Bulk Micromachined 2D Lens Scanners for Transparent Optical Fiber Switches

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As an alternative approach of constructing 3D MEMS optical crossconnectors (OXC), we propose **bulk micromachined electrostatic 2D lens-scanner arrays** instead of tilting mirrors. Having carefully investigated the optical and mechanical designs of MEMS OXC, we have concluded that collimator lenses have the most significant influence upon the optomechanical switching performance. In particular, fiber array's core-position dispersion with respect to the collimator lenses gives random offset in the direction of the collimated light beams (as shown in Fig. 1); this leads to large optical insertion loss and limited number of optical channels that could be accommodated. When scanning mirrors are used as a beam steering device, the mirror size has to be designed large enough not to suffer from beam-clipping loss; this may also lead to degraded mechanical switching response.

On the other hand, the fiber-core deviation would not be a serious problem if collimator lenses are individually position-controlled with sub-micron accuracy. At the same time, such scanning lenses work as a beam steering device when each piece is two-dimensionally actuated with large enough mechanical stroke. Figure 2 illustrates the schematic view of our OXC using a microlens scanner array with a fiber array. The MEMS scanning lens chip is placed at its focal length from the fiber facet in order to steer the collimated beams. Fundamental concept has been reported elsewhere [1].

Different from our previous device made of photoresist microlens on a polysilicon surface micromachined XY-stage, we have developed **bulk-micromachined 2D scanners with silicon lenses** as shown in Fig. 3. The center disk (diameter 300 microns) supported at the middle of "H" shaped suspensions (width 6 microns) is a silicon microlens. Stationary electrodes are arranged around the suspensions for making X- and Y-motion of the lens by electrostatic forces. In our prototype, a **4x4 array** of such microlens scanners has been designed with a **1-mm pitch**.

Figure 4 shows simplified fabrication process using a 50-micron-SOI (silicon-on-insulator) wafer. Microlens patterns formed by the photoresist reflow technique are transferred to silicon by isotropic RIE (reactive ion etching). Spherical shape of silicon lens and high-aspect ratio structures of electrostatic actuator are made by engineering the mask-combination prepared at the beginning of the process: aluminum for field-protection during isotropic RIE of microlens, and LOCOS oxide for Deep RIE of actuator parts. Figure 5 shows a typical optical microscope image of silicon microlens array (test run, diameter 260 microns, sag 9 microns, **focal length estimated to be 400 microns**).

Our first mechanical test has shown **8-micron displacement** in the X-direction with a dc 250 V (Fig. 6), which could potentially steer a beam by 2 mm at a 10-cm distance. Typical mechanical resonance was found around 7 kHz. The design is under improvement for larger displacement with lower driving voltage. Our optical design is shooting for a simple optical packaging for a medium scale OXC with beam steering angle of over 4 degrees.

[1] H. Toshiyoshi, G.-D. J. Su, J. LaCosse, M. C. Wu, "Surface Micromachined 2D Lens Scanner Array," Proc. IEEE/LEOS Optical MEMS, Kauai, Hawaii, Aug. 21-24, 2000, Late News Session, PD-1.

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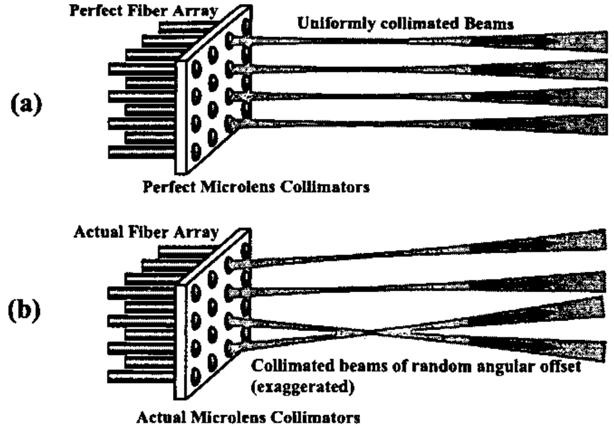

Fig. 1: (a) Ideal fiber collimator array and (b) actual one with angular offset in the beam directions.

