Improved comb drive design for MEMS piston mirror arrays

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ABSTRACT

In this poster we propose an improved actuator concept for a MEMS based piston type micro mirror array (MMA). Based on electrostatic and structural FEM simulations, this design uses the small features of deep ultra violet lithography (DUV) to improve the actuator performance and to meet the demanding specifications of an SLM capable of real time holography, see [1] and [2].

parameter	value
pixel count	4000 x 2400
pixel size	4µm x 6µm
frame rate	> 1kHz
vertical deflection range	0 … 350nm
deflection precision	8 bit
mirror tilt	< 0.1°
pixel addressing voltage	0 … 3.3V
power dissipation	< 2.5W

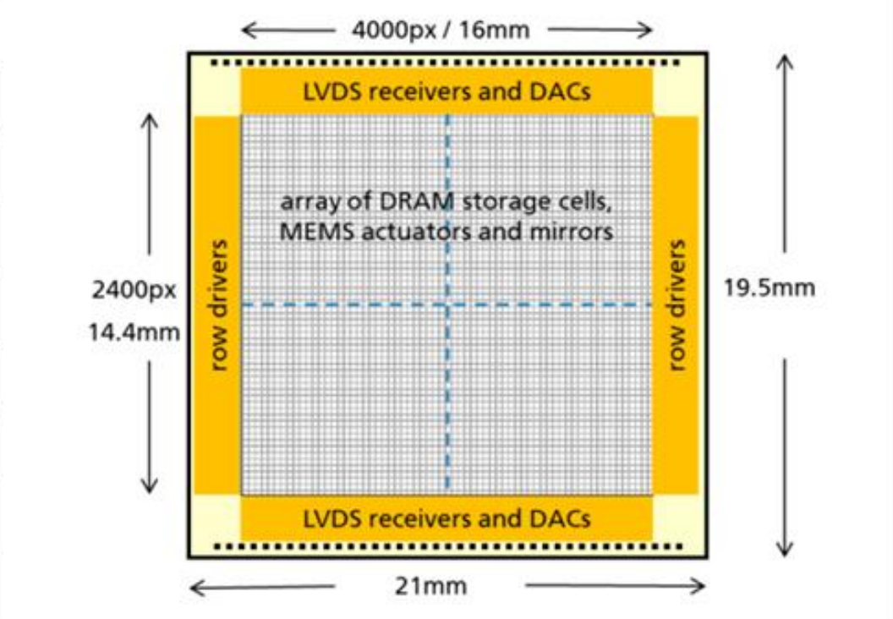

Table 1: SLM key specifications and device floor plan

INITIAL COMB DRIVE DESIGN

The Initial com drive design (Figure 1) consists of the base plate (cyan) that holds the main post which connects the hinges (blue) with the stator plane (orange). The second post connects the movable yoke (green) with the hinges and the micro mirror (transparent grey).

