Developing a Micro Mirror Array for Holographic 3D Displays

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Abstract: To overcome accommodation-vergence-conflict related side effects of 3D displays a MEMS based phase modulation spatial light modulator is under development. The paper investigates different spring designs based on electrostatic and structural FEM simulations.

Keywords: computer generated holography, MEMS, phase modulation, comb-drive actuator, finite element simulation

1. Introduction

Over the last years, many attempts were made to improve 3D displays. Starting with stereoscopic displays, TV's which used polarization or shutter goggles, over several generations of augmented, virtual or mixed reality (AR/VR/MR) 3D display, the overwhelming majority of the users experience unwanted physiological side effects like nausea, dizziness, motion sickness and eye strain. These effects are mostly introduced by the accommodation-vergence-conflict, and becomes more dominant when the image plane of the content gets closer to the user. The ideal solution is a real hologram of the displayed content, which requires a full reconstruction of the field of light in all three dimensions as if it came from the real object. To achieve this, a spatial and temporal modulation of coherent light is required. Phase modulators that fulfill all requirements of a 3D display are currently not available on the market. Within the EU Horizon 2020 project REALHOLO Fraunhofer IPMS and various consortium partners are currently developing a MEMS based modulator that overcomes the former limitations by introducing a comb-drive actuator with a dual spring design on top of a CMOS backplane. The target application for the REALHOLO device is an automotive driver assistance holographic 3D head-up display, but the field of applications can easily be extended to medical applications like visualization of MRT/PET or remote surgery. For a reasonable image quality, the project partners anticipate that the SLM needs to have a pixel size of a few µm with 350nm of stroke, 8 bit deflection precision, a frame rate of about 1 kHz and nearly 10 million pixels.

2. Actuator Design

Piston mirror arrays are typically based on the parallel plate capacitor approach, which is a simple design, but has a limited ratio of mirror size to stroke and would suffer from significant crosstalk due to the high level of integration, see [1].

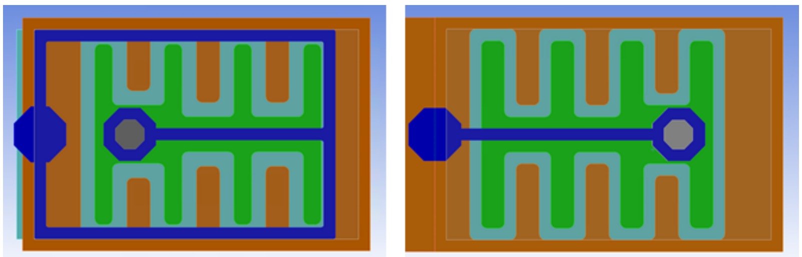

Figure 1: Geometry models of comb-drive actuator from a top view. Q-Spring design (left) and straight spring design (right)

To overcome these limitations an electrostatic comb-drive actuator with different dual hinge designs is shown in Figure 1 and discussed in more detail in [1,3], is developed. In principle, such an actuator can be designed with a single spring [2], but as shown in [1] such a design is very sensitive to manufacturing tolerances like overlay errors, thickness variations and stress gradients. By introducing the second spring, the actuator can be stabilized significantly. Figure 1 shows two different spring designs with the springs shown in dark blue, the fixed stator plate in orange and the moveable yoke in light green. The Q-spring design (Figure 1, left) introduces a rather soft variant, which is unsusceptible against manufacturing tolerances but can suffer from stress gradient-related spring bending (Figure 2, left) that can cause spring to mirror contact, which will likely result in a defect pixel. The stiffer straight spring design (Figure 1, right) is less tolerant to thickness variations but does not exhibit the bending behavior of the Q-spring design (Figure 2, right). The maximum deformation in z direction for this design is only 12nm compared to 227nm for the Q-spring design.

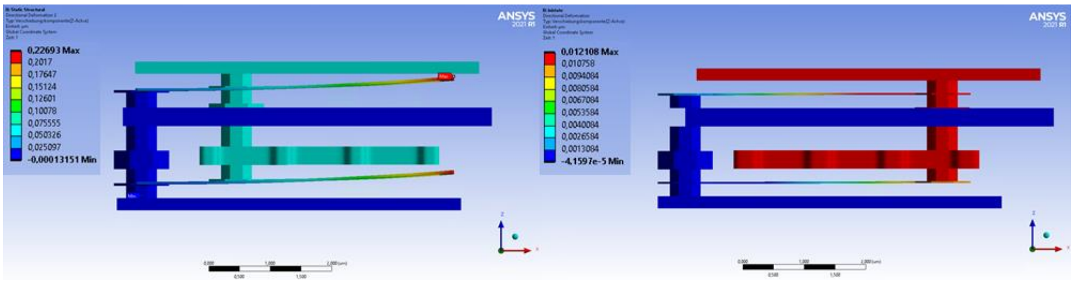

Figure 2: Reaction of the actuator to an introduced stress gradient of 100MPa (650MPa-550MPa); left: Q-spring right: straight spring. Both deflections are shown in their true scale

Due to the limited electrostatic force of the actuator, the required spring stiffness is quite low (depending on the comb-drive design k~40 nN/µm (Figure 3, right)) and will result in a thin spring between 25nm to 50nm. Figure 3 (left) shows the calculated spring constants from structural FEM simulations of straight springs with a width of 200nm, 300nm, and a Q-spring with a width of 200nm.

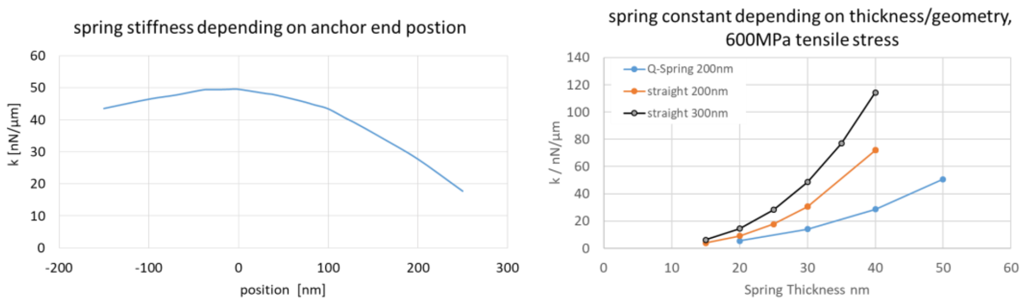

Figure 3: Required spring stiffness depending on the desired anchor end position (left) and spring constant depending on the thickness for various spring designs calculated from structural FEM simulations (right)

The critical parameter is the gradient of the spring stiffness, which equals the sensitivity of the spring design with respect to variations of design parameters. Depending on the design, a variation in spring thickness of about ±0,2nm will result in a change of the spring constant of ±1nN/µm.

3. Conclusions

MEMS based spatial light modulators might be the most promising approach to fulfill the very demanding requirements for the generation of computer-generated holograms in display applications. Due to the combinations of small pixel pitch, stroke and high level of integration in general, all design parameters of the actuator must be taken into account for a working device. The spring design is a key element to reach this goal. This paper shows two designs in different variants and discusses the impact of manufacturing tolerances on the general behavior of a SLM device.

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