$1xN^2$ Wavelength-Selective Switches with High Fill-Factor Two-Axis Analog Micromirror Arrays

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Abstract: A $1xN^2$ wavelength-selective switch is demonstrated using a high fill-factor two-axis analog micromirror array and a monolithic 2D collimator array. A 1x2 (scalable to 1x14) WSS with 50-GHz channel spacing is experimentally demonstrated.

OCIS codes: (060.1810) Couplers, switches, and multiplexers
(060.4510) Optical communications

1. Introduction

MEMS-base wavelength-selective switch (WSS) has drawn a great deal of attention due to its routing capability. Several works on 1xN WSS have been reported [1-3]. The maximum port count reported to date is N = 4, limited by the optical diffraction. WSS with larger port count ($N \geq 10$) is desired for WDM networks. The port count can be increased from N to N^2 by using a 2D collimator array in conjunction with two-axis beamsteering functions. Previously, we have reported a $1xN^2$ WSS using two linear arrays of one-axis analog micromirrors with orthogonal scanning directions in a 4-*f* confocal system [4-6]. However, only half of the optical aperture is usable in this approach. The optical system is greatly simplified by using a monolithic 2-axis analog micromirror array. More importantly, the port count can be doubled because the full optical aperture can be used. We have recently successfully developed a 2-axis analog micromirror array with high fill factors [7]. The feasibility of implementing $1xN^2$ WSS using such mirror array was demonstrated using discrete collimators.

In this paper, we report on the first $1xN^2$ wavelength-selective switch using a 2-axis analog micromirror array with 98% fill factor and a monolithic 6x6 collimator array. A 1x2 WSS with 50-GHz channel spacing is experimentally demonstrated. A 1x14 WSS can be realized if the fill factor of the collimator array is increased from 50% to 90%. The optical system is capable of supporting 1x20 WSS if the scan ranges of the micromirrors increase to +/- 1.9° mechanically.

2. $1xN^2$ Wavelength-Selective Switch

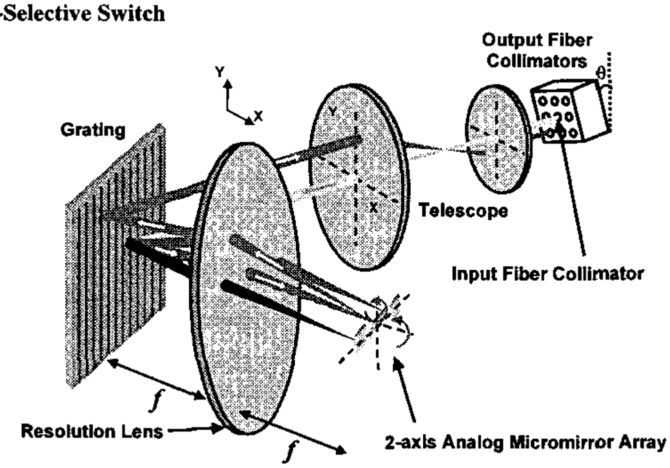

Figure 1. Schematic of the $1xN^2$ wavelength-selective switch using a 2-axis analog micromirror array and a monolithic 2D collimator array. The telescope expands the size of the optical beam.

Figure 1 shows the schematic of the $1xN^2$ WSS with a 2-axis micromirror array and a 2D collimator array. The WDM signals are spatially dispersed by the diffraction grating, and focused onto its corresponding micromirror by the resolution lens. The 2-axis mirrors direct individual wavelengths to any arbitrary output port in the 2D collimator array. A monolithic 2D collimator array in conjunction with a telescope beam expander are employed here. The beam expander reduces the optical spot size on the MEMS mirror.

3. Two-Axis Analog Micromirror Array

The schematic of the 2-axis analog micromirror is shown in Figure 2(a). Crossbar torsion springs [8] hidden underneath the mirror are employed to achieve high fill factor. Four terraced electrodes [9] are employed to reduce the actuation voltage. The devices are fabricated using the SUMMiT-V surface micromachining process provided by Sandia National Laboratory. Figure 2(c) shows the scanning electron micrograph (SEM) of the 2-axis micromirror. The left half of the mirror is removed intentionally to reveal the underlying structures. The SEM picture of the array is shown in Figure 2(d). A high fill factor of 96% is achieved (96-μm mirror on 100-μm pitch). This is the highest fill factor ever reported for linear arrays of 2-axis micromirrors. Figure 2(b) shows the DC scanning characteristics. Maximum scan angles of ±4.4° (at 90V) and ±3.4° (at 91.5V) are achieved around x and y axes, respectively.

