

NRC Publications Archive Archives des publications du CNRC

Design and simulation of a scaled-up continuous deformable mirror system driven by MEMS-based Lorentz actuator arrays

Park, Byoungyoul; Bergren, Adam John; Belov, Miroslav; Burley, Greg; Shafai, Cyrus

NRC Publications Archive Record / Notice des Archives des publications du CNRC :

<https://nrc-publications.canada.ca/eng/view/object/?id=dd121e8a-6a7d-45c7-ab06-d5f7f0e434bf>

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=dd121e8a-6a7d-45c7-ab06-d5f7f0e434bf>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at

PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

Design and Simulation of a Scaled-up Continuous Deformable Mirror System Driven by MEMS-Based Lorentz Actuator Arrays

Byoungyoul Park¹, Adam John Bergren¹, Miroslav Belov¹, ~~and~~ Greg Burley², ~~and~~ Cyrus Shafai³

¹Nanotechnology Research Centre, 11421 Saskatchewan Drive, Edmonton, AB T6G 2M9 Canada.

²NRC-Herzberg Astronomy & Astrophysics, 5071 W. Saanich Rd., Victoria, BC, V9E 2E7, Canada

³Dept. Of Elec. and Comp. Eng. University of Manitoba, Winnipeg, MB, R3T 5V6, Canada

*Corresponding author: Nanotechnology Research Centre, 11421 Saskatchewan Drive, Edmonton, AB T6G 2M9 Canada. Byoungyoul.Park@nrc-cnrc.gc.ca

Abstract

This paper presents the design and simulation results of a MEMS-actuated deformable mirror (DM) consisting of a 20×20 Lorentz-force actuator array bonded to a flexible mirror. The DM is the critical component of an Adaptive Optics (AO) system targeted for ground-based telescope applications to actively compensate for optical aberrations due to atmospheric turbulence. In addition, there are several other applications for such AO systems, including microscopy, medical imaging, and optical communication. In order to meet the needs of various applications, Finite Element Method simulation of actuator performance is carried out using COMSOL Multiphysics software.

The DM consists of a flexible mirror-coated face sheet bonded to an array of 10s to 1000s of individual actuator elements that can push or pull the mirror vertically to shape the mirror surface. This study focuses on scaling up to a 20×20 actuator array from previously demonstrated 5×5 arrays for application in the Thirty-Meter Telescope (TMT). The Narrow-Field Infra-Red Adaptive Optics System (NFIRAOS), which is being developed for use in the TMT, requires two different DMs of 64×64 , and 72×72 for use in correcting 11.8 km and ground atmospheric turbulence, respectively. Previous work showed results for a 5×5 Lorentz actuator array DM simulated using COMSOL Multiphysics software, as presented at the COMSOL 2015 conference [3]. Demonstration results of the 5×5 Lorentz actuator array and DM manufactured using a microfabrication process were published in reference [4] and [1], respectively.

For the scaled-up version of the 20×20 actuator array DM, the various mechanical and thermal properties of the actuators and mirror are simulated using COMSOL Multiphysics software. The simulation starts by computing the inter-actuator coupling of the mirror according to the spring constant of the Lorentz actuator consisting of crystalline silicon. A total of $10 \mu\text{m}$ mirror deformation is targeted, and the maximum force to reach this deflection is calculated for both SU-8 and nitride face sheet. Finally, the Lorentz actuator and mirror design were refined by considering the Joule heating magnitude (less than 0.1 K is required for the telescope application). The results of the simulations are represented in Figure 1.

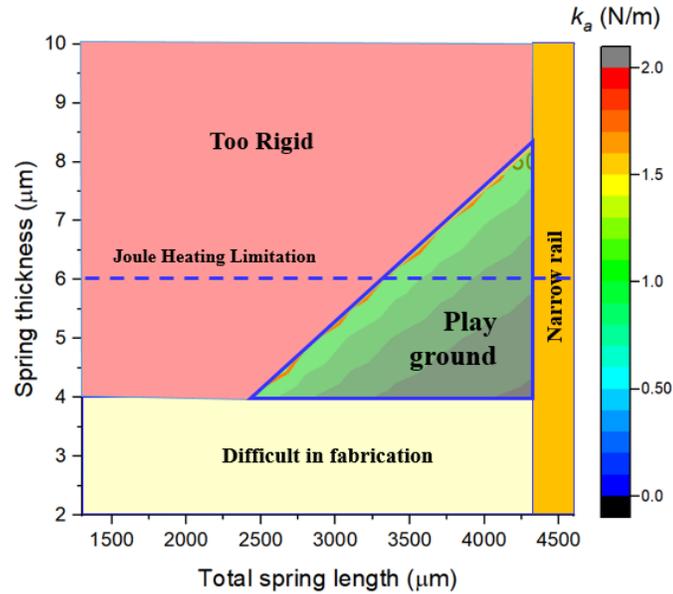


Figure 1. Design and fabrication playground of the MEMS Lorentz actuator according to spring and rail dimension and Joule heating

References

- [1] B. Park, E. Afsharipour, D. Chrusch, C. Shafai, D. Andersen, and G. Burley, "A low voltage and large stroke Lorentz force continuous deformable polymer mirror for wavefront control," *Sensors and Actuators A: Physical*, vol. 280, pp. 197–204, Sep. 2018, doi: [10.1016/j.sna.2018.07.047](https://doi.org/10.1016/j.sna.2018.07.047).
- [2] J. Crane et al., "NFIRAOS adaptive optics for the Thirty Meter Telescope," in *Adaptive Optics Systems VI*, Austin, United States, Jul. 2018, p. 144, doi: 10.1117/12.2314341.
- [3] B. Park, T. Chen, and C. Shafai, "Design and Simulation of A MEMS Based Horseshoe Shaped Low Current Lorentz Deformable Mirror (LCL-DM)," presented at the COMSOL 2015, Boston, MA, Oct. 2015, Accessed: May 05, 2020. [Online]. Available: <https://www.comsol.com/paper/design-and-simulation-of-a-mems-based-horseshoe-shaped-low-current-lorentz-defor-28552>.
- [4] B. Park, E. Afsharipour, D. Chrusch, C. Shafai, D. Andersen, and G. Burley, "Large displacement bi-directional out-of-plane Lorentz actuator array for surface manipulation," *Journal of Micromechanics and Microengineering*, vol. 27, no. 8, p. 085005, Aug. 2017, doi: 10.1088/1361-6439/aa7970.