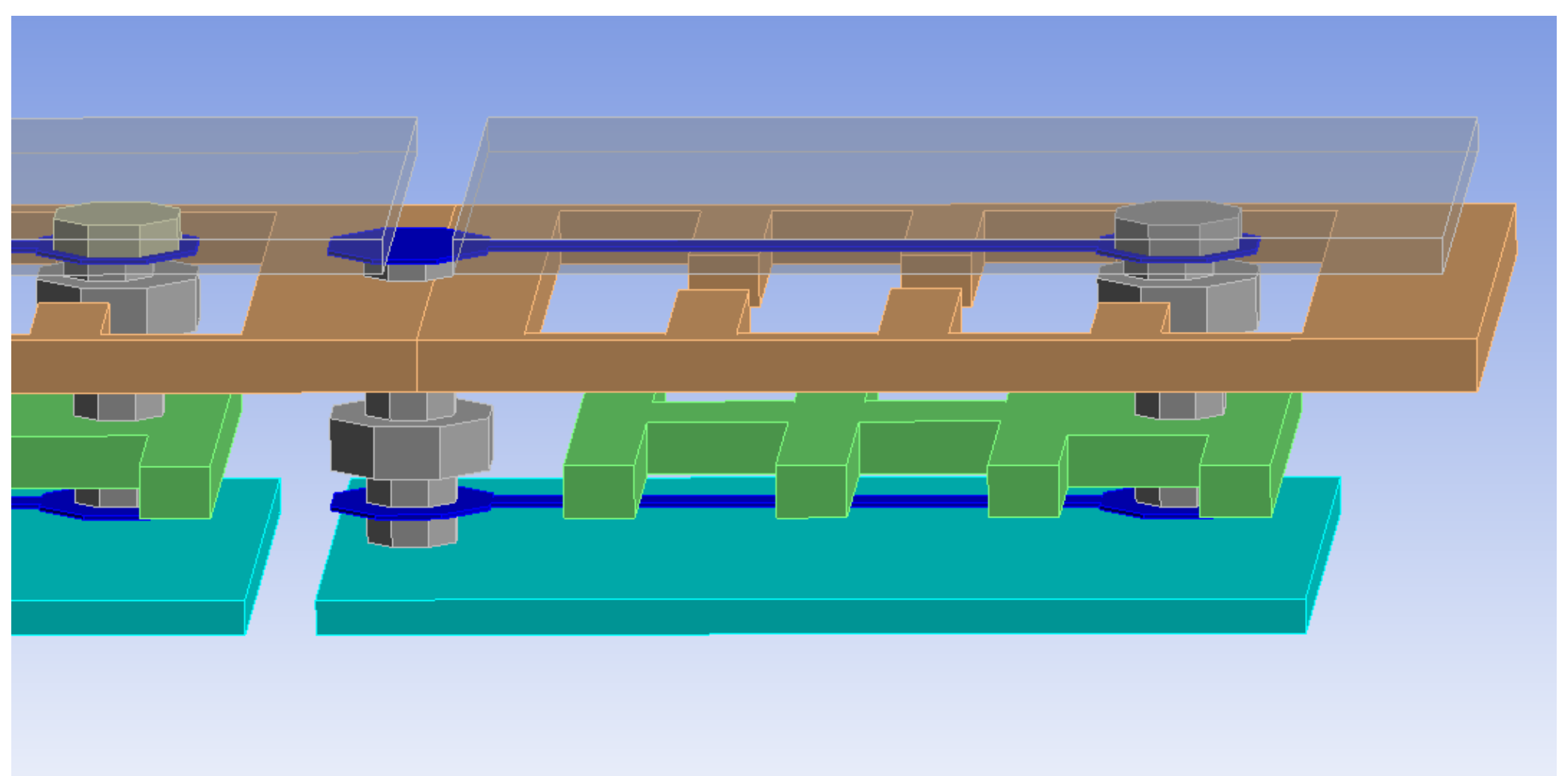

Figure 1: initial comb drive design with base plate (cyan), a dual hinge (blue), the stator plane (orange), a movable yoke (green) and the mirror (transparent)

FEM SIMULATIONS

For a reduction in calculation time the FEM simulations were split into electrostatic and mechanical simulations. For the electrostatics the mechanical model was subtracted from an air filled cuboid

