Realization of a shearing interferometer with LED multipoint illumination for form characterization of optics

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We present an optical measurement technique based on shear interferometry to determine the surface form of optical elements. A partially coherent multispot light source realized by an LED coupled into several fibres is used. This method secures optimal illumination and resolvable data all over the measurement area, so even aspheric surface forms can be measured.

1 Introduction

Within a Deutsche Forschungsgemeinschaft (DFG) joint project between the Physikalisch-Technische Bundesanstalt (PTB) and Bremer Institut für angewandte Strahltechnik (BIAS), a new approach to interferometric form measurement based on shearing interferometry [1] with low coherence light is investigated. Since shear interferometry only requires the coherence of field amplitudes at positions separated by the shear, it permits multibeam LED illumination. Artefacts due to the coherent amplification of parasitic reflections are significantly reduced by using partially coherent light. We make use of a multi spot light source which comprises an LED coupled into several fibres that can be individually adapted to the specimen. Each light source yields an interferometric pattern at the camera section. The individual patterns are combined into an overall pattern. A high degree of flexibility in surface form measurement can be reached by applying the required number of illumination spots with individual orientation. A realization of a shearing interferometer in combination with threefold LED point illumination and corresponding experiments measuring the form of the optics will be shown.

2 Experimental setup

A shearing interferometer [2] is core to the experimental setup. The specimen is imaged on the image sensor by two lenses in 4f configuration (see Fig. 1 and Fig. 2). A spatial light modulator (SLM) is placed at the Fourier plane and operates as a shearing element. The birefringent properties of the SLM allow 45° polarized light to reflect 50% of the incoming light directly to the image sensor, whereas the other 50% are diffracted by an inscribed blazed grating at the SLM. This results in a directly reflected wavefront and a slightly lateral shifted copy of the wavefront, which interfere in the detector plane and show an interferometric pattern, which can be evaluated. The shear can be chosen by the grating constant and the orientation of the blazed grating. The illumination unit consists of an LED, which is coupled into a 7-fibre bundle. The position of each fibre tip can be individually adapted to the specimen surface form, so optimal illumination all over the measurement area is secured. In this case, specimens with steep slopes can be measured.

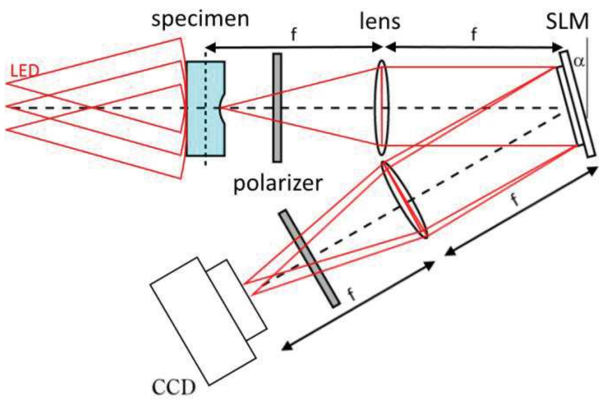

Fig. 1 *Sketch of the experimental setup corresponding to [1].*

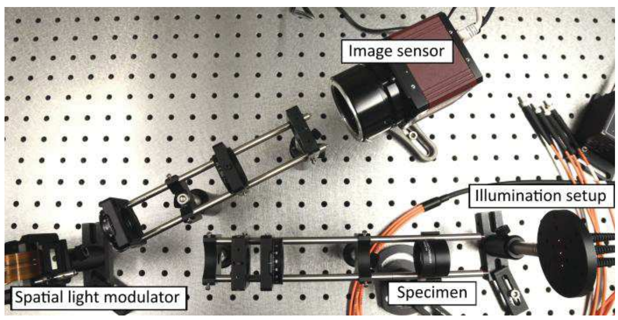

Fig. 2 *Photo of the experimental setup.*

3 Measurement procedure

To measure the surface form of an optical element, interferograms by two different shears in the x and the y direction [3] were captured. The phase is determined by a four-step phase shifting algorithm. Thus in total 16 interferograms are needed to obtain the phase information for all four shears. With a gradient descent numerical process, the specimen surface is reconstructed from the four phase maps. The full procedure is shown in Fig. 3.

