National Aeronautics and Space Administration

FY23 Innovative Spontaneous Concepts Research and Technology Development (ISC)

MEMS Deformable Mirror (DM) for coronagraph instruments

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Objectives

Our main objective was to design a MEMS deformable mirror (DM) with a stroke movement up to 1 μm, a 400 μm pitch and an actuation voltage below 100V, and to look into the integration of the electrical interconnects with the DM cells, for a 100x100 array. This task was also intended to provide a path forward for a JPL-led white paper proposal, in response to the Deformable Mirror Technological RoadMap (DMTR) identified gaps for the Habitable Worlds Observatory (HWO) coronagraph instrument.

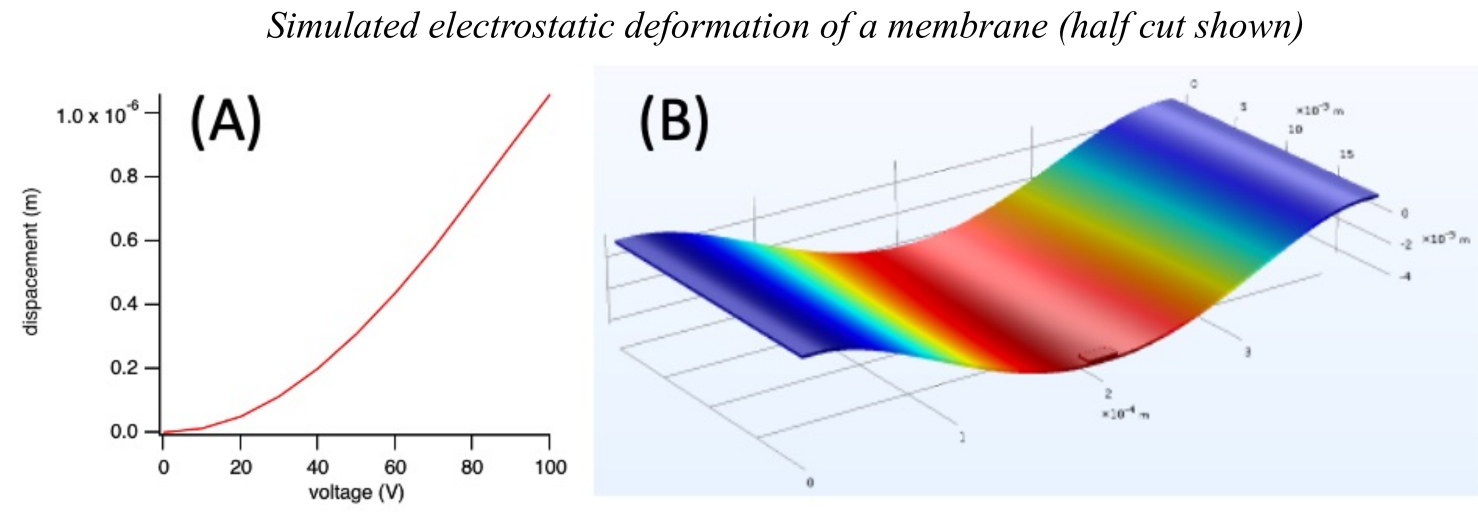
Background

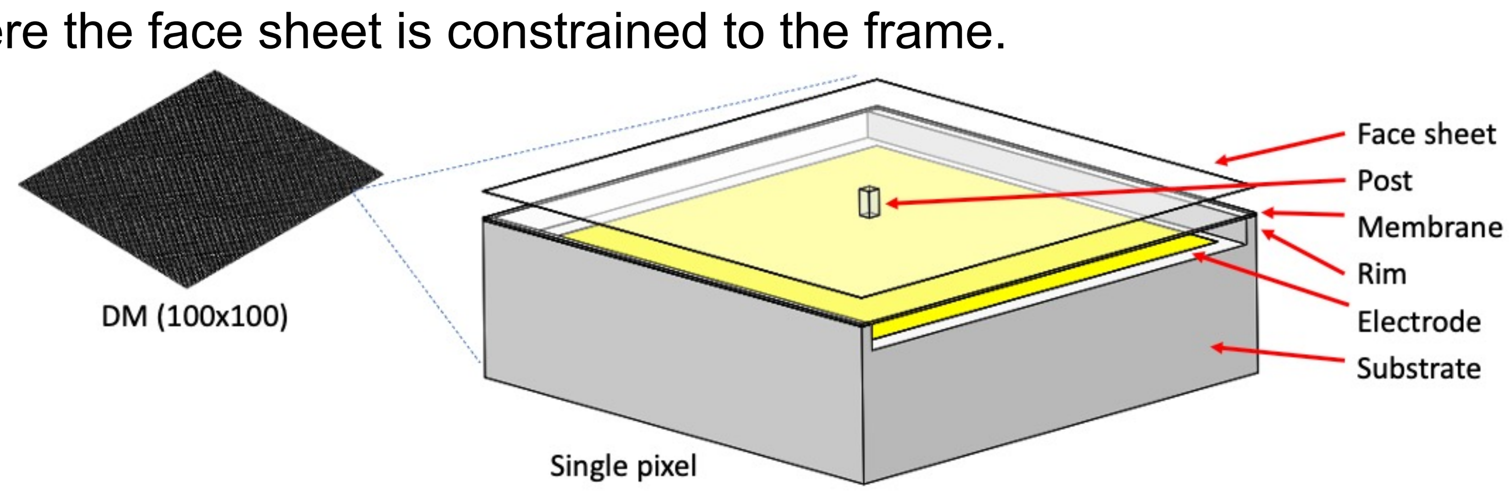
Deformable Mirrors (DMs) are the workhorses of coronagraph instruments and are one of the key enabling technologies to achieve better than ~1e-6 contrast in a real system. Coronagraphs typically contain two DMs, which are utilized to compensate