4:15pm - 4:30pm
OIPS2.3

# Realization of Free-Space Fiber Optic Switches Using The Surface-Micromachining Technology

**S. S. Lee, L. Y. Lin and M. C. Wu**
**UCLA, Electrical Engineering Department, Los Angeles, CA 90024-1594**

We report a novel free-space fiber optic switch implemented using the surface-micromachining technology. Most of conventional fiber optic switches are made in waveguide. Free-space approach offers lower coupling loss and smaller cross talk. Currently, these switches are realized by manually assembled bulk elements and are very expensive. Bulk-micromachining of Si substrate has been applied to free-space optical fiber switches [1]. However, monolithic integration is difficult and a substantial assembly is still required. Surface-micromachined micro-optical elements can be optically pre-aligned in the design stage and are monolithically patterned during the microfabrication process. They can be made compact and light weight, and are potentially integrable with the optical sources/detectors and controlling electronics. Therefore, using this approach, the size, weight and cost of current fiber optic switches can be dramatically reduced. The fabrication and characterization of various three-dimensional micro-optical elements have been demonstrated [2][3].

The schematic diagram of the switch is shown in Fig. 1. The fabrication of the switch is done using the three-layer polysilicon surface-micromachining technology at MEMS Technology Application Center at North Carolina (MCNC) under the ARPA supported Multi-User MEMS Processes (MUMPs). The switch consists of a three-dimensional movable mirror and four optical fiber guiding rails. The mirror is coated with a 500 nm-thick gold. The mirror sitting vertically on a sliding plate is positioned at the center of the switch and allowed to move along the x-axis. Figure 2 shows the scanning electron micrograph (SEM) of the mirror with the sliding plate. Four multimode fibers come from four diagonal directions along the guiding rails to the center of the switch and form a "cross". The facets of two fibers along the same diagonal direction are separated by less than 100 $\mu$m. When the mirror/sliding-plate is moved away from the fibers (the center), the fibers along the same diagonal directions are allowed to communicate with each other. This is defined as CROSS state. In the BAR state, the mirror/sliding-plate is slid into the center and the light signal is redirected into the orthogonal fiber. The top-view photographs of the switch in CROSS and BAR states are shown in Fig. 3(a) and (b), respectively. The total insertion loss of the switch has been measured to be 2.8 dB for the CROSS state and 3.1 dB for the BAR state. From these two measurements, the reflectivity of the mirror is estimated to be 93%. The cross-talk between two states is measured to be 26.1 dB. The insertion loss can be further improved with smoother gold coating on the mirror, anti-reflection coating on fiber facets, smaller spacing between fibers, or lensed fiber tips.

In conclusion, a free-space fiber optic switch has been demonstrated using the surface-micromachining technology. With its monolithic microfabrication capability and three-dimensional characteristics, the switch can be made compact, light weight and low cost. The switch is potentially integrable with other micro-optical elements and controlling electronics. This project is supported by the ARPA/ESTO and the Packard Foundation.

## References

[1] M. F. Dautartas, A. M. Benzoni, Y. C. Chen and G. E. Blonder, " A silicon-based moving-mirror optical switch", J. of Lightwave Technology, Vol. 10, No. 8, August, 1992.
[2] L. Y. Lin, S. S. Lee, K. S. J. Pister and M. C. Wu, "Micro-machined three-dimensional micro-optics for integrated free-space optical system", IEEE Photonic Technology Letters, Vol. 6, No. 12, December, 1994.
[3] S. S. Lee, L. Y. Lin, K. S. J. Pister and M. C. Wu, " Hybrid integration of 8x1 micromachined micro-Fresnel lens arrays and 8x1 vertical-cavity surface-emitting laser arrays for free-space optical interconnect", in *Tech. Dig.* of The 40th International Electron Device Meeting (IEDM'94), December 11-14, 1994.