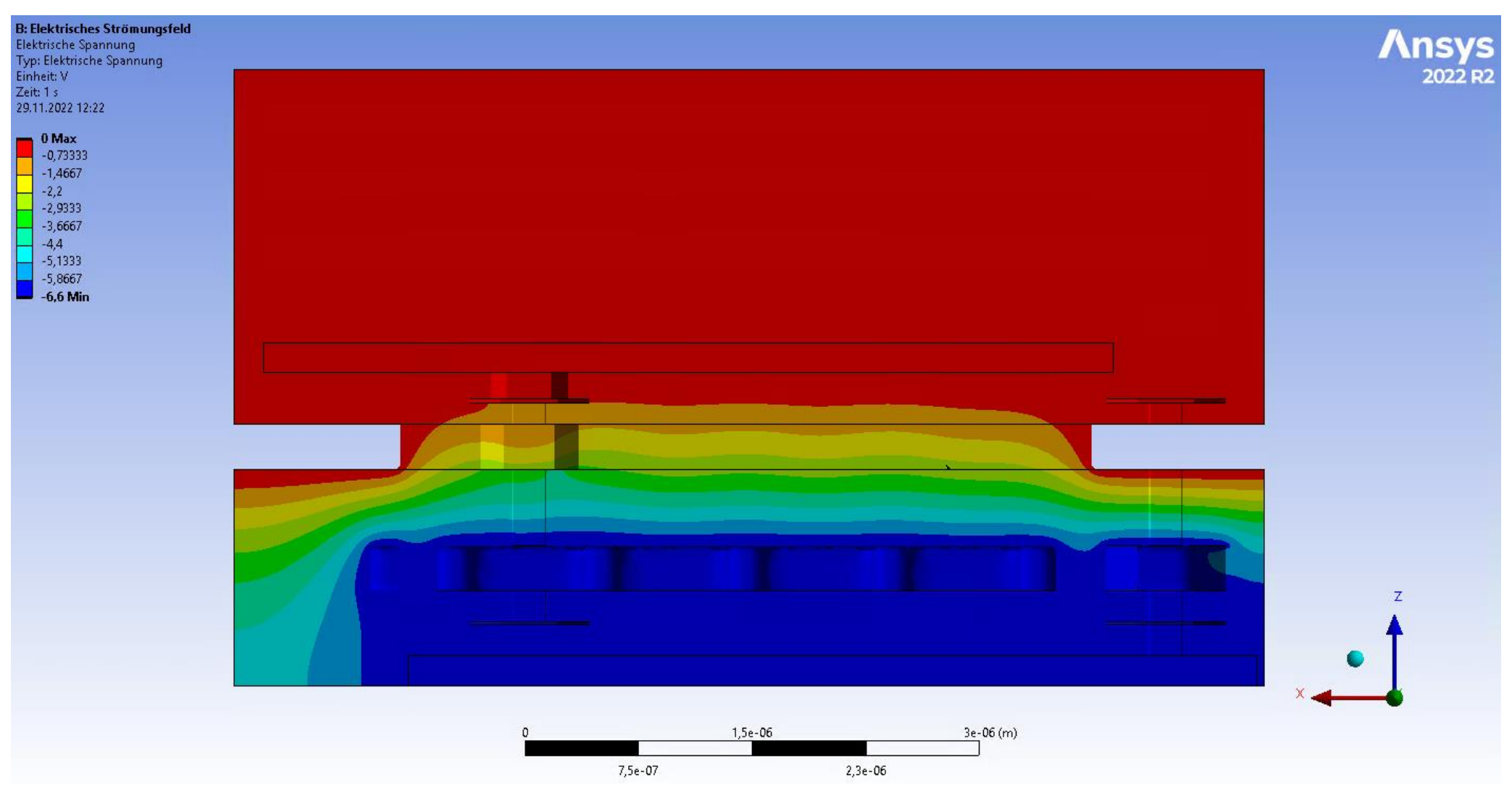

Figure 2: FEM model for electrostatics with applied addressing voltage (central cut)

Each position of the actuator yoke relative to the stator plane in combination with a given addressing voltage will result in a specific force.

DESIGN OPTIMIZATION

The DUV lithography with its improved feature size enabled a five-finger actuator within the available pixel space which could be produced reliably. To further reduce the crosstalk between neighbor pixels, other measures like additional shielding structures and shorter fingers were considered. The best results have been achieved by introducing a shield ring around the yoke see Figure 3.

