Simulation of Planar Microshutter Array for Multi-object Spectroscopy

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A planar microshutter array (MSA) is described in which light is modulated at each shutter. An MSA can allow columnated light from selected objects of a multi-object image to pass through a prism or diffraction grating for spectrographic analysis. MSAs have been developed at the NASA Goddard Space Flight Center for use with the Near Infrared Spectrometer carried on the James Webb Space Telescope. This abstract provides an alternative design with significant advantages over the Goddard array [1, 2].

Prior actuation methods include magnetic and electrostatic force pull-in, with voltages ranging from 60 to 125 volts and flexures that open out-of-plane with independent control of each shutter. The shutters of the present design open in the plane and share a single input line. Each shutter of the present design contains two layers of lines and spaces of long etch holes that either enable the transmission of light when the two layers of etching holes are fully aligned upon pull-in actuation or block the transmission of light when the two layers of etching holes are fully misaligned at zero state (Figure 1). In-plane resonance pull-in is used to select which shutters open, where each shutter resonates at a different frequency. Prescribed variations in flexure geometry enable each shutter window to have a different resonance frequency. Resonance pull-in relies on displacement amplitude to reduce the initial gap size. Resonance pull-in can be achieved when the electrostatic force generated by the DC voltage is greater than the mechanical forces acting in the opposite direction of gap closure. The closer the resonance displacement peak is to complete gap closure, the smaller the DC voltage needs to be (Figure 2).

While voltage can be reduced to less than a volt, light transmission is reduced by about 50%, so twice the exposure time may be required. A smaller vertical gap between the two layers reduces the transmission ratio (Figure 3).

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[1] M. J. Li et al., "James Webb Space Telescope micro shutter arrays and beyond," *J. of Micro/ Nanolithography, MEMS, and MOEMS*, 16 (2),025501 (2017)

[2] M. P. Chang et al., "Development of the Next Generation Microshutter Arrays for Space Telescope Applications," *IEEE 15th International Conference on Nano/Micro Engineered and Molecular Systems (NEMS)*, pp. 89-92 (2020)

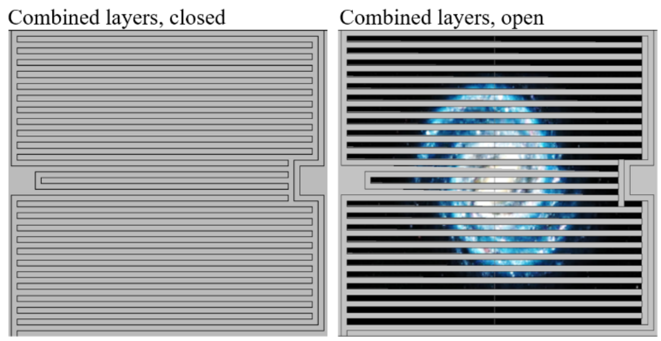

Fig. 4: Shutter states. Closed state versus actuated open state.

Figure 1: Shutter states. Closed state versus actuated open state.

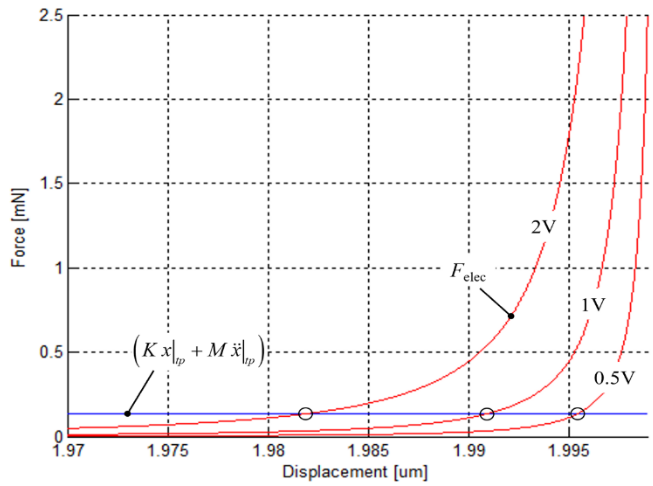

Figure 2: Pull-in voltage. The x-axis represents the displacement upon closure of a 2 µm gap. The blue curve is the sum of mechanical forces (stiffness x displacement + mass x acceleration) acting against pull-in. Each red curve is the electrostatic force for a given voltage, acting in the direction of pull-in. The circles represent the onset of pull-in when electrostatic forces overcome mechanical forces.

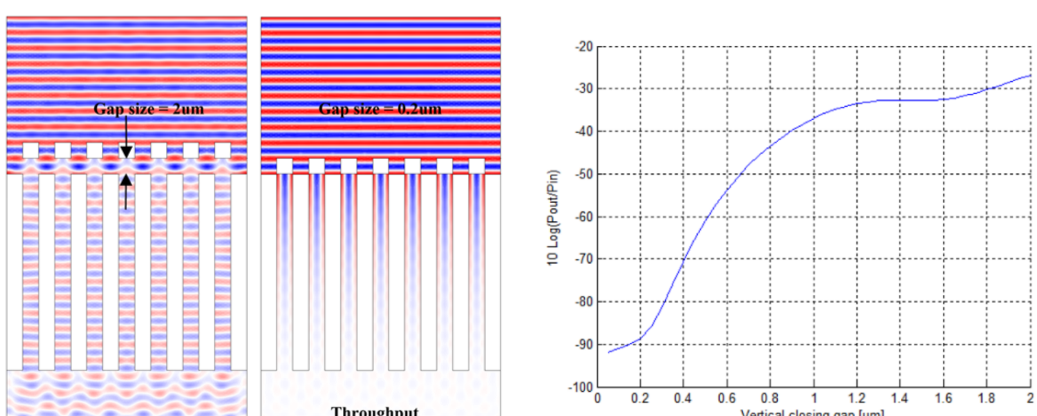

Figure 3: (Left) Transmission of closed microshutter vs. gap size. (Right) Light power transmission ratio vs. closed gap size.