Design and Simulation of A MEMS Based Horseshoe Shaped Low Current Lorentz Deformable Mirror (LCL-DM)

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1. Introduction

- A deformable mirror (DM) is used to achieve wavefront control and correction of optical aberrations in many optical systems (telescopes [1], retinal imaging systems [2], and optical communications [3]).
- MEMS technology enables the miniaturization of actuator elements to decrease power consumption, reduce space occupancy, and enable the fabrication of large numbers of actuator elements together. These benefits can increase device reliability compared to that of classical actuators.

2. Design

- The low current Lorentz force deformable mirror (LCL-DM) system is comprised of an underlying horseshoe shaped actuator attached to an overlying mirror.
- Design specifications for the DM were ± 5 μm deformation, aluminum metal reflective surface, and below 10% inter-element crosstalk between adjacent mirror locations.

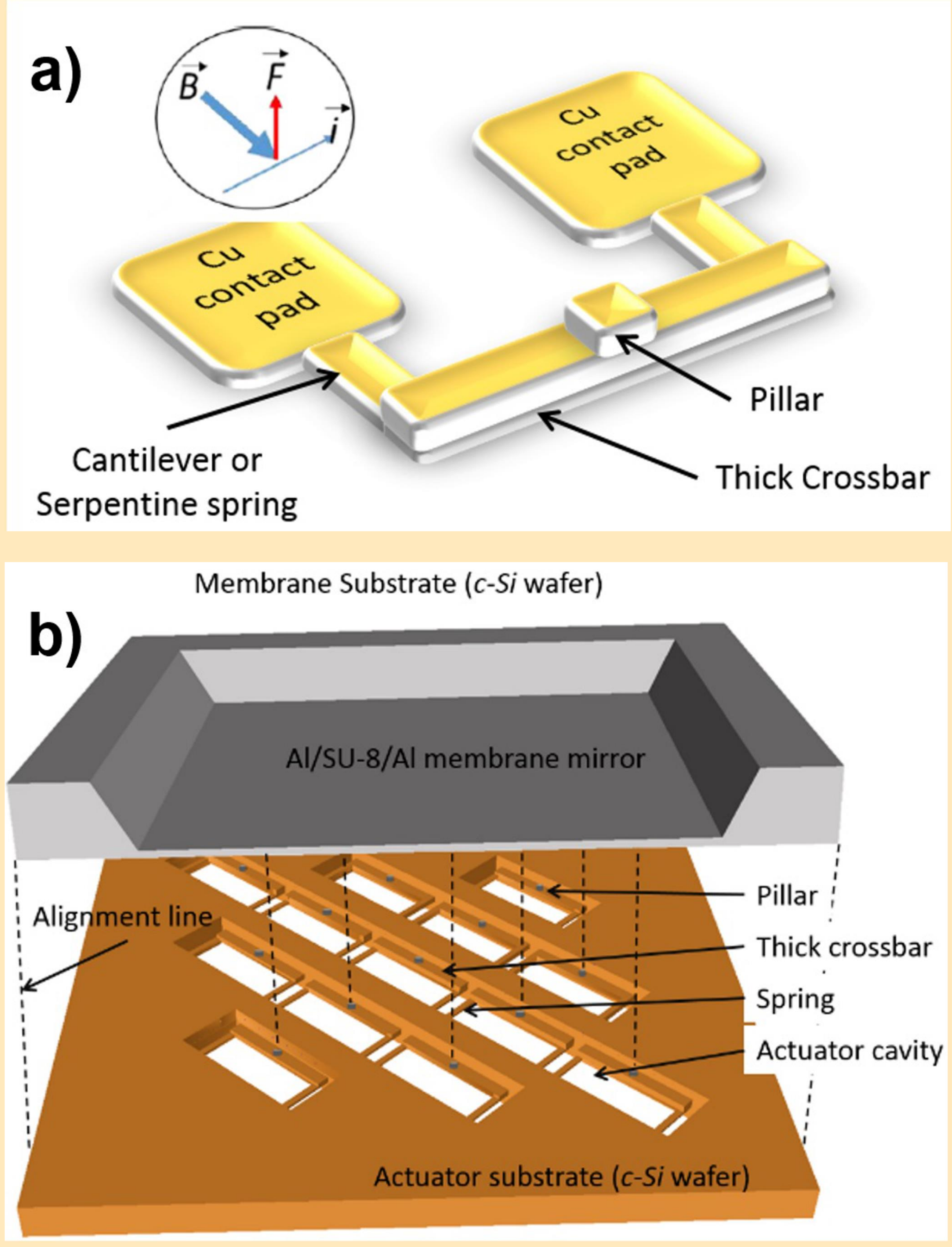

Figure 1. a) Illustration of Lorentz force actuator and force relationship (shown in the black circle), b) Illustration of a 3 x 3 array of Lorentz actuators below the DM structure.