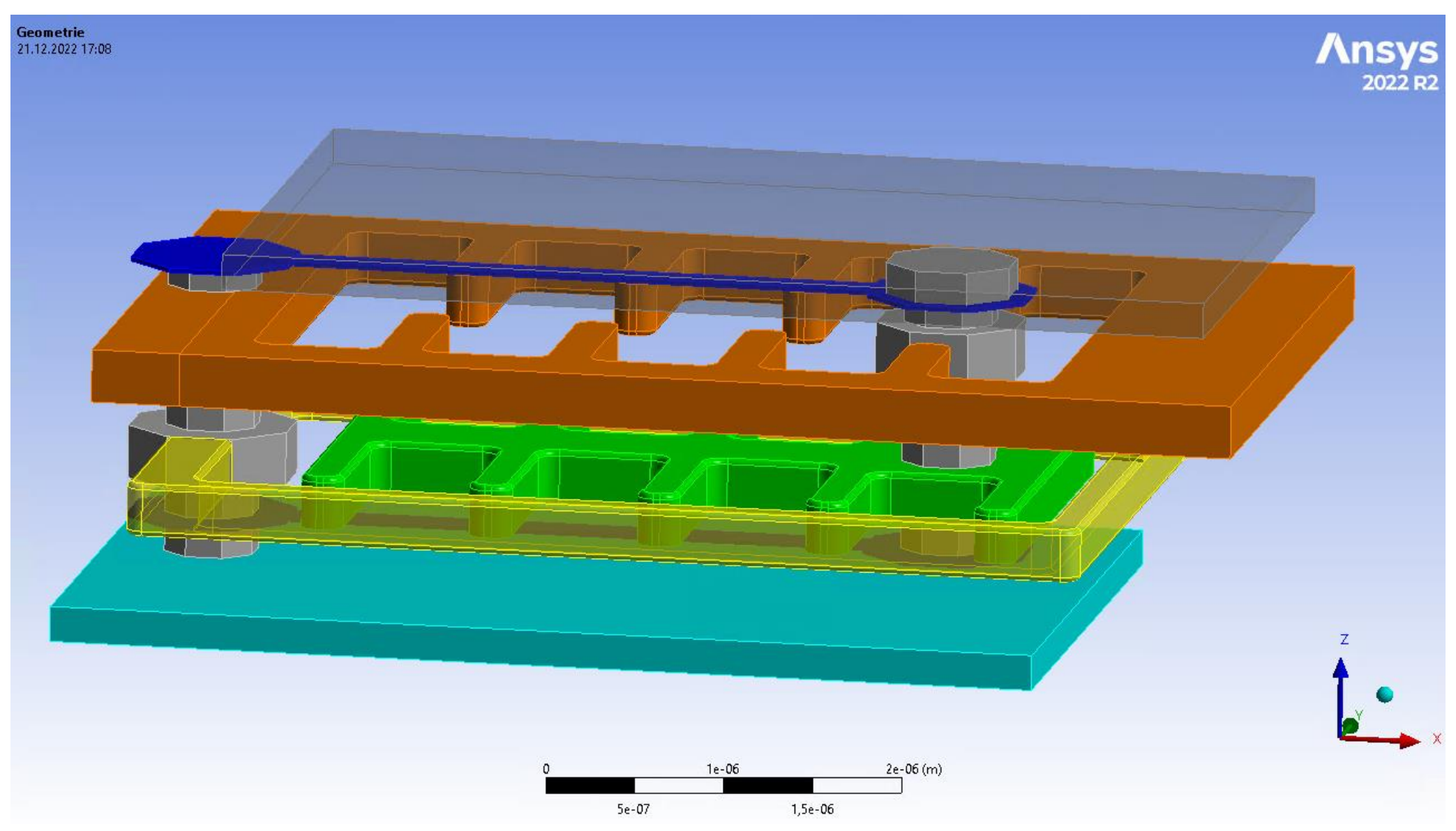

Figure 3: improved actuator design with base plate (cyan), a dual hinge (blue), the stator plane (orange), the movable five-finger yoke, screening ring (transparent yellow) and the mirror (transparent grey)

The electrostatic design optimization resulted in a 150 nm shorter hinge.

Improved actuator performance

The improved actuator design enabled a significant increase in available electrostatic force. Corresponding to the increased circumference the electrostatic force in Z for an horizontal gap of 260nm increases from 15.5nN to 18.1nN.

