Compact Design for MEMS Cross-connect Switches

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MEMS cross-connects based on arrays of insertable mirrors [1] and opposed planes of tilt mirrors [2] have been demonstrated for large scale optical switching. Some attempts have been made to develop general systematic approaches for optimising designs in the former case [3]. However, less progress has been made with tilt mirror switches.

Generally, tilt mirror designs are limited by the mirror turn angle. In principle, the number of ports can be raised by increasing the separation between the mirror planes, because a mirror on one plane will then subtend a smaller angle at the other. However, this also involves an increase in the optical path. Because the beams are narrow, they diverge as they propagate, so increasing the path will increase the beam diameter. Larger mirrors are then required for efficient reflection, which nullifies the effect of separating the mirror planes further. Maximisation of the port count therefore involves identification of an effective layout rather than an increase in the overall size of the switch.

Here a simple approach for designing large-scale mirror-rotation free-space optical cross-connect switches based on arrays of MEMS tilt mirrors is described. The layout of a compact switch is first presented (Figure 1a). Using existing theory of Gaussian beams [4], the parameters of the beam that maximises the port count for a given mirror turn angle is then identified. This beam is the narrowest that can propagate over a fixed distance, and its maximum mode radius forms a limiting envelope to the variations in mode radius of all Gaussians (Figure 1b). Because this beam has known and predictable parameters, it can be used as a yardstick to compare designs with different port number. The supporting optics needed to create this beam from a given fibre is defined.

Using simple estimates of the loss caused by propagating the Gaussian beam through apertures such as lenses and mirrors, scaling laws for the optical path length needed for a given number of ports are then derived. Numerical simulations based on the ABCD method [4] are used to verify the ideal configuration (Figure 2), and equivalent lenses are inserted to model mirror curvature (Figures 3 and 4). Operating conditions that minimise the effect of mirror curvature are identified; for example, when both mirrors are similar, the variation of throughput efficiency with curvature is substantially flatter than when one mirror alone is curved (Figure 5). In fact, it can reach 100%. Scaling laws in terms of the number of ports, mirror turn angle and a simple loss parameter are proposed for this and other departures from the ideal, to allow comparison of designs.

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Figure 1. a) Assumed layout of OXC; b) definition of optimum Gaussian beam.

Figure 2. a) Unfