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Concept for improving the form measurement results of aspheres and freeform surfaces in a Tilted-Wave Interferometer

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Summary:
Non-null-test interferometry, such as tilted-wave interferometry, has gained attention for accurate and flexible form measurement of aspherical and freeform surfaces. However, additional information is needed to improve the measurement results and distinguish between certain form errors and misalignment of the specimen. One way to achieve this is to improve the knowledge about the absolute measurement position of the specimen within the interferometer setup. In this work, we propose a method to measure the specimen-to-objective distance by utilizing a white light interferometer and a transparent test specimen.

Keywords: white light interferometry, distance measurement, tilted-wave interferometry, metrology, aspheres, freeforms, optical form measurement

Introduction

In the past decades, the usage of aspherical and freeform surfaces has become quite popular in optics. As a way of creating compact optical systems with low aberrations, they are now widely used both in consumer devices and professional applications. However, reliable fabrication of high-quality freeform surfaces is limited by the ability to accurately measure such surfaces. Measurement comparisons between different measurement methods show that the uncertainty of the determination of the spherical form error dominates in the form measurement of aspheres and freeform surfaces in both point-based and area-based measurement methods [1].

In interferometry, which belongs to the most accurate area-based measurement methods, different methods exist for the form measurement of such complex surfaces. For all these methods, it is difficult to distinguish between misalignment of the specimen and certain form errors [2]. The reason is that the (best-fit) radius of the test wavefront depends on its propagation distance, which depends on the position of the specimen within the measurement setup. This is also true for the tilted-wave interferometer (TWI, [3]), which is a promising non-null test method for the form of aspheres and freeform surfaces. Thus, to improve the measurement results of a TWI, additional information is needed. A solution is to improve the knowledge of the absolute measurement position of the specimen within the interferometer setup [4].

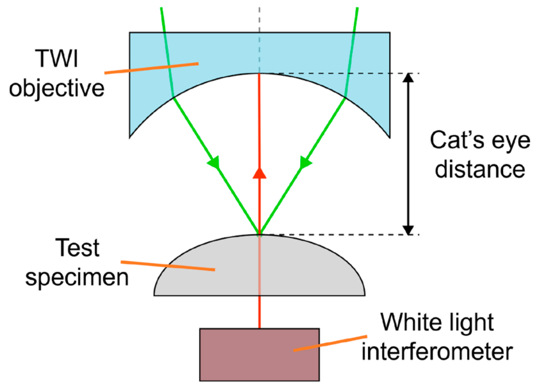

Fig. 1. Scheme of the measurement task. Measuring the distance between the surface of the test specimen and the surface of the TWI objective.

In this work, we investigate the concept of using a white light interferometer (WLI) to measure the absolute distance between a specimen surface in a reference position and the last surface of the TWI's objective.

Measurement task

To improve the knowledge about the absolute specimen position within the interferometer setup, a transparent test specimen is used. It is brought into a specified position in relation to the TWI's objective and the distance between the top surface of the specimen and the last surface of the objective is measured (Fig. 1).

As a fixed reference position, the cat's eye position of the objective is used. In this position the light from the TWI is reflected from a single spot on the crest of the specimen and therefore, the optical path length difference (OPLD) is unaffected by the surface structure. The alignment of the specimen in the reference position plays an important role and the accuracy of current alignment concepts will be investigated with the help of the setup developed in this work.

For the current TWI setup, the distance between the last surface of the objective lens and the cat's eye position is approximately 48 mm. In future work, the setup will be expanded to other objective lenses.

White light interferometer design

A white light interferometer based on a Michelson configuration can be used to measure the distance between different surfaces of transparent materials [5]. The proposed interferometer consists of a low coherent light source, a beam splitter, a measurement arm, which contains the objective and the specimen, a reference arm, an image detector and some optics for beam intensity control and focus. A scheme of such an interferometer is shown in Fig. 2.

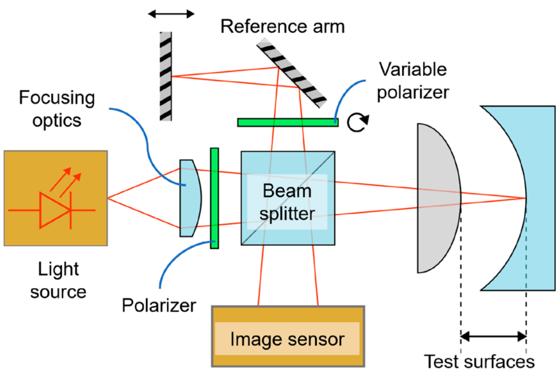

Fig. 2. Scheme of a white light interferometer for measuring the distance of two consecutive transparent specimens.

As light source a high-power LED with narrow spectral width of a few nanometers can be utilized. A resulting spectral coherence length of a few tens of micrometer is desirable. The interference pattern is recorded by an image sensor and the recording is analyzed by software employing envelope and phase evaluation.

Due to weak reflection from the transparent specimens' surfaces, intensity from the measurement arm is substantially decreased. However, to allow for a high interference contrast, the intensity from the reference arm should be equal to the measurement arm's intensity. Therefore, the reference beam intensity can be reduced by a variable polarization filter.

Measurement Procedure

In WLI, an interference pattern becomes visible on the sensor when the OPLD between a reflection in the measurement arm and the reference arm is within the coherence length of the light source. Further, its contrast is maximized when both lengths are equal. For multiple surfaces, each surface produces a local contrast maximum when reference and measurement arm length match. Since the medium between the two surfaces of interest and in the reference arm is ambient air, the measured distance based on the interference pattern contrasts directly translates into the distance between the surfaces along the measurement beam.

Conclusion

In this work we proposed an additional absolute distance measurement to improve the form measurement result of aspheres and freeform surfaces with a TWI. The proposed concept is based on a white light Michelson interferometer configuration. We have presented the basic ideas to improve the measurement results of a TWI by such a concept.

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