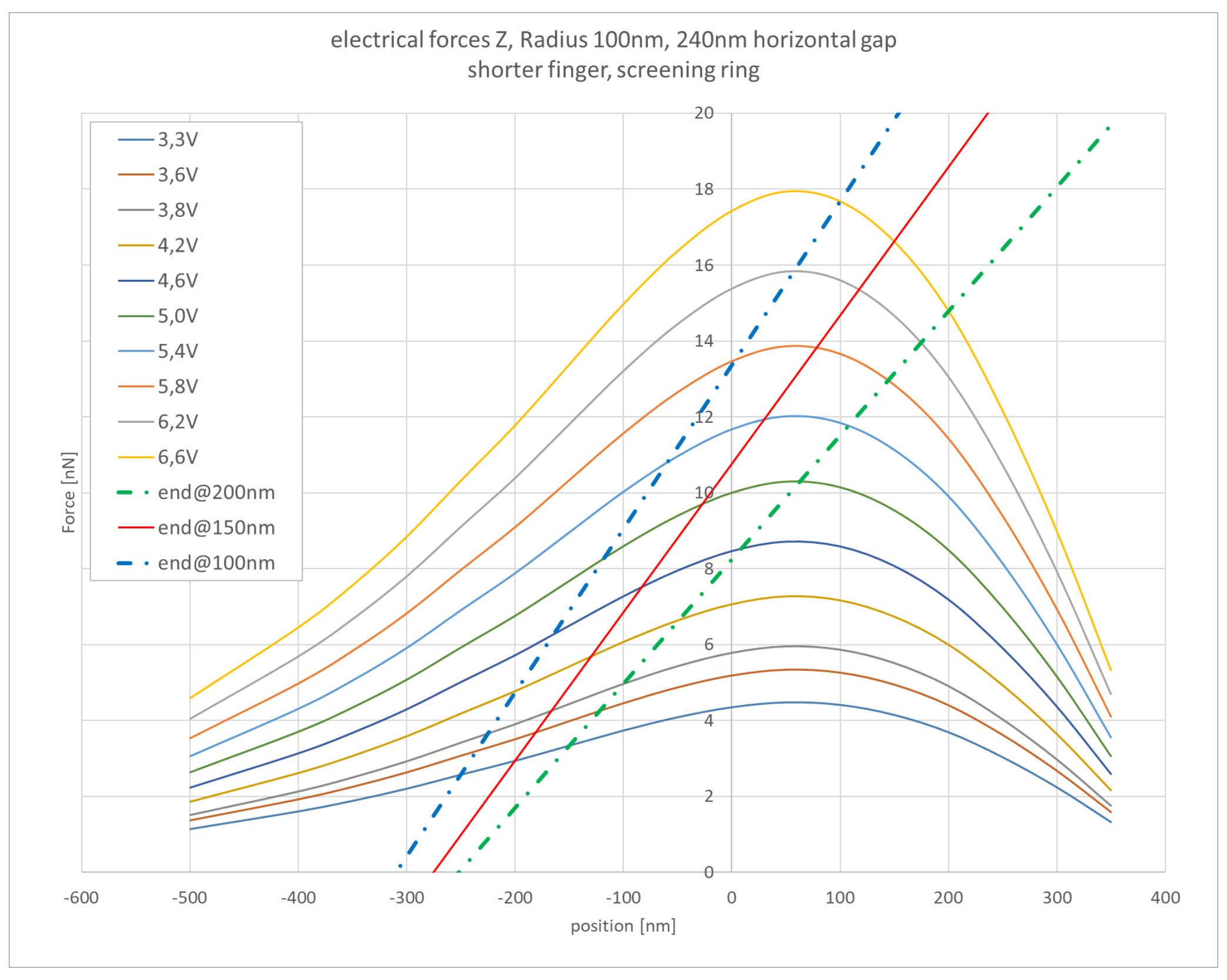

Figure 4: electrostatic force of the improved 5-finger actuator for different addressing voltages and three possible actuator end positions (relative to stator)

With the increased force countermeasures to prevent pixel crosstalk could be applied. By adding a screening ring around the actuator in its non deflected position and shortening of the electrode fingers the crosstalk could effectively be reduced to 0%. Therefor the complete voltage budget of the CMOS backplane can be used for calibrated deflection of the individual pixels, while remaining effective with the required voltage resolution and staying manufacturable.