the wavefront error in the system, producing a clean starting slate. After that process has concluded, an algorithm is used to compute the ideal command to the DMs to improve the contrast. This is looped several times, until the desired performance is reached, e.g. 1xe^{-10} for the Habitable Worlds Observatory (HWO). The DM being continuously variable and having high spatial resolution is essential in their use to produce extremely high contrast in coronagraphs. MEMS-based DMs are preferable over lead magnesium niobate or similar for high yield, consistency and scalability, thanks to the use of semiconductor processes.

Approach and Results

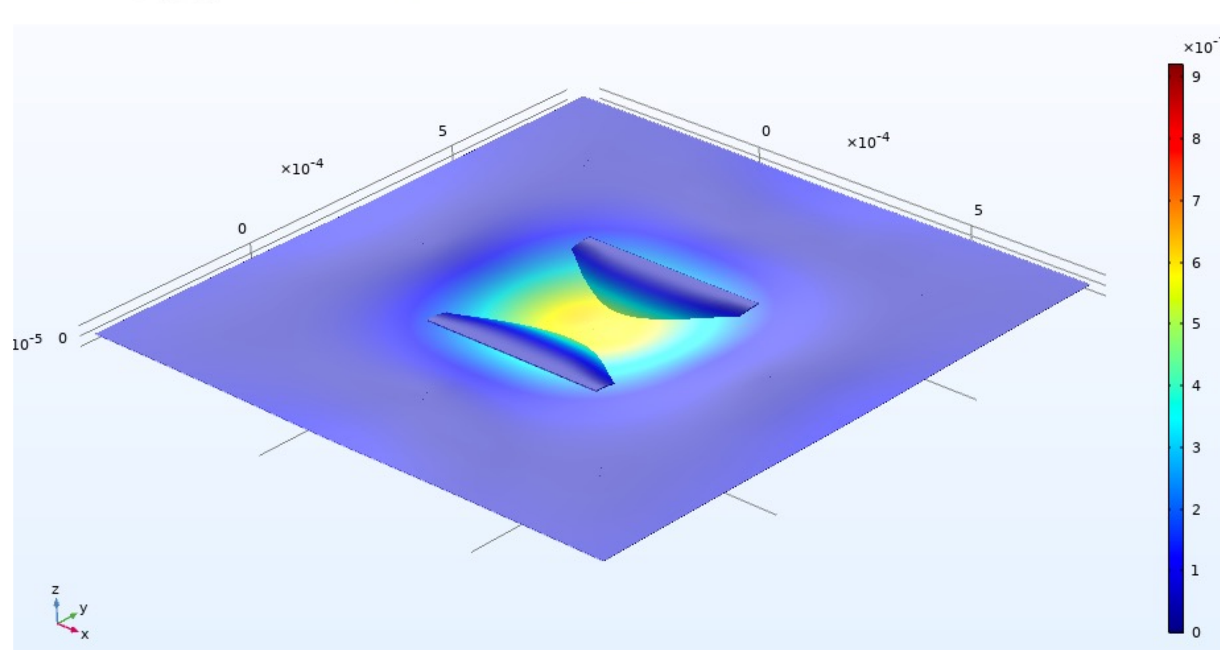
Preliminary simulation shows that a silicon-based DM with 1 μm face sheet and 1 μm membrane thickness, 2 μm electrostatic gap can deform approximately 1 μm at the applied 100V DC voltage. The displacement will be impacted by roughly 40% if neighboring pixels are fixed, but this extreme case only applies to the DM perimeter pixels where the face sheet is constrained to the frame.