3. COMSOL Multiphysics®

STEP 1: Simulate the spring constant of a corner clamped SU-8 membrane over a 3x3 actuator array, with 2000 μm actuator pitch.

STEP 2: Simulate the spring constant of the spring supported crossbar.

STEP 3: Simulate the mechanical deformation behavior of the continuous SU-8 membrane spanning a 3x3 actuator array.

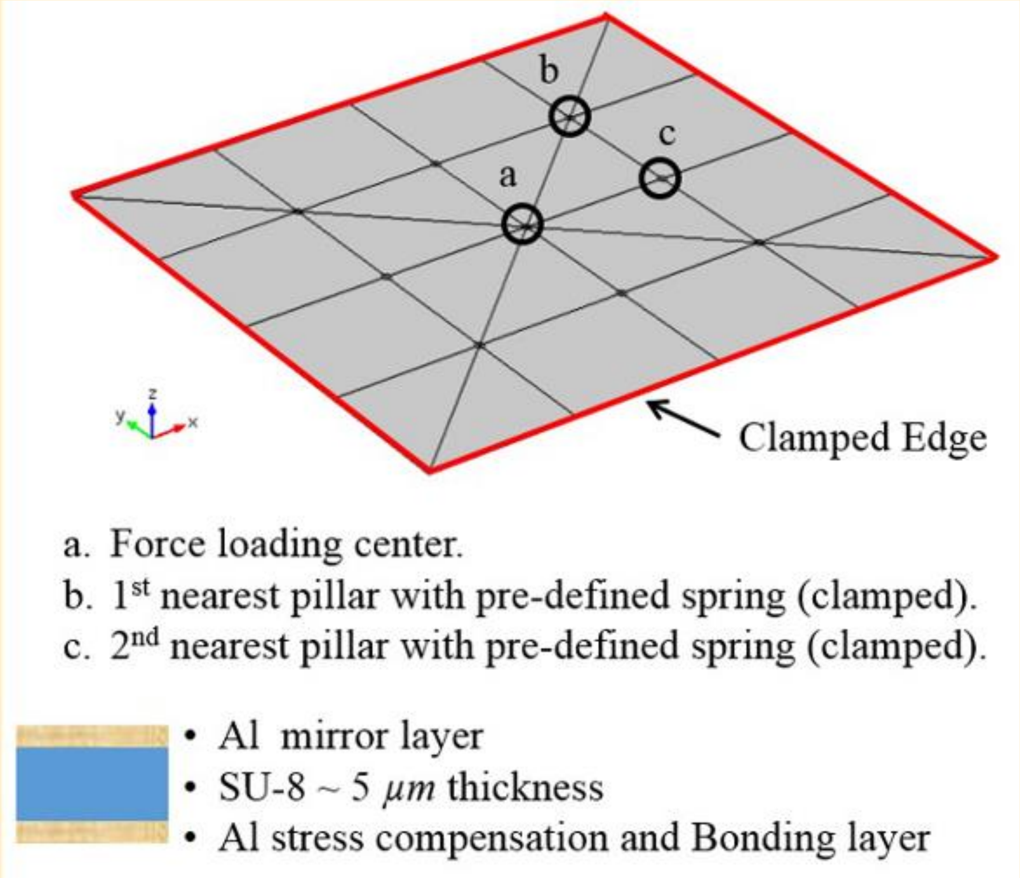

Figure 2. Boundary conditions of the membrane and its vertical structure.

4. Results

STEP 1

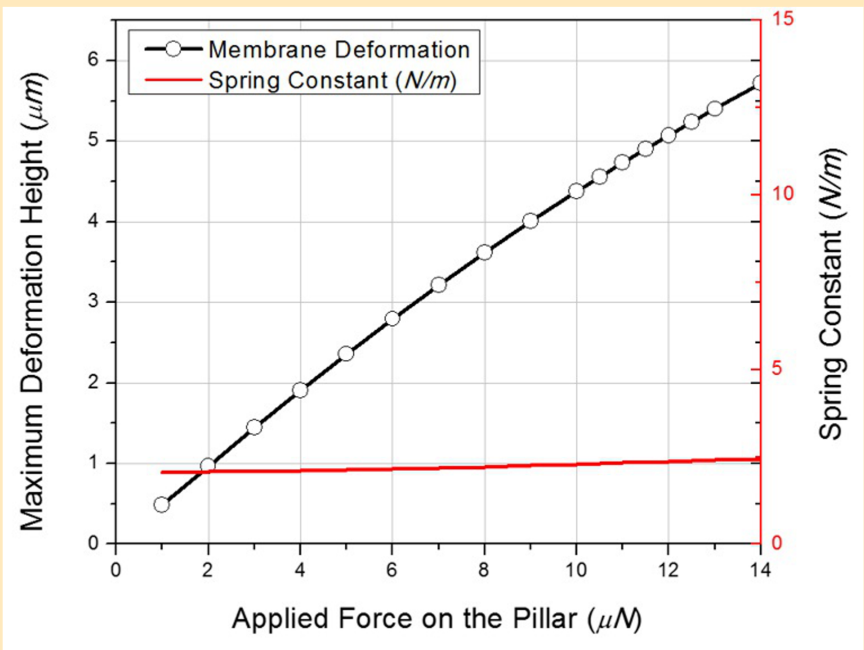

Figure 3. Double side aluminum coated SU-8 membrane deformation versus applied force, with determined membrane spring constant.

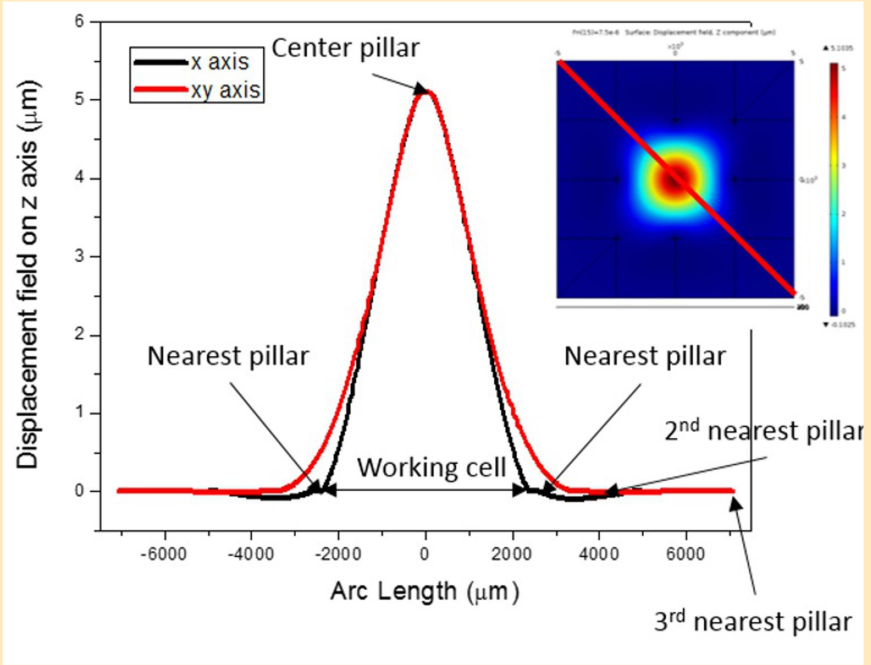

Figure 4. 5 μm membrane deformation profile in x and xy axis with 11.8 μN loading on the pillar, and with 1st and 2nd nearest pillar actuators fixed in place.

STEP 2

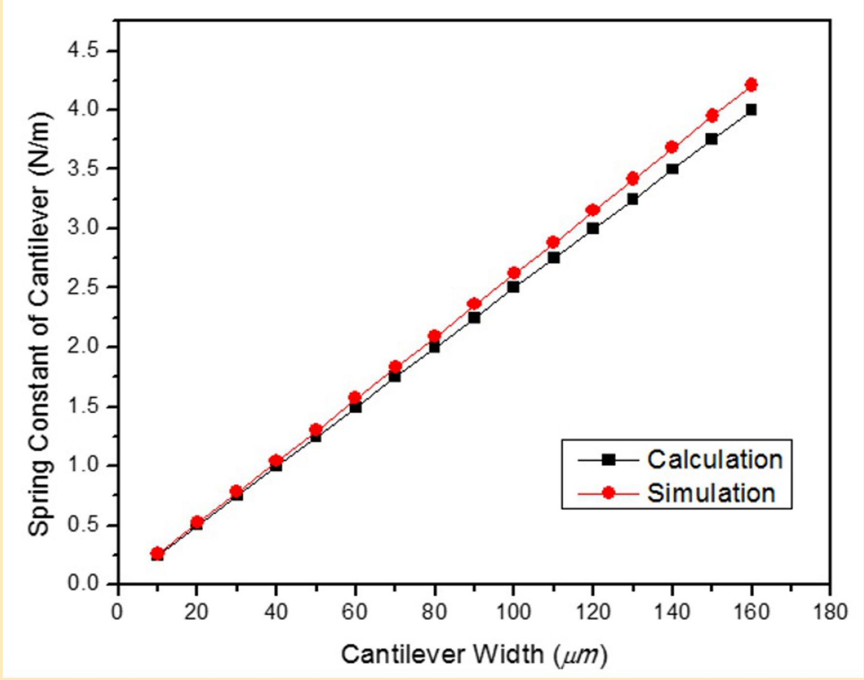

Figure 5. Cantilever spring constant with various width (red; simulation result, black; calculation result).

