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

B. Park[1], T. Chen[1], C. Shafai[1]

[1]Department of Electrical and Computer Engineering, University of Manitoba, Winnipeg, MB, Canada

Abstract

This paper presents the design and analysis of a novel horseshoe shaped MEMS actuator for adaptive optics. The actuation mechanism is Lorentz force enabling low current (below 10 mA) operation. The actuator combined with an overlying aluminum coated SU-8 soft polymer membrane for the mirror, together form the complete adaptive optics system to enable correction of wavefront distortion of optical aberrations. Simulations using COMSOL Multiphysics® software detail actuator design, mirror motion, and inter-element crosstalk between actuators. Thermal effect by Joule heating, a major drawback of high current actuators, is simulated, and show the Lorentz actuator has less than a 0.1 K temperature change.

The presented low current Lorentz deformable mirror (LCL-DM) system offers many advantages compared to the widely used MEMS electrostatic actuated deformable mirrors. Electrostatic MEMS actuators commonly require a high operation voltage and shows nonlinear behavior [1]. By contrast, Lorentz force excited MEMS actuators are low voltage devices and additionally offer bi-directional motion with no magnetic hysteresis effects, enabling them to push upwards as well as pull downwards. This enables the correction of surface flatness issues due to gravity-induced deformation on larger diameter mirror membranes. These advantages, combined with a simple actuator design, fast response, and reasonable power consumption, make them ideal for a large stroke applications [2,3].

The various mechanical and thermal properties of the device are modeled using COMSOL Multiphysics® software. The overall simulation was divided into three main steps, in order to achieve accurate computation and reduce computation time. First, the spring constant of a corner clamped SU-8 membrane over 3 x 3 actuator array is simulated. Second, the spring constant of the spring-supported crossbar is defined by using simplified cantilever structure. Last, the mechanical deformation behavior, resonant frequency, and inter-element crosstalk is simulated by combining the first and second simulation into a 3D structured Lorentz deformable mirror system. In addition, Joule heating, which can be a significant problem for Lorentz devices using higher current flow, was studied, and the results show a minimal 0.1 K change with a maximum operation current of 7.7 mA.

Reference

1. Yellin, M. (1976). Using Membrane Mirrors In Adaptive Optics (vol. 0075, pp. 97–102). http://doi.org/10.1117/12.954743

2. Hsu, T.-R. (2008). MEMS & Microsystems: Design, Manufacture, and Nanoscale Engineering. John Wiley & Sons.

3. Lv, X., Wei, W., Mao, X., Chen, Y., Yang, J., and Yang, F. (2015). A novel MEMS electromagnetic actuator with large displacement. Sensors and Actuators A: Physical, vol. 221, pp. 22–28. http://doi.org/10.1016/j.sna.2014.10.028

Figures used in the abstract

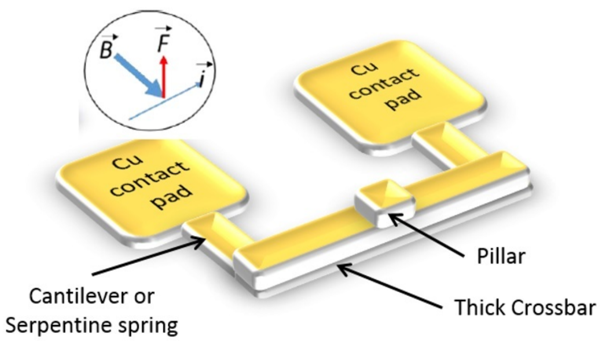

Figure 1: Illustration of Lorentz force actuator and force relationship (shown in the black circle)

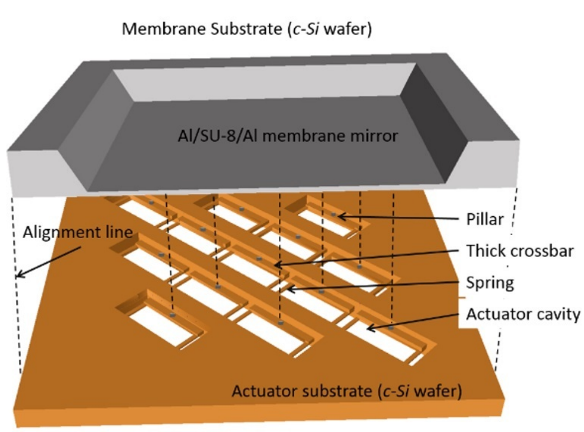

Figure 2: Illustration of a 3 x 3 array of Lorentz actuators below the DM structure.

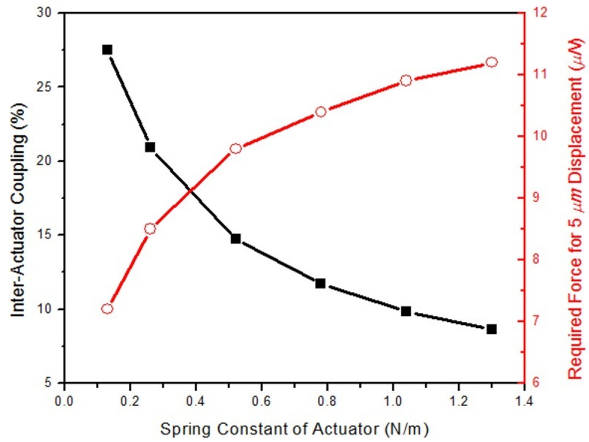

Figure 3: Inter-actuator coupling (crosstalk) and membrane deformation.

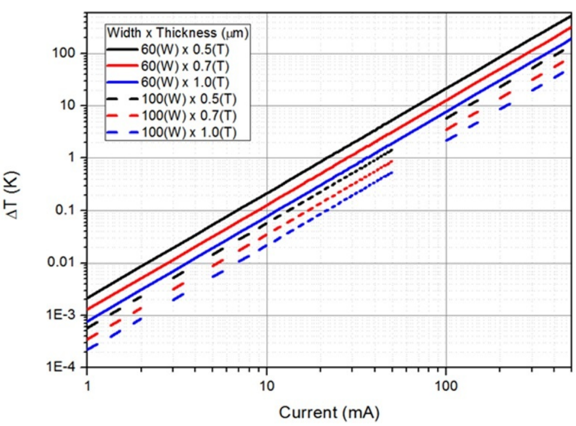

Figure 4: Maximum temperature change on the center of crossbar vs. current level of various thicknesses and widths of two horseshoe shaped Lorentz actuators.