Optical form measurements with a scanning point sensor in null configuration

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Asphere and freeform metrology systems often need coarse preinformation about the form of the specimen. For this purpose, we used a three-axis system in combination with a point sensor in null configuration. This system has the ability to measure the form with sub-µm accuracy. The setup can be applied for various specimens with a surface slope of up to 30°.

1 Introduction

Optical form measuring instruments often require a coarse knowledge of the specimen's form. This knowledge is obtained at PTB by means of a form measurement system consisting of three translational axes (see Fig. 1). The system has a measuring volume of 800 x 400 x 400 mm^3. The chromatic confocal point sensor is mounted on the z-axis and has a working distance of 4.5 mm, a measurement range of 300 µm and an acceptance angle of ± 30°.

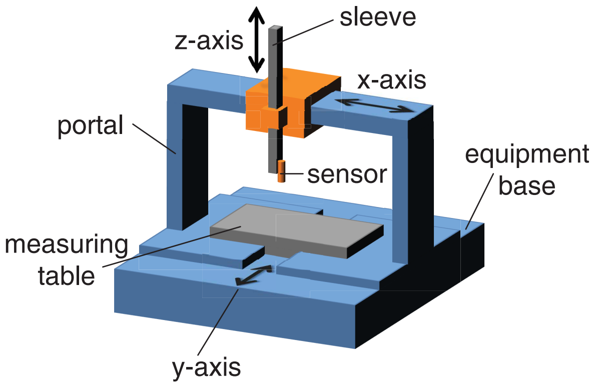

Fig. 1 *Setup of form measurement system used to measure the form in the sub-µm range*

The system is controlled to keep a constant distance between the sensor and the specimen at each measurement point, which thus represents a null-sensor configuration. Residual deviations for the exact null position are considered. The measured line profiles can be merged to create a 3D topography. The measuring system was tested by using an unknown spherical surface and an asphere and freeform standard developed at PTB.

2 Measurement procedure

The surface is scanned along the measuring path and measured data is taken at points with fixed increments. At each measurement point, the z-axis of the system is moved to a constant distance between the sensor and the specimen. The positions of the three-axis scanning system represent the coordinates of the surface profile (Fig. 2)[1].

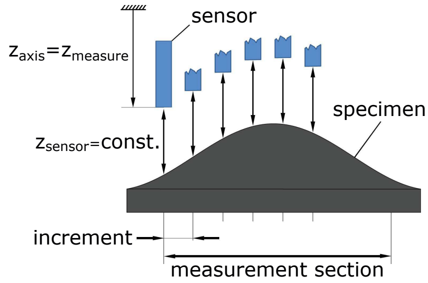

Fig. 2 *Scheme of the null-sensor configuration*

3 Measurement of a spherical specimen

The form of a sphere can be determined by measuring a line profile through the pole because of the rotation symmetry. This line can be identified by measuring distributed points on the specimen surface and fitting a sphere. The fit result yields the coordinates of the specimen's pole with respect to the coordinate system of the scanning system. These coordinates make it easier to measure multiple lines on the specimen's surface. As an example, a plano-convex lens with a 50 mm design radius was measured with 348 profiles, which were merged to create a 3D topography (see. Fig. 3). The best-fit radius of this measurement is R=50.017 mm.

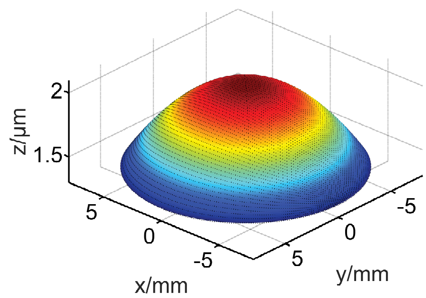

Fig. 3 *348 profiles with a measured best-fit radius of R=50.017 mm*

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4 Measurement of asphere and freeform standards

At PTB, asphere standards have been developed. These standards consist of plateaus, multi-sphere or modulated chirps superimposed on a spherical shape (see Fig. 4).

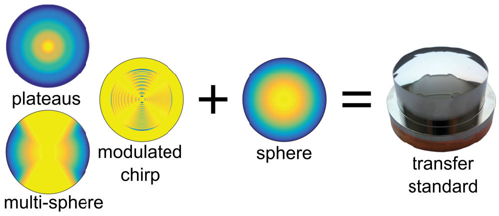

Fig. 4 *Metrological asphere and freeform standards*

One of these standards is a multi-sphere specimen with a design radius of R_1=37 mm and R_2=40 mm. This specimen is made of copper with a nickel-phosphorous coating and is suitable for tactile and optical sensors [2, 3]. The result of the measurement of this multi-sphere specimen is shown in Fig. 5 and Fig. 6.

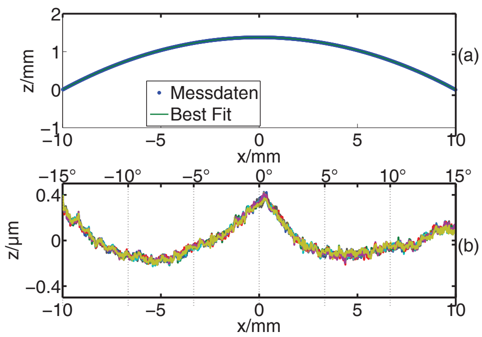

Fig. 5 *Measurement profiles of the two-sphere specimen with a design radius of R_2=37 mm; (a) measurement data and fit; (b) deviation of 12 repeated measurements from fit*

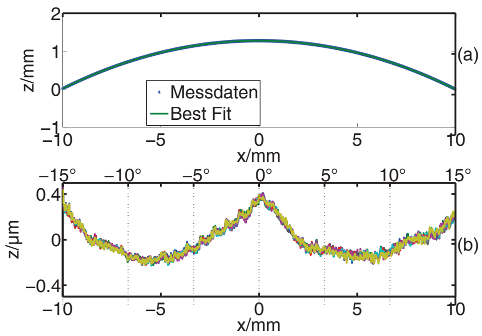

Fig. 6 *Measurement profiles of the two-sphere specimen with a design radius of R_1=40 mm; (a) measurement data and fit; (b) deviation of 12 repeated measurements from fit*

In Fig. 5(a) and Fig. 6(a), the measured data with the best-fit circle are plotted and in Fig. 5(b) and Fig. 6(b), the deviations from the best-fit circle are shown. For the design radius R_1=37 mm, we measured a best-fit radius of 36.970 mm; for the design radius of R_2=40 mm, we measured a best-fit radius of 39.968 mm. The chromatic confocal point sensor has a measurement deviation, which depends on the angle of the sensor to the specimen. This property is observable in Fig. 5(b) and Fig. 6(b). Deviations from the design can also be caused by surface imperfections. The results show that this null-sensor configuration enables measurements with a 15 nm repeatability (standard deviation of 12 scans). An aperture of 20 mm was measured with a surface slope of up to 15°. Since the surface angle is known, these deviations can be corrected.

5 Summary and outlook

A measurement procedure was implemented to get information about the form of unknown specimens. It can be applied to various specimen geometries. The system supports a scanning line sensor, which was developed within a DFG project [4, 5]. The distance error of the optical point sensor depends on the surface angle and can be measured by means of a well-known sphere. This deviation can be corrected. The system has the ability to measure the form with sub-µm accuracy, and will be used to measure the whole 3D topography of the metrological asphere and freeform standards in future.

6 Acknowledgements

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