STEP 3

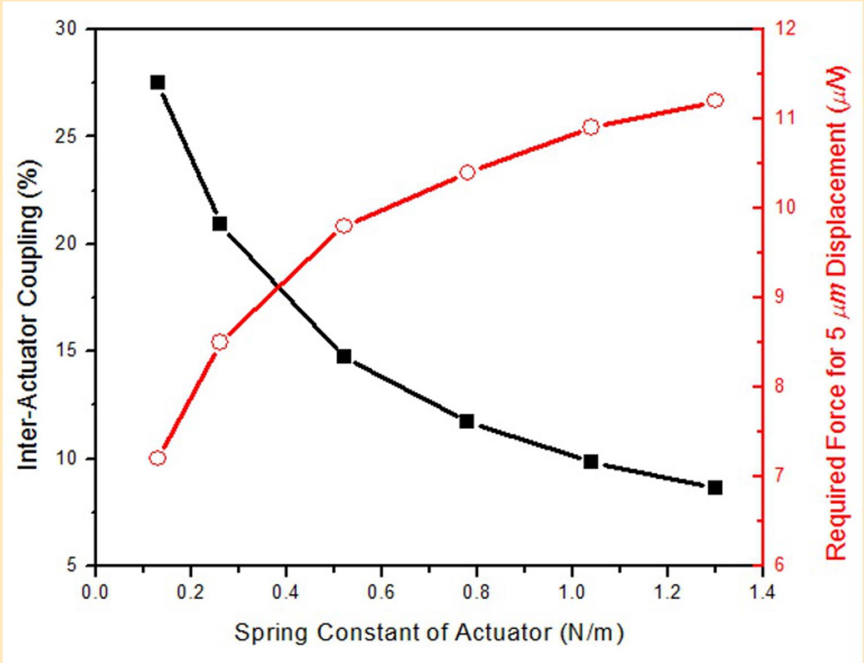

Figure 6. Inter-actuator coupling (crosstalk) and membrane deformation.

Heat Concern

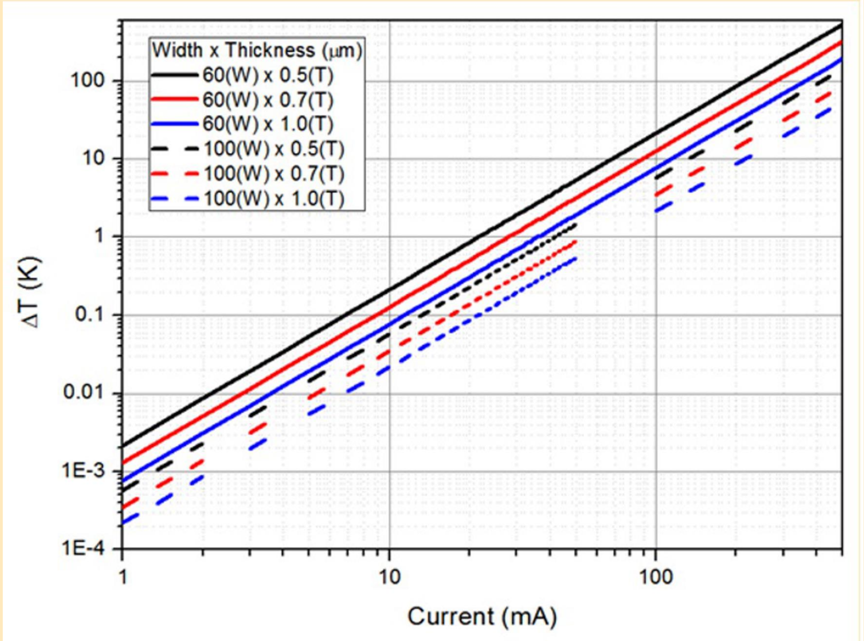

Figure 7. Maximum temperature change at the center of the crossbar vs. current level for various thicknesses and widths.

5. Conclusions

- ✓ The crosstalk was shown to vary from 10 to 25 % depending on actuator softness.
- ✓ The thermal stress induced by Joule heating is determined to be minimal for the required low operating current of the LCL-DM.
- ✓ The designed LCL-DM offers low voltage operation compared to conventional electrostatic DMs.

References

1. Madec, P. -Y. Overview of deformable mirror technologies for adaptive optics and astronomy. In *SPIE Astronomical Telescopes+ Instrumentation* (pp. 844705–844705) (2012).
2. Vera-Díaz, F. A., and Doble, N. *The Human Eye and Adaptive Optics*. INTECH Open Access Publisher (2012)
3. Vinevich, B. S., Evdokimovich, L. N., Safronov, A. G., and Smirnov, S. N. Application of deformable mirrors in industrial CO2 lasers. *Quantum Electronics*, ***34***(4), 333. (2004).

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