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

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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 µm 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.

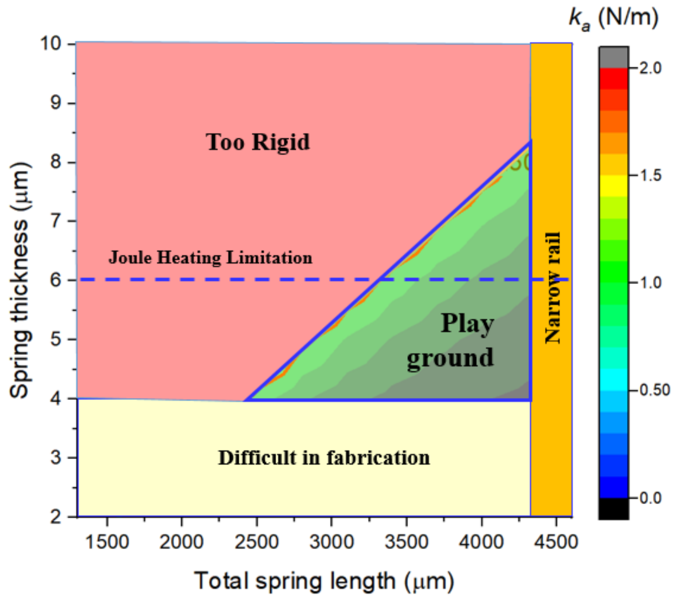

Figure 1. Design and fabrication playground of the MEMS Lorentz actuator according to spring and rail dimension and Joule heating

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