A new optical flatness reference measurement system

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A new optical deflectometric flatness reference (DFR) measurement system is being set up at PTB. This system offers the possibility of flatness measurements of large samples with a diameter up to 700 mm. A measurement uncertainty in the sub-nanometre range for a confidence interval of 95 % is aimed at.

1 Introduction

Deflectometric procedures offer the possibilities of absolute topography measurements for flat specimens. As a flatness reference, the straight propagation of light is used, and the measured topography can be traced back to SI units by traceable angle and length measurements. As well as the three-flat test [1], the deflectometric procedures make an absolute characterization of a flatness specimen possible. A Fizeau-interferometer is, for example, only a comparative measuring system and can never become more accurate than the reference surface which is known.

The new optical deflectometric flatness reference (DFR) system is designed for absolute and traceable measurements of flat specimens. It offers four different measurement methods: the direct deflectometric and the difference deflectometric method for horizontal as well as vertical specimens. The highly accurate angle measurements of the deflected beams will be accomplished by a calibrated autocollimator which has an accuracy better than 0.01 arcsec for a measurement range of 20 arcsec. With the *direct deflectometric mode* [2] the surface will be scanned by a pentaprism and the slopes will be measured by the autocollimator. Afterwards the slopes will be integrated [3], resulting in the surface topography. With the *difference deflectometric mode* [4-8], difference angles between constant shears will be measured. Using natural extension and shearing transfer functions, an exact reconstruction of the slopes is possible and the topography can be determined again by the integration of the slopes. The direct deflectometric method has the advantage of short measurement times and the disadvantage that the optical path of the autocollimator changes due to the movement of the prism. The advantage of the difference deflectometric procedure is that there is no influence on the measurement result, if the specimen tilts during the measurement, and if the autocollimator follows the pentaprism, the optical path length is almost constant. The disadvantage is that the measurement time is longer.

The dimensions of the specimens which can be measured with the new DFR system are listed in Table 1.

Tab. 1 *Specifications of the samples.*

	Round samples	**Elongated samples**
Max. size	Diameter: D = 0.7 m Thickness: T = 0.2 m	Length: L=1.0 m Width: W=0.5 m Thickness: T=0.2 m
Max. mass	120 kg	120 kg
pV value	≤ 200 nm	≤ 200 nm

2 Set-up of the DFR system

The DFR consists of two separate systems. System I is designed for the measurement of horizontal specimens by direct and difference deflectometry as well as vertical specimens by direct deflectometric measurements. System II is designed for measuring vertical surfaces by difference deflectometry. Fig. 1 shows a design drawing of system I.

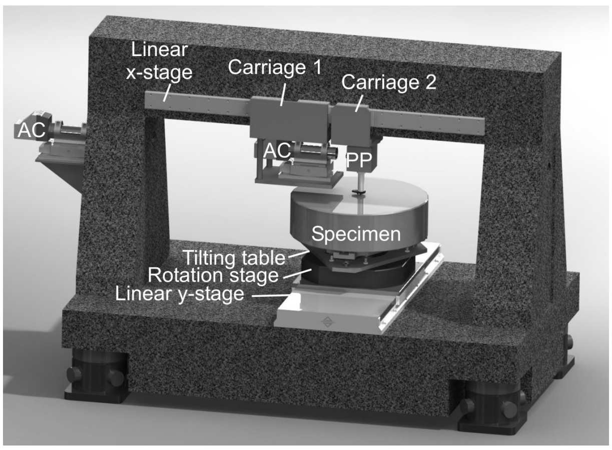

Fig. 1 *Design drawing of the deflectometric flatness reference for horizontal specimens (AC: autocollimator, PP: pentaprism or double mirror)*

The system is composed of a granite base with a granite bridge where an air bearing stage is mounted. Carriage 1 of this air bearing stage is used for the autocollimator and carriage 2 for the pentaprism or double mirror. A straightness and flatness reproducibility of less than 0.5 µm and an angle reproducibility of less than 0.5 arcsec over a travel range of 1 m is aimed at. The specimen lies on a tilting table which is equipped with two piezo-electric actuators for the fine adjustment of the specimen. In order to scan the specimen at different locations – also off-axial – the rotation stage and the linear stage mounted on the granite base can be used. Fig. 2 shows the system II which can measure the complete topography of a vertical specimen with the difference deflectometric method. Some details of the sensor head are shown in Fig. 3. It consists of a shearing stage where the pentaprism is mounted on a 3-axis rotational stage which is used for an accurate alignment. With the x- and z-linear stage, each measurement point on the specimen can be scanned.

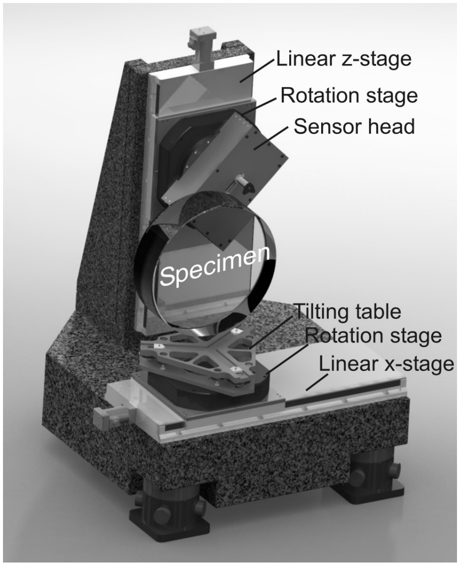

Fig. 2 *Design drawing of the deflectometric flatness reference for vertical specimens*

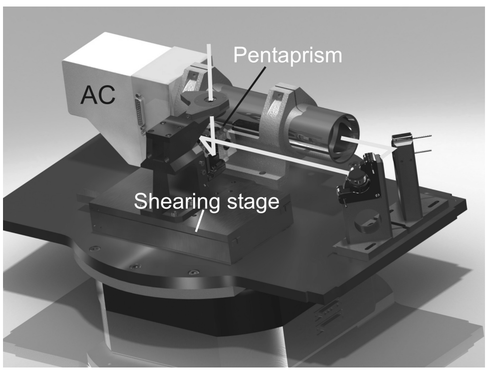

Fig. 3 *Sensor head of the system in Fig. 2*

3 Modelling

We have started to implement a realistic model of the DFR system with the PTB working group "Data Analysis and Measurement Uncertainty" for the estimation of the measurement uncertainty. Many input quantities like errors of the x-guidance with the autocollimator and the pentaprism, initial tilting errors between the autocollimator and the pentaprism, the flatness of the pentaprism, the calibration of the autocollimator, the dependence of the optical path length of the autocollimator and environmental quantities e. g. temperature, humidity or air-pressure will be considered. The first results show that a measurement uncertainty, even for a large sample, in the sub-nanometre range is realistic.

4 Conclusion/Outlook

The concept and the principle of the new DFR system have been presented. It will be able to measure large flatness specimens in horizontal and vertical directions. The measurement uncertainty is expected to be in the sub-nanometre range. Different measurement modes like direct and difference deflectometric procedures will be implemented. The DFR system now is under construction and will be ready for measurements in 2010. With it, we can provide industrial and other customers with highly accurate flatness calibrations.

Literatur

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