Simulated electrostatic deformation of a membrane (half cut shown)





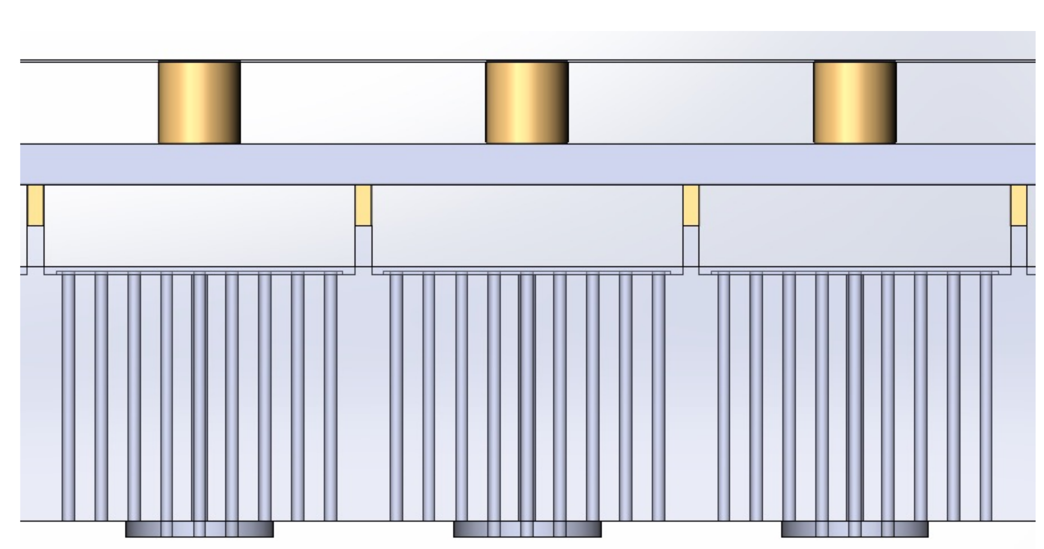
Deformable mirror single pixel geometry (not to scale).



Simulated 3x3 pixels array DM. Only the center pixel is actuated.

The sacrificial layers used during the fabrication and bonding are released from the backside of the DM, leaving the <u>reflective mirror surface flat with no holes</u>. As backside processing is needed for the release holes, it also allows for the vertical integration of the interconnects, to route them from the back of the wafer rather than the side, dramatically reducing the overall size of the DM.

Limiting the number of wires that are required would be beneficial to reduce the overalls size of the deformable mirror diameter, minimizing wire routing on DM, and limiting routing on interposer. Some ways to reduce the number of interconnects would be to gang pixels outside the lens aperture to one drive, and possibly <u>build in a multiplexing integration directly onto the interposer interconnect</u>.



Cross-section view of a 3x3 silicon-based DM, with the fabrication process using SOI wafers and Au-Au thermo-compression bonding.

Significance/Benefits to JPL and NASA

One of the objectives of this task was to find a path forward for MDL and JPL to lead a white-paper proposal, in response to the Deformable Mirror Technological RoadMap (DMTR) identified gaps for the Habitable Worlds Observatory (HWO) coronagraph instrument. Our task identified two potential routes for us to propose, one as a collaborative effort with Boston Micromachined Coorporation, and one as a sole identity for the fabrication/integration of the DMs, <u>strategically positioning JPL</u> as a technology hub for the delivery of future DMs.

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