Optical Measurement on a Small Aperture Liquid Lens

Thanin Schultheis[1,2], Luca Spani Molella[1], Eduard Reithmeier[1,2]
[1]Leibniz Universität Hannover, Hanover Center for Optical Technologies, Hanover, 30167, Germany
[2]Leibniz Universität Hannover, Institute of Measurement and Automatic Control, Hanover, 30167, Germany
Email: thanin.schultheis@hot.uni-hannover.de

Summary

A refractive spherical water-air boundary surface was used as a liquid lens with variable radius of curvature. The lens mapped a line resolution target onto a detector behind it. To analyze the low pass behaviour in terms of spatial frequency an USAF1951 resolution target was used.

Introduction

Continuous tuneability and the smooth spherical boundary surface make liquid lenses tempting for their good imaging properties. Therefore, it is of interest, within the field optofluidics, to merge liquid optical components and mechanical parts to a small or miniaturized optofluidic system [1]. The surface tension causes the free form of the liquid lens to assume the definite shape of a spherical cap [2, 3]. This refractive surface acts as a light focussing convex-plano lens.

Discussion

The refractive properties of the boundary surface of a fluid droplet are one of the research objectives of the DFG Collaborative Research Program 'Active Micro Optics', where a low voltage micro-system driving a fluid lens is under investigation. Here we will concentrate on its optical performance. The volume displacement inside the supply channel is directly connected to the curvature radius of the resulting lens by:

$$V = AD = \frac{\pi}{3}\left(r - \sqrt{r^2 + R^2}\right)^2 \left(2r - \sqrt{r^2 + R^2}\right)$$

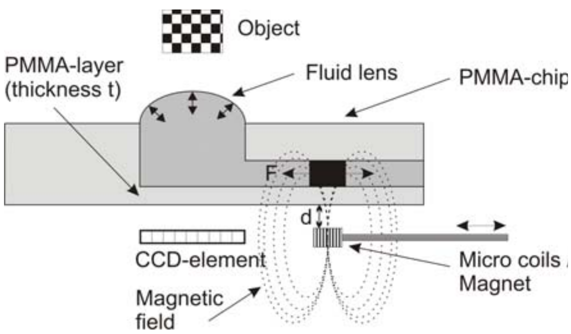

Fig. 1: Schematic of the measurement setup and working principle.

A denotes the cross-sectional area and D the displacement length, R the radius of the outlet and r the curvature radius. One can derive the focal length f from the refractive index of the used liquid. According to the image equation $\frac{1}{f} = \frac{1}{b} + \frac{1}{g}$ [4] the resolution varies with the scaling factor $\beta = \frac{b}{g}$.

Following the setup-scheme displayed in fig. 1 a USAF 1951 resolution target was used for measurement. At first, image processing served the correction of rotational misalignment. After this, the group elements of various spatial frequencies were parallel to the edges of the image (see fig. 2). Therewith, we extracted each group element and calculated the Michelson-contrast $contrast = \frac{I_{max}-I_{min}}{I_{max}+I_{min}}$ [5] line by line (vertical element, e. g. no. 4) or column by column (horizontal element, e. g. no. 3) respectively and took the mean value for the resulting contrast. Fig. 3 shows the analysis of the measurement for b=20mm, g=22mm and r~10.5mm. The contrast decreases of about 55% within a spatial frequency span of 30 lp/mm. The resolution depends on the geometrical ratio of b and g.

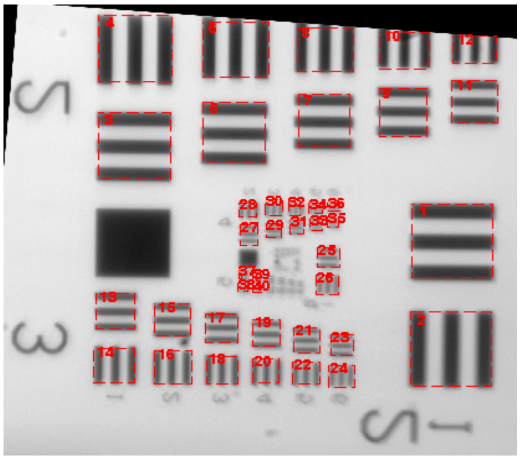

Fig. 2: Detail of the USAF target being image processed (b=20mm , g=22mm, r~10mm).

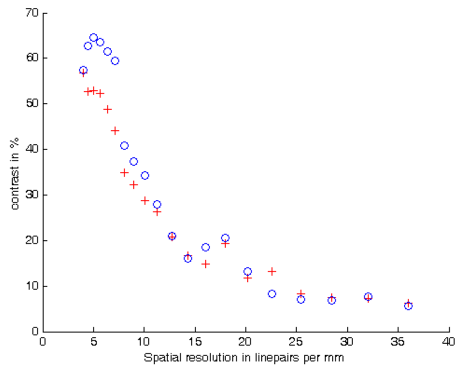

Fig. 3: Evaluated series of measurement for b=20mm , g=22mm and r~10.5mm. "+" represents horizontal and "-" vertical resolution.

Conclusion

We presented measurement results on the spatial frequency resolution of a small aperture liquid lens. Experimental measurements showed a significant influence of the illumination of the target on the quality of the results. Small changes in the illuminating light-intensity lead to large differences in the intensity distribution of the image and, therefore, have a major impact on the calculated contrast.

Acknowledgment: This work is financially supported by the German Research Foundation (DFG) within the Special Priority Program no. SPP1337.

References

[1] Fleger, M.: "Polymerbasierte Mikrofluidiksysteme mit integrierten optischen Komponenten", *Der andere Verlag*, **Diss.**, 2008

[2] Dong, L; Agarwal, A. K. et al.: "Adaptive liquid microlenses activated by stimuli-responsive hydrogels", *Nature*, **442**, 551-554, 2006

[3] Ren, H.; Wu, S.-T.: "Variable-focus liquid lens by changing aperture", *Applied Physics Letters 86*, **Nr. 21**, 1-3, 2005

[4] Demtröder, W.: "Experimentalphysik2", **Springer**, 2009

[5] Gross, H.; Zügge, H.; Peschka, M.; Blechinger, F.: "Aberration Theory and Correction of Optical Systems", **Wiley-VCH.**, vol. 3 (2007).