used to reconstruct the shape of the wavefront with high accuracy.

Wavefront series measurements

Fig. 2 shows the new Trioptics WaveMaster PRO Wafer instrument. It contains a high resolution Shack Hartman sensor in a reverse projection set up. In this configuration, the sample lens is illuminated by a point

light source and the lens pupil is imaged onto the wavefront sensor by a telescope which in addition magnifies the wavefront for maximum utilization of the sensor area and -dynamic range. To allow for fully automatic operation all of these elements including the sample holder are located on PC-controlled linear stages.

For each type of wafer a unique tray representation file has to be generated once, which is then used by the software to find the optimum measurement conditions for each single lens on an unlimited number of wafers of the same kind. Due to a newly developed easy to use wafer loading and alignment tool high precision alignment of each new wafer before measurement is not needed anymore. After inserting a wafer into the wafer holder the instrument determines rotation as well as offset of the lens pattern compared to the corresponding tray file by using alignment marks which are located on the wafer. By this the position of each lens on the wafer can be determined and used during the series measurement resulting in a reproducibility of $< \lambda/200$ RMS.

In addition a new wafer bow compensation technique has been introduced to face the problem which usually occurs for very thin large diameter wafers. Since the lenses on a wafer change their position along the z-axis due to wafer bow light source as well as the telescope have to track this position shift. The wafer bow algorithms ensure that the exit pupil of all lenses is always imaged onto the wavefront sensor.

During the measurement of a wafer a real time analysis of each wavefront is performed and every single lens is classified directly according to the selected pass-fail criterion. For this a large variety of different criteria can be chosen including e.g. comparison to theoretical lens data or a master lens amongst others.

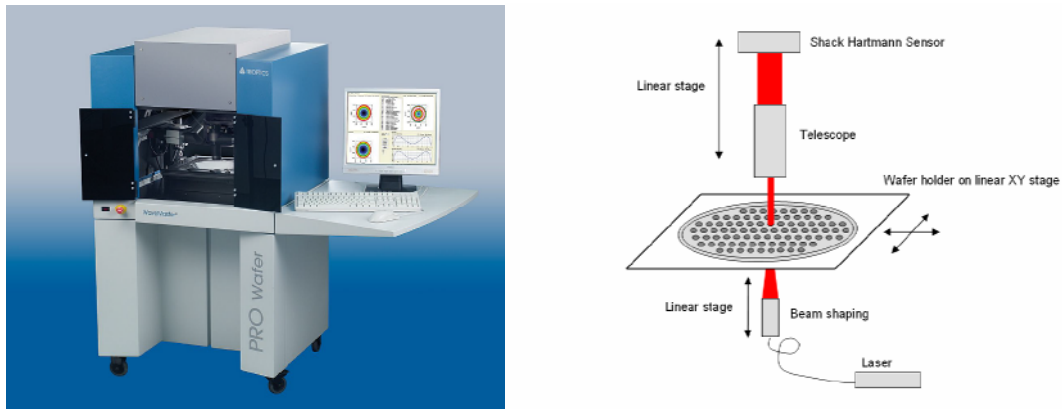


Fig. 2. WaveMaster[®] PRO Wafer instrument and optical layout

While the wafer is measured the wavefront of each single lens and its pass- and fail classification is displayed live while 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.

By now there are already several of these instruments in use in industrial sites measuring large diameter wafers holding several thousand lenses.

The WaveMaster[®] PRO Wafer instrument provides lateral resolved information about scratches, lens impurities and deviations from design or reference data within a measurement time of less than 3 seconds for each single lens on the wafer under test. This allows for direct feedback into the large volume production process.

Instrument specifications are displayed in table 1.

Tab. 1. Specifications of WaveMaster PRO Wafer

Repeatability (RMS)	$< \lambda/200$
Reproducibility (RMS)	$< \lambda/200$
Measurement time per lens	< 5 sec
Wavelength	635 nm, 532 nm
Maximum allowed lens dislocation out of measurement plane due to bow	0.5 mm
Minimum diameter of single lenses on the wafer	0.5 mm
Aperture dimensions of wavefront sensor	15 x 15 mm ²
Number of lenslets	135 x 135