Design and Simulation of a Planar Resonance Pull-in Microshutter Array

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We present the design and model of the performance of a planar microshutter array. A microshutter array can be used to allow columnated light from selected objects of a multi-object image to pass through a prism or diffraction grating for spectrographic analysis. Prior microshutter arrays developed by NASA for the James Webb space telescope used shutters with torsional flexures that open out-of-plane by magnetic or electrostatic force pull-in, with voltages ranging from 60 to 125 volts [1, 2].

Each shutter of the present design contains two layers of lines and spaces of long etch holes that either enables 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. The cross-sectional geometry of a shutter element is shown in Figure 1. Prescribed variations in flexure geometry enable each shutter window to have a different resonance frequency (Figure 2).

AC resonance pull-in is used to latch open the microshutter window at low DC voltages. The voltage required for resonance pull-in decreases as displacement amplitude increases, which reduces the initial gap size (Figure 3). A single input line is used to select which shutters are to be opened. Since each shutter window has a slightly different resonance frequency, each window can be selectively opened. Any number of shutter windows can be opened. It takes about 0.02 seconds to open the shutter.

Our in-plane shutter opens at a much smaller voltage than out-of-plane by one to two orders of magnitude. A tradeoff with our in-plane design is a reduction in light throughput. Light transmission is reduced by about 50%, so twice the exposure time may be required.

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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)

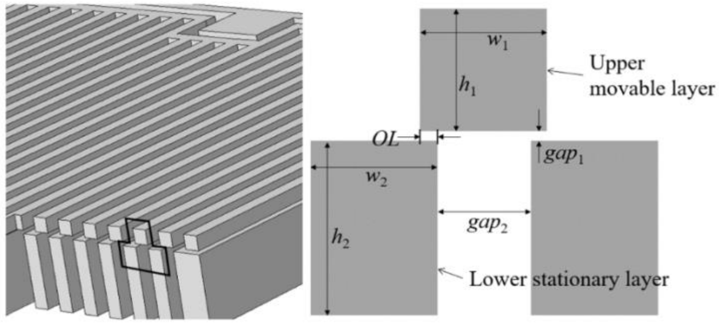

Figure 1: (Left) Gap cross-section. (Right) Parameters of the enlarged cross-section.

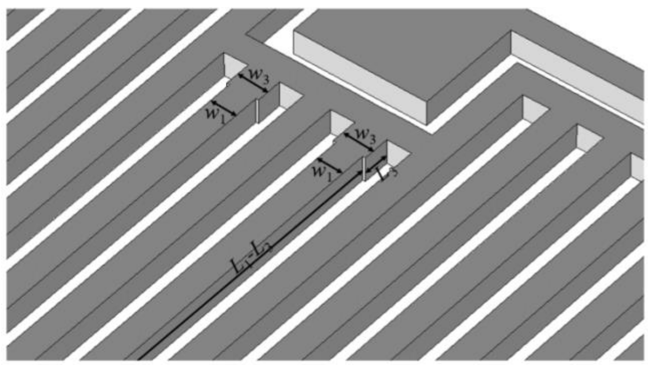

Figure 2: Flexure geometry. Each shutter resonates differently due to intentional design variation in w_3 and L_3

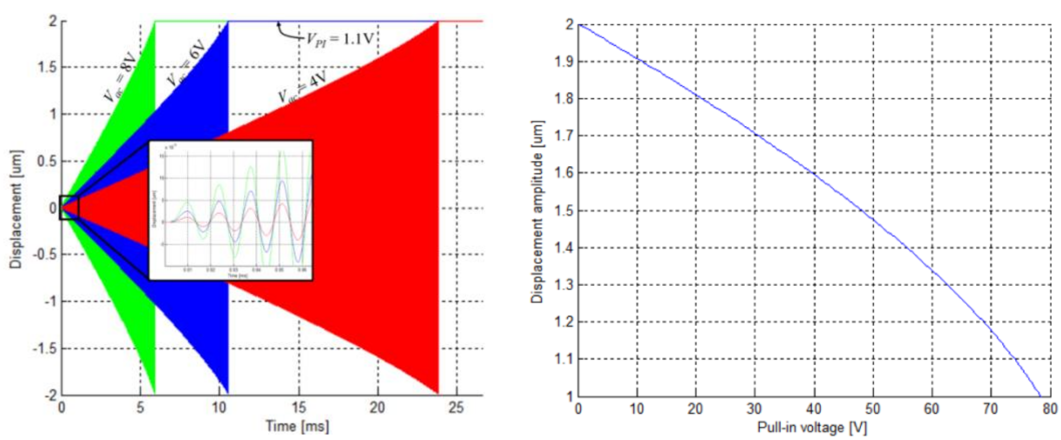

Figure 3: (Left) Dynamic simulation of pull-in. A resonance pull-in is achieved by applying an AC voltage of 4V to 8V to increase the displacement amplitude to the right amount, followed by a DC voltage of 1.1 V applied exclusively. (Right) A plot of displacement amplitude versus pull-in voltage.