Transmissive Microshutter Arrays

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A two-dimensional array of transmissive microshutters is designed in which light throughput can be digitally modulated at each pixel. This function is important for certain instruments, such as the Microshutter arrays have been developed at the NASA Goddard Space Flight Center for use with the near infrared spectrometer to be carried on the James Webb Space Telescope [1]. The microshutter may also have applications to other lens imagers such as microscopes, telephoto lenses, or cheaper digital light processors DLP. This abstract provides a new design with significant advantages over the Goddard array and our previous design [2].

Each pixel in the array contains two layers of lines and spaces of long etch holes that either enable the transmission of light when the two layers of etch holes are fully aligned upon pull-in actuation (window open) or block the transmission of light when the two layers of etch holes are fully misaligned at zero state (window closed) (Figure 1). We can conveniently control the states of each shutter in a large array of microshutters. Each column can be controlled by a V_{dc} line, and each row can be controlled by a V_{ac} line. Only when a row and column are actuated with both $V_{ac} + V_{dc}$, then that one shutter will be open.

We fabricate the microshutter with standard SOI process (Figure 2). The size of each shutter is about 800 µm x 400 µm, with a thickness of about 370 µm. Although the quasi-static pull-in voltage is 178V, which is very large, we can reduce the required pull-in voltage significantly by using a biased sinusoidal input voltage, which dynamically reduced the gap through resonance. Upon pull-in, only a small amount of voltage is required to maintain closure. Figure 3 shows the difference in trajectories between linear (quasi-static) pull-in at 178V and biased sinusoidal pull-in that only requires 0.6V to maintain closure. It takes about 56 milliseconds for a shutter to transition from a closed state to an open state using these low input voltages. Different combinations of V_{ac} and V_{dc} can also be used for biased sinusoidal excitation that result in pull-in. However, not all combinations will result in pull-in due to the nonlinear driving force. For an array of 128×64 shutter windows, the dc power loss due to leakage is expected to be 1.5µW, such that the energy consumed to stay open for 1 minute is 93µJ. The design can be scaled down to reduce the actuation voltages. It is totally electrostatic. Low voltage and power loss are major advantages of the present design compared to conventional transmission arrays.

[1] M. J. Li et al, “James Webb Space Telescope microshutter arrays and beyond,” *J. of Micro/ Nanolithography, MEMS, and MOEMS*, 16 (2),025501 (2017)
[2] L. Jiang, M. Vangari, and M. Feldman, “Design of Electromechanically Driven Transmission Light Valve Arrays,” *Journal of Electronic and Electrical Engineering*, 2(2), 37-41 (2011)

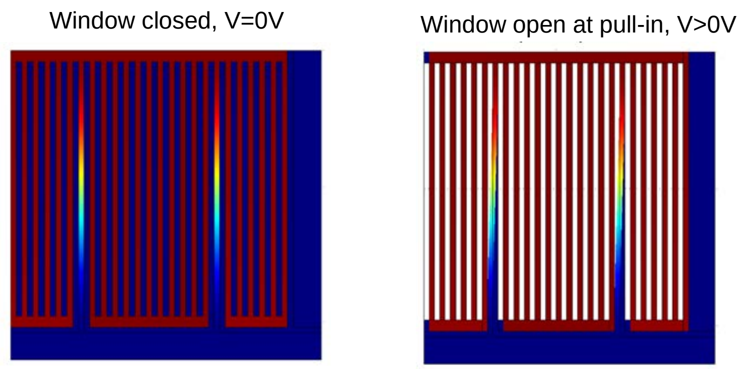

Figure 1: Schematic diagram of different states of the window opening.

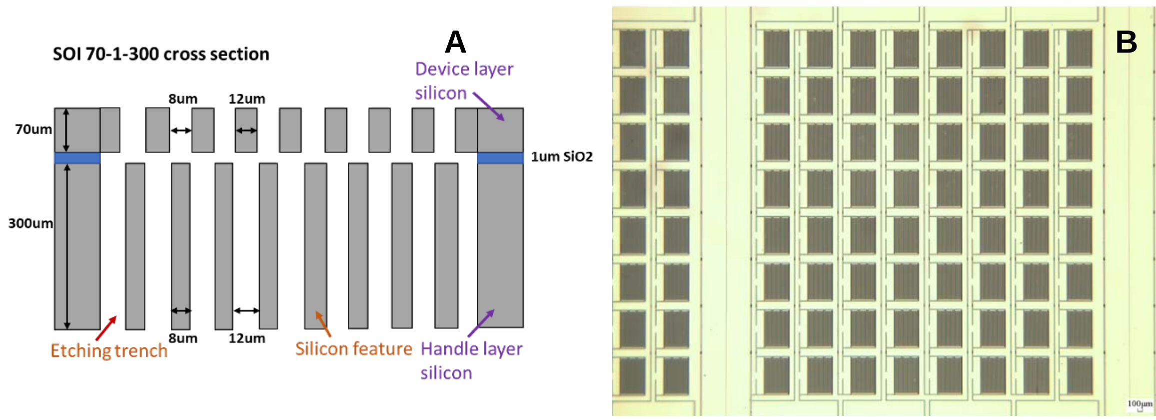

Figure 2: (A) Schematic diagram of cross section of each shutter. Lines and spaces are fabricated in the device layer and handle layer of an SOI wafer respectively. (B) Microscope image of the microshutter arrays.

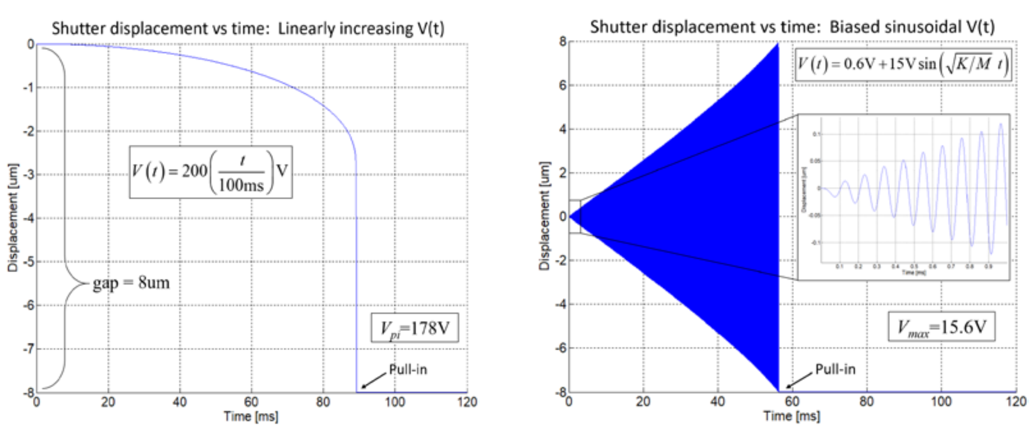

Figure 3: Dynamic simulation of pull-in. Maximum voltage is 178V versus 15.6V.