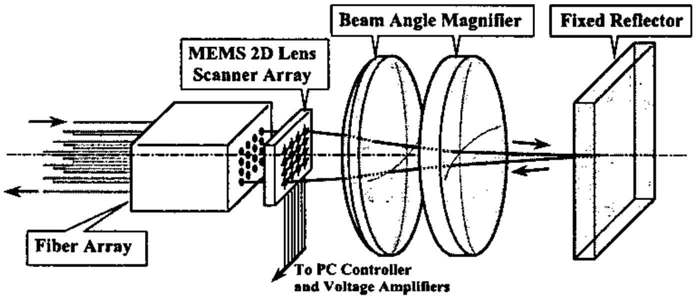

Fig. 2: System architecture of OXC using micro lens scanner array. Each lens is 2D-controlled for beam steering.

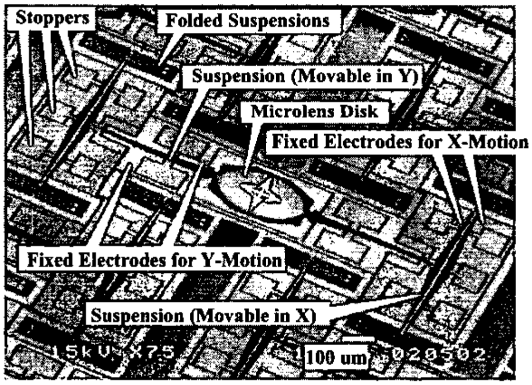

Fig. 3: Close-up SEM image of DRIE micromachined electrostatic 2D lens scanner.

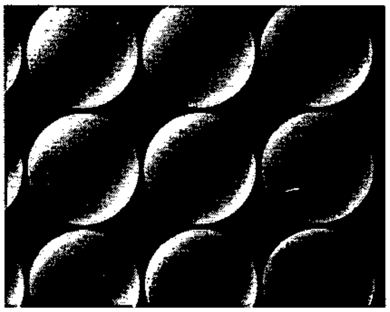

Fig. 5: Typical optical microscope image of silicon microlens (300 um in diameter, test run of step-3 in Fig. 4). Color effect is due to ND and polarization filters.

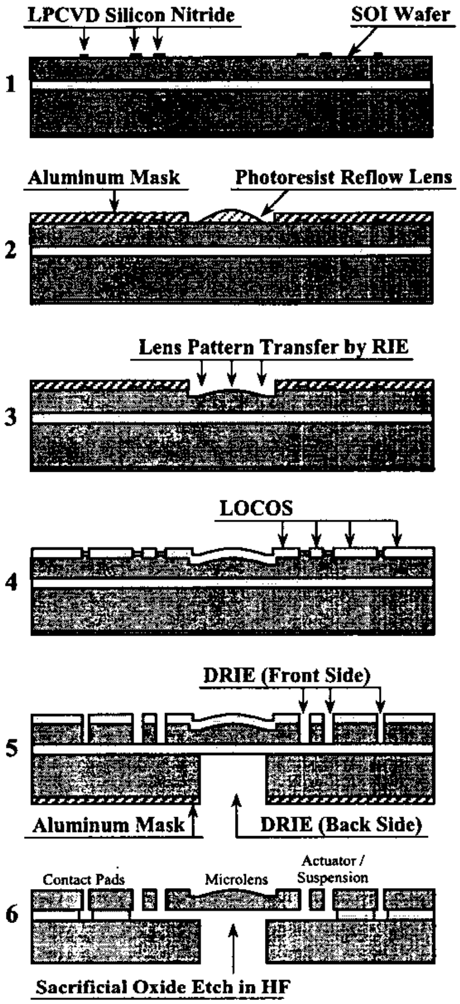

Fig. 4: Fabrication process integrating XY-scanning mechanism with silicon microlens.

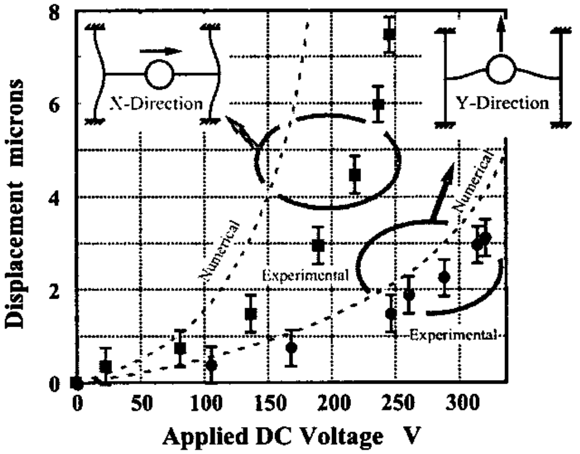

Fig. 6: Typical electrostatic displacement curve as a function of applied voltage. Dashed curves are FEM simulation results.