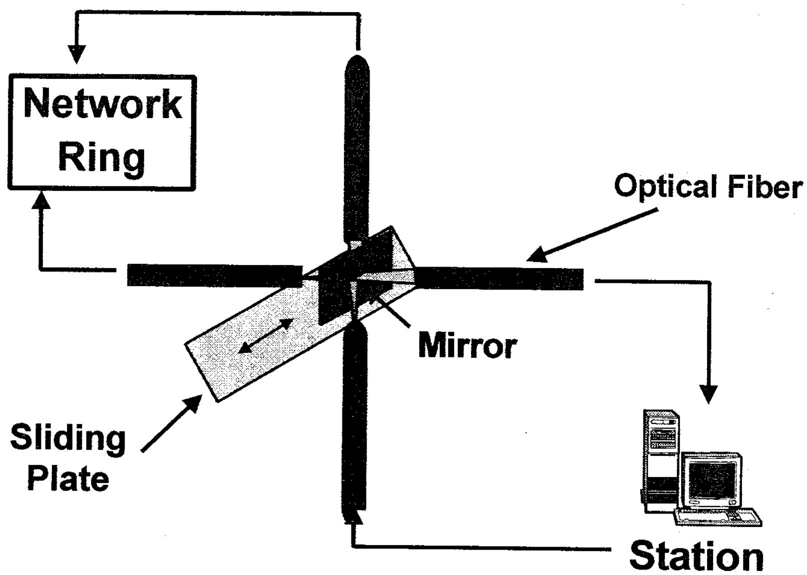


Figure 1. The schematic diagram of the free-space fiber optic switch

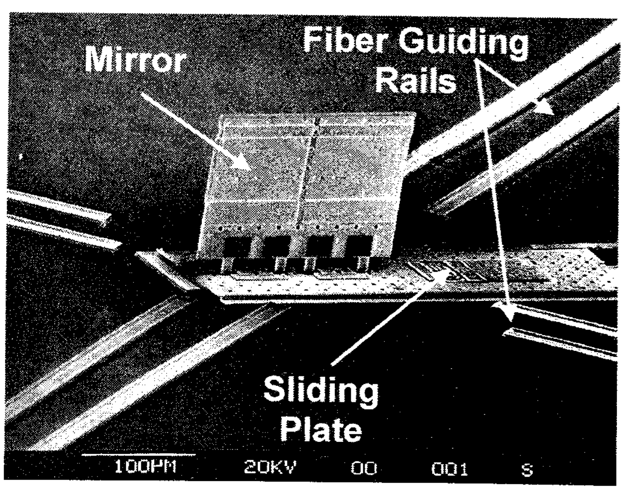


Figure 2. The SEM of the three-dimensional mirror sitting on a sliding plate

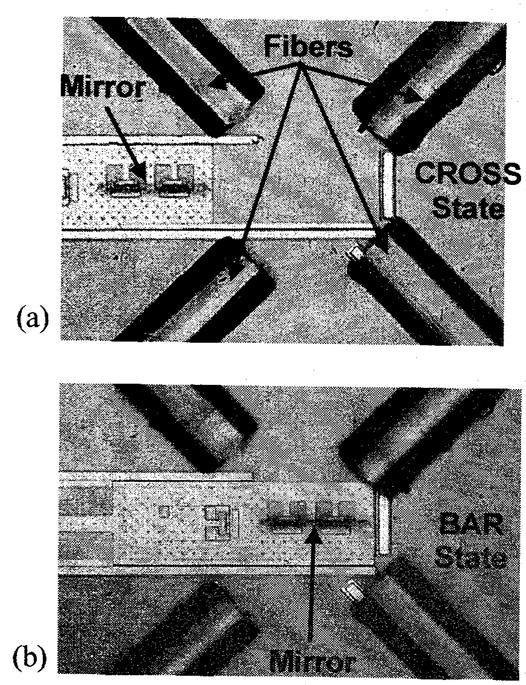


Figure 3. The top-view photographs of the switch in (a) CROSS state and (b) BAR state