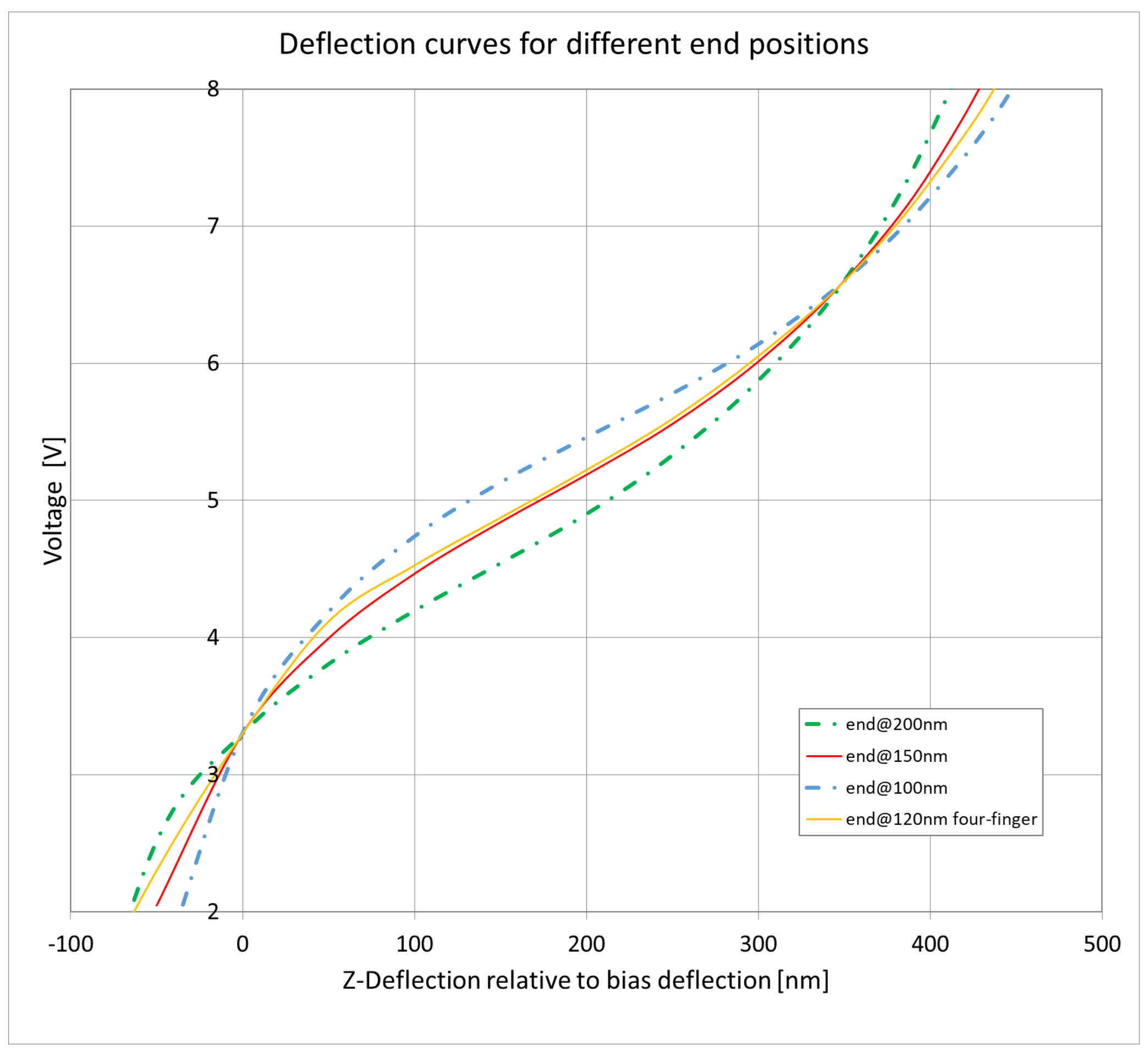

Figure 5: deflection curves of the improved five-finger yoke with two different yoke end positions and the initial four-finger design

As shown Figure 5 the response curve of the improved actuator design is similar to the behaviour of the initial design, while allowing stiffer springs. For small deflections the behaviour slightly differs because of the characteristics of the additional screening ring, which leads to a decreased force in the lower and increased force in the upper positions.

CONCLUSION

By using advanced DUV lithography we were able to improve the design of the comb drive actuator to better fit the tight requirements for real time computer generated holography. The solution, the five-finger actuator in with slightly shorter fingers and an additional screening ring offers more actuator force than the original design and almost zero cross talk.

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1 REALHOLO internet site: https://realholo.eu/

2 P. Duerr, A. Neudert, M. Nitzsche, C. Hohle, H. Stolle, J. Pleikies: " MEMS Piston Mirror Arrays for Computer Generated Holography", SPIE OPTO Proceedings Volume 12013, MOEMS and Miniaturized Systems XXI; 1201306 (2022), https://doi.org/10.1117/12.2608081

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