Developing a high precision auto-focus system and comparing two different measuring methods

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Kinegrams are optically variable devices which are used as security marks for banknotes and identification cards. A scanning, highly focused laser beam is used to manufacture these optical structures. It illuminates a substrate, which has to be in focus, at any time. Therefore a high precision autofocus system has to be developed which measures distances within the range of a few nanometres.

Introduction

The Swiss company, OVD Kinegram AG, produces kinegrams for customers all over the world. The laser to illuminate the substrate has such a small depth of focus so that its objective has to be controlled in the range of some nanometres to stay in focus. To measure the substrate's position two optical principles were investigated, assembled, and compared with each other.

Set-up

A laser beam is focused by means of a microscope, onto the substrate, where it is reflected. With the reflected beam the position of the substrate is determined with two different methods. When using the Foucault principle, being out-of-focus causes a semi-circle, which is detected with a position sensitive detector (PSD). The other principle, astigmatism, causes an ellipse which is recorded with a camera. Two cylinder lenses create the astigmatism while an algorithm is calculating the ellipticity of the spot (Fig. 1).

To calibrate the focal-error-signal (FES), a piezo actuator is used to move the substrate on a known position. The system is focussing by changing the position of the microscope which is mounted on another piezo-actuator.

Approach

For both methods a simplified focal-error-signal was calculated, with geometrical optics and ray tracing (Zemax), to compare it with the measured FES of the assembled auto-focus system (Fig. 2). The optical system was then adapted in order to obtain the required sensitivity and to make it more compact.

Results

Comparing the FES of the two methods, revealed that with the used set-up the astigmatism is approximately 50 times more sensitive than the Foucault principle. The final system is therefore realised with the astigmatism method.

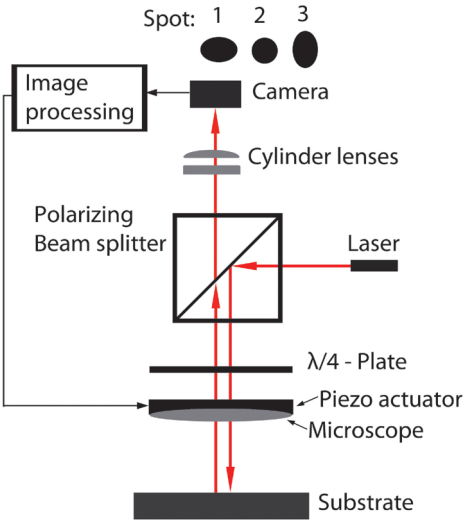

Fig. 1 Final set-up for the astigmatism principle. Spot 1+3 substrate out of focus. Spot 2 substrate in focus

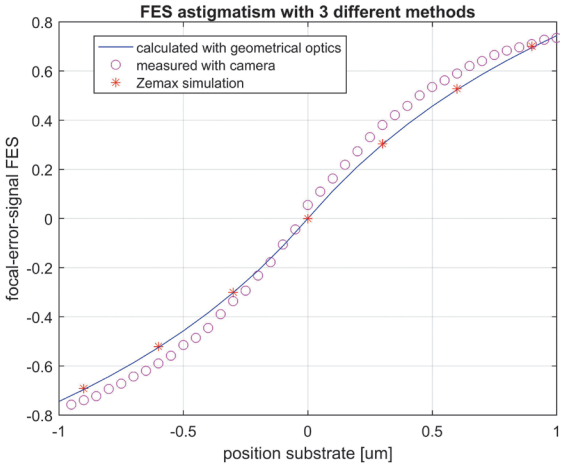

Fig. 2 Focal-error-signal for astigmatism, determined with three different methods

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