An Innovative Concept of a Magnetically Driven Liquid Lens

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Summary
The refractive surface shape of liquid lenses can be tuned to change its curvature radius. We introduce an innovative mechanism to adjust the refractive surface shape and present how to vary the focal length by a liquid volume displacement by driving a magnetic sensitive ferrofluidic plug inside a micro channel.

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 tuneable 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 the shape of a spherical cap [2, 3], a circular shaped outlet assumed.

Discussion

The refractive properties of the boundary surface of a fluid droplet are of major interest within the collaborative research program ‘Active Micro Optics’. The main advantage of this low voltage system is a continuously tuneable curvature radius respectively focal length. Compared to other micro fluidic lens systems, the here proposed driving mechanism is different. A magnetic sensitive ferrofluidic plug, which origins from a pair of micro coil actuators [4], can be moved by an applied magnetic field (see fig. 1) inside a micro channel. The generated driving force causes a volume displacement, which, again, is transferred to another non miscible lens fluid. This lens liquid exits through a small aperture outlet and performs the lens surface. The volume displacement caused by the plug’s movement is directly connected to the curvature radius of the resulting lens:

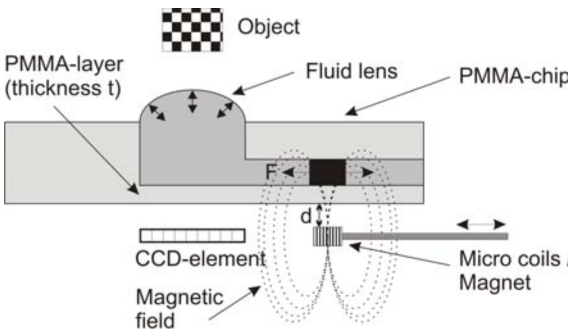

Fig. 1: Schematic of the PMMA housing and working principle.

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

where V is the volume, A the cross section area and D the displacement in channel direction, R the radius of the outlet and r the curvature radius.

In a preliminary experiment, we proved the working principle of our system by mapping an object to a coupled charged device (CCD), as figure 2 shows. The micro coil actuators are separated from the ferrofluid by a ~20 µm PMMA layer. Since we still work on the thinning process, the electromagnetic force was generated by a permanent magnet. The thickness t of the PMMA bottom layer is about 100 µm. Nevertheless, to maintain comparability, an appropriately chosen permanent magnet is positioned at a distance d such that its magnetic field intersperse the ferrofluidic plug with a comparable magnetic field strength. In a second preliminary experiment, we measured the specified electric current (380 mA) supplied to the coils and could visualise the magnetic field of the micro coil actuator with a magnetic viewer device (Arnold B-1022, USA).

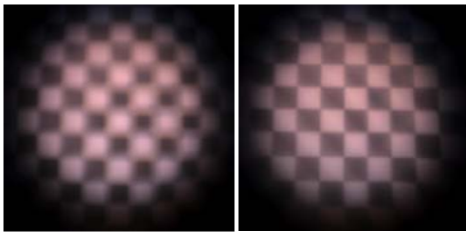

Fig. 2: Image of a chessboard pattern seen through the liquid lens. Left defocused, right focussed state.

Conclusion

The two preliminary experiments showed some promising results: first, as a proof of concept, the fluid lens is able to take clear pictures [5]. Second, the introduced driving mechanism, deflecting the refractive surface by displacement of the ferrofluidic plug can be used to adjust the focal length of the lens to obtain a clear and sharp image. It also could be shown that the amplification circuit, which controls the micro coils, drives the coils with a specified current; the coils, therefore, generate a specified magnetic field, which we visualised. Since the functionality of single parts is proven, consequently, the next step to full system integration of all the part-systems is driving the ferrofluid plug through the magnetic field of the micro coil actuator.

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