Determination of the optical properties of a magnetically driven liquid lens by raytracing

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Summary

Liquid lenses can be tuned in their (global) surface shape. We determine the optical properties (e.g. distortion values) of a lens as a function of the adjusted surface shape. The possibility to vary the focal length by a liquid volume displacement through a magnetically driven ferrofluidic piston in a micro channel is presented.

Introduction

Combinations of micromechanics and microfluidics are more and more popular in engineering. Optofluidics deals with the merging of liquid optical components and mechanical parts [1]. Continuous tunable liquid lenses are especially suitable for a miniaturized optofluidic system due to their smooth spherical boundary surface. Because of surface tension the free form of a liquid lens has a spherical shape [2], [3], a circle shaped boundary as outlet assumed. To characterize such a lens it is necessary to know not only the focal length but also other optical properties, like radial and tangential distortion coefficient.

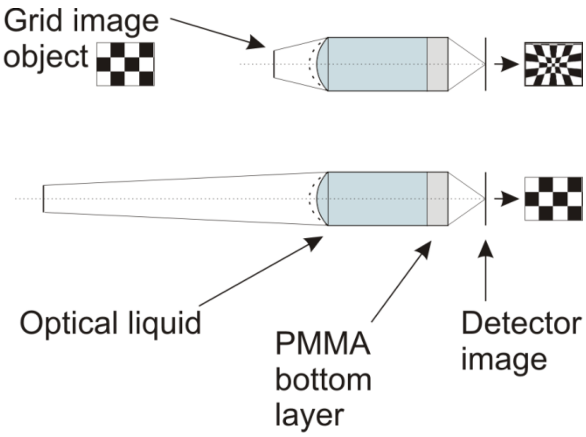

Fig. 1: Schematic of the ZEMAX model. The liquid lens projects an image onto the detector.

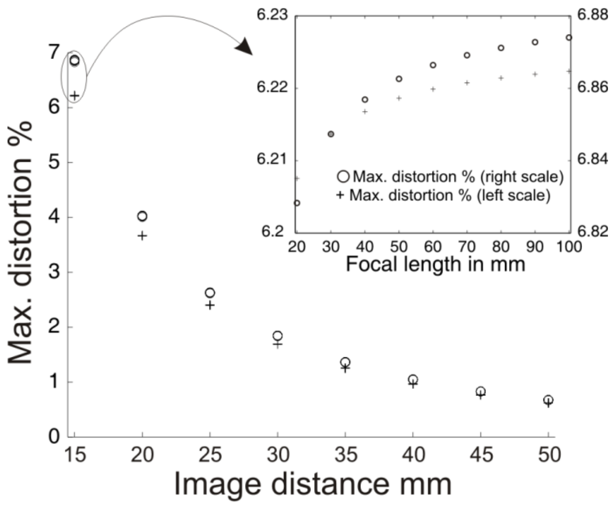

Fig. 2: Set of curves for glass and water as lens material. Magnification of an exemplary point to show the minor dependency on the focal length (inlay).

The spherical aberration increases with decreasing focal length. For correction purposes it is also relevant to know the behavior of other optical effects depending on the change of the focal length or image distance. In order to obtain this distortion information, an optical ray tracing model has been employed. In a second step, an experiment has been designed (Fig. 3) to compare the results of the model with the experimental ones.

Discussion

Figure 1 shows the optical setup used in the ZEMAX simulation: the optical path from the object through the spherical liquid lens, a cylindrical drill-hole filled with the same optical liquid, and the bottom layer of the Polymethylmetacrylat (PMMA) substrate. It turns out that the variation of the focal length has no major impact on the distortion factor whereas the distance between the object and the lens itself has significant influence. In this simulation we used two different lens materials to investigate the impact of the refractive index on the distortion coefficients: water (n=1.33) and glass (n=1.51). The very small difference in the refractive index between the two materials does not lead to relevant changes in the general behavior.

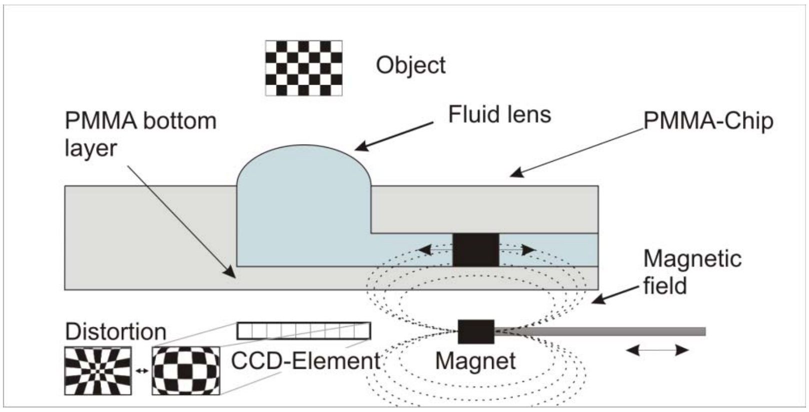

Fig. 3: Drawing of the experimental setup. An object is seen through a liquid lens of variable state. The focal length is defined by the position of the ferrofluidic plug.

Conclusion

The simulation results reveal a major dependency of image distortion on the distance between object and lens. If the light rays come from the far field they are nearly parallel. The distortion decreases due to less refraction on the boundary surface. Therefore, a software correction based on the algorithm introduced by [4, 5] can be used to correct the distortions in the case of objects near to the lens. For this correction the distortion coefficients have to be known. This dependency shall be compared and verified soon with the experimental setup shown in Fig. 3.

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