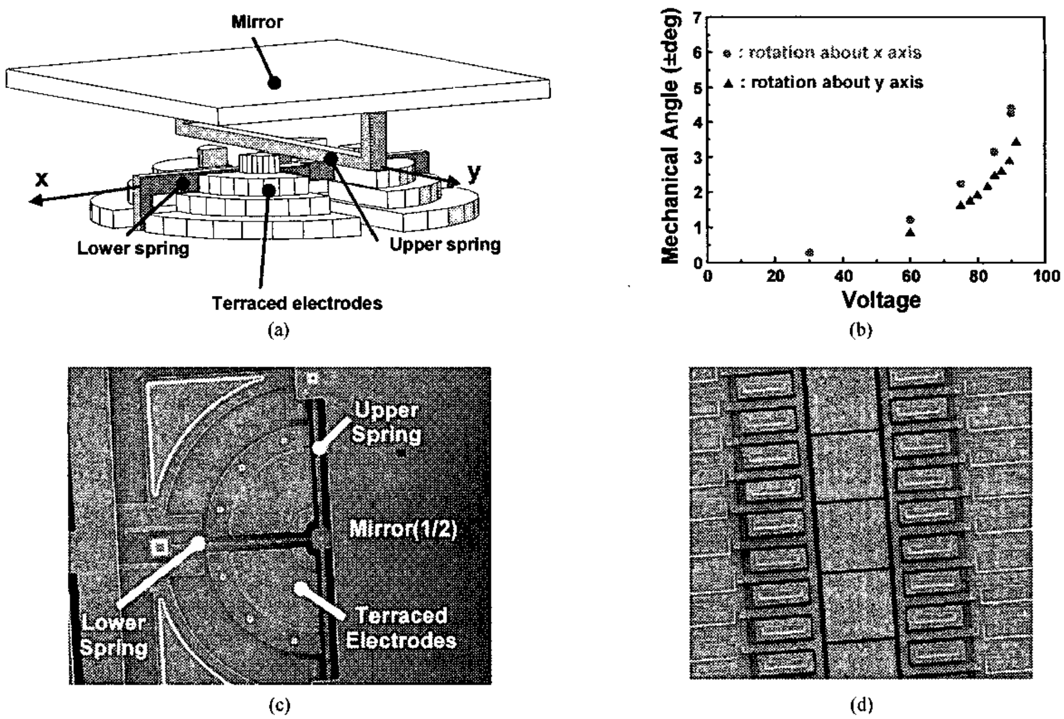

Figure 2. (a) schematic of the two-axis micromirror, (b) DC scanning characteristics around x and y axes, respectively, (c) SEM picture of the 2-axis micromirror with the left half of the mirror removed, and (d) SEM pictures of the two-axis micromirror array.

4. System performance

The 1x10 two-axis micromirror array used in the experiment has a slightly different design. It has a 200-μm pitch with 98% linear fill factor. The scan angles are ±2.63° (at 14.1V) and ±1.27° (at 21.1V). An 1100 grooves/mm grating is used. The focal length of the resolution lens is 30 cm. A commercial 6x6 collimator array is incorporated into our system. The pitch of the array is 1 mm, with a beam radius of 125 μm. A 16x telescope expands the optical beams before they are dispersed by the grating. The collimator array is rotated by a small angle (10°) to mitigate the undesired coherent coupling that resulted in large inter-channel response [10].

The fill factor of the 2D collimator is relative low (50%). Three ports of the telescope-expanded 2D collimator array are covered by the lens area and the mirror scan angles. If higher fill factor (90%) can be achieved, a 3x5 collimator array can fit into the optical system. It functions as a 1x14 WSS. The fiber-to-fiber insertion loss is 9.7 dB when the light is coupled back to the input port. The insertion loss in 14.1 dB with the light coupled to an output port. The insertion loss can be further improved with more precise optical alignment. Figure 3 shows the spectra measured at the output port across five mirrors. The channel spacing is 50 GHz. The solid curve is the spectrum when the 1549.25-nm and 1550.5-nm wavelength channels are switched to the output port. The dashed curve is the spectrum when all the WDM signals are coupled back to the input port.

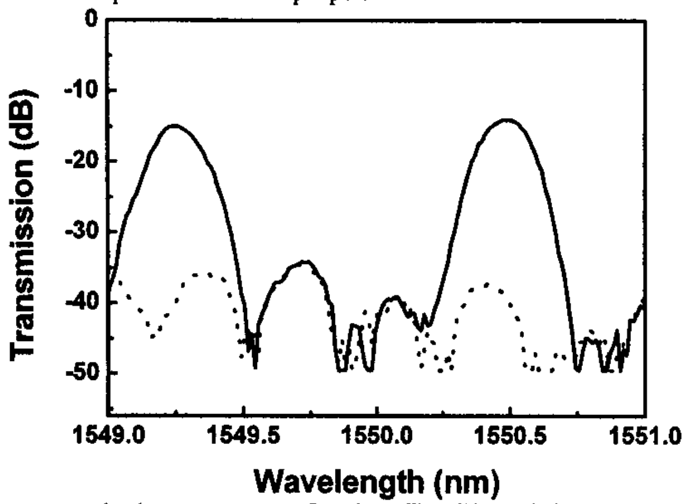

Figure 3. The spectra measured at the output port across five mirrors. The solid curve is the spectrum when the 1549.25-nm and 1550.5-nm wavelength channels are switched to the output port. The dashed curve is the spectrum when all the WDM signals are coupled back to the input port.

5. Conclusion

We have demonstrated a $1xN^2$ wavelength-selective using a two-axis analog micromirror array and a monolithic 2D collimator array for the first time. A 1x2 WSS with 50-GHz channel spacing is realized, with a fiber-to-fiber insertion loss of 9.7 dB. A 1x14 WSS is achievable by increasing the fill factor of the 2D collimator array from 50% to 90%. The optical system can support 1x20 WSS if the scan range of the 2-axis mirror is increased to +/- 1.9°.

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6. References

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