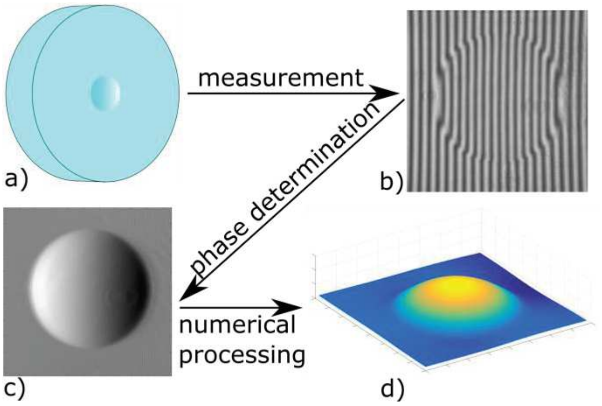

Fig. 3 *Measurement procedure: a) example specimen with a mould (4 µm depth and 5 mm diameter), b) one of 16 measured interferograms, c) one of four phase maps received by phase shifting, d) reconstructed surface form.*

4 Measurement example

For our first demonstration we measured an aspherical lens with a 50 mm focal length illuminated by three light sources. An example of an interferogram is shown in Fig. 4a. By phase shifting, the phase is extracted (see Fig. 4b). As described in Section 3, from four phase maps of different shears, the surface form of the specimen is reconstructed and plotted in Fig. 4c.

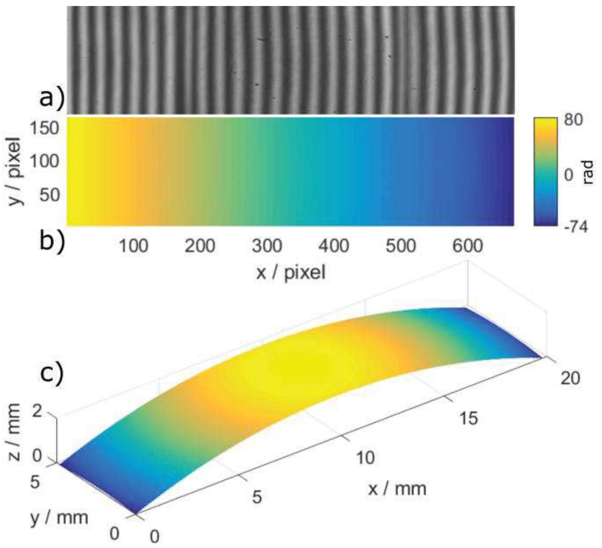

Fig. 4 *Measurement of an aspherical lens with 50 mm focal length: a) interferometric pattern with a three spot illumination, b) phase map, c) reconstructed surface topography.*

The original measurement data includes the illumination wavefronts incident on the specimen, which are presumed by the knowledge of the positions of the light sources and removed afterwards.

5 Discussion

Shearing interferometry with LED multispot illumination is possible. A flexible fibrebased illumination setup has been developed, which allows an individually adapted configuration to the specimen geometry. Several light sources enable a larger measurement range. Transition areas can be critical, but are mostly fixed through numerical processing. A crucial point of the measurement is the determination of the wavefronts between the light sources and the specimen. This is important for an accurate surface reconstruction.

6 Conclusion and outlook

The first results with the multispot illumination are shown. Embedding more LED spots will enlarge the measurement area and increase the range of measurable surface forms. The model of the input wavefronts as well as the evaluation of the topography are not accurate enough and will be improved. A virtual shearing interferometer will therefore be implemented. The virtual experiment also allows the consideration of various error influences on the measurement uncertainty.

7 Acknowledgement

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http://gepris.dfg.de/gepris/projekt/258565427

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