Calibration Strategies for a New Fast Line-based Form Measuring System

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As part of a research project a line based interferometric form measurement system is developed. The line sensor is moved over the surface to measure its topography by line-based sub-aperture stitching. Calibration methods and first measurements will be shown.

1 Introduction

Common approaches to measure the form of optical components comprise single point as well as optical matrix sensors. Single point sensors are slow, because the sensor has to be guided point-by-point with respect to the specimen. Optical full aperture matrix sensors measure the specimen at once but are limited in their height measurement ranges. Our approach of a new form measurement system uses a fast interferometric line sensor in combination with a five-axes movement system, which allows fast measurements of arbitrary rotational symmetric specimens. With additional measurements of the relative position of the sensor and the specimen as well as redundant information due to the overlap of the line-shaped sub-apertures, the error of the movement axis can be corrected. As the sensor is tilted by the five-axes movement system for the purpose of having the optical axis of the sensor perpendicular to the surface. Appropriate calibration strategies of the movement system by using the line sensor in combination with a calibrated sphere were developed and will be presented.

2 Measurement system and procedure

The measurement system consists of a line sensor in Michelson configuration with an actuated reference mirror and a five axes movement system [1, 2].

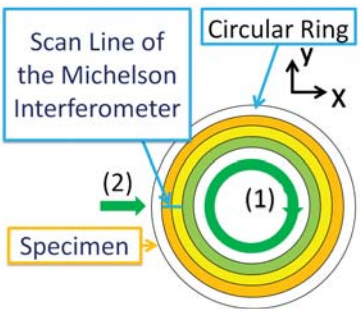

Fig. 1 Scheme of the measurement procedure: (1) c-axis rotation, (2) radial translation axis

There are three linear axes and one rotational axis for the perpendicular positioning of the sensor with respect to the specimen. An additional rotational axis (c, see Fig. 2) is needed for the scanning process of one scan ring. The measurement procedure was introduced earlier [1, 2, 3]. In principle the idea is to scan single sub-aperture rings (Fig. 1) and stitch them together to generate a 3D topography.

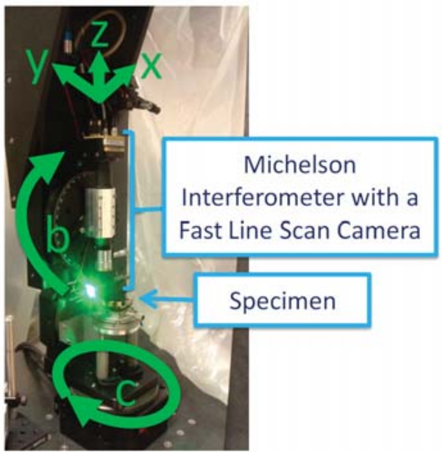

Fig. 2 Photo of the movement system in combination with the interferometric line sensor. As light source a green LED is used.

3 Calibration strategy with a known spherical artefact

The challenge for the tilting of the sensor is, that the distance r_d between the sensor and the centre of the specimen has to be known. So the distance of the coordinate system of the sensor and the coordinates of the specimen has to be calibrated. This can be done by a spherical artefact of known radius r_k.

It is assumed that the optical axis of the sensor and the mechanical axes of the movement are well aligned. In a first step the sensor is positioned almost perpendicularly to the specimen by searching the minimal fringe density. The distance of sensor to the specimen can be determined in the working distance of $13\ \mathrm{mm}$ within a measurement range of $330\,\mu\mathrm{m}$. First the focal point (x_1, z_1) is determined by moving the sensor in x and z direction and by searching the minimum fringe density. Then the sensor is tilted by a known angle ϑ and the procedure of searching the minimum fringe density and the best focus position is repeated which yields a second focal point (x_2, z_2). The principle is shown in Fig. 3. With these two points and the known angle ϑ the distance r_d can be calculated using Eq. 1. If a more accurate calibration is necessary a white light source instead of the green LED can be used and the sensor can be operated as a scanning white light interferometer.

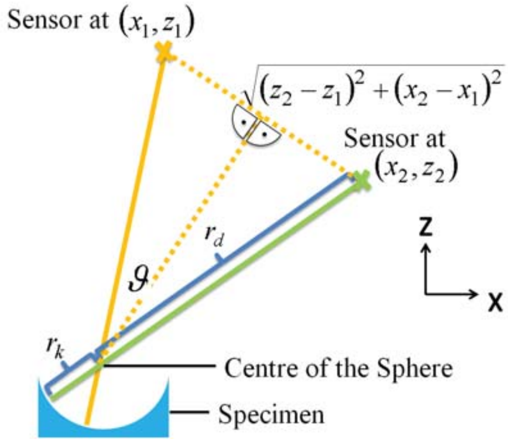

Fig. 3 *Scheme of calibration strategy*

$$r_d = \frac{\frac{\sqrt{(z_2-z_1)^2+(x_2-x_1)^2}}{2}}{\sin\frac{\vartheta}{2}} \qquad (1)$$

With the knowledge of r_d and the approximate radius r_k of the spherical specimen the tracking of the specimen for the subsequent form measurement can be calculated.

A spherical mirror was measured by 13 sub-aperture rings with an overlap of $50\,\%$. After the measurement the single sub-apertures were stitched together by correcting the tilt and offset in the overlap regions of the neighbouring sub-apertures.

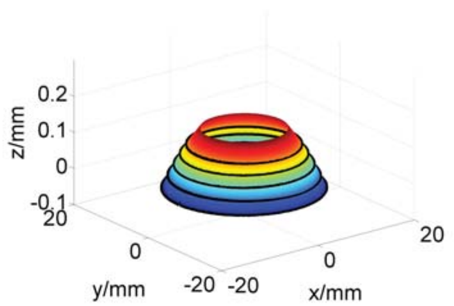

Fig. 4 *Result of stitching five single sub-aperture rings of the spherical specimen together. One edge of each sub-aperture ring is marked in black to illustrate the stitching process.*

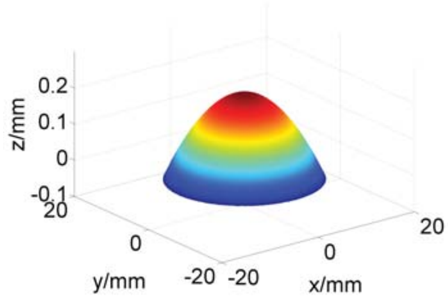

Fig. 5 *Result of stitching 13 single sub-aperture rings of the spherical specimen together*

Fig. 4 shows stitching of 5 sub-aperture rings and Fig. 5 the stitching of 13 sub-aperture rings.

4 Summary

A form measurement system with a fast scanning line sensor has been established. Measurement and stitching results of a spherical mirror with a diameter of $2.54\,\mathrm{cm}$ are shown. For keeping the sensor in its measurement range, a calibration strategy has been developed and tested.

5 Acknowledgements

The financial support of this research work (LE 992/7-1, EH 400/4-1) by the Deutsche Forschungsgemeinschaft (DFG) is gratefully acknowledged. This project is a cooperation between the Chair in Measurement Technology, Dept. of Electrical Engineering, University of Kassel (CMT) and the Form and Wavefront Metrology working group at the Physikalisch-Technische Bundesanstalt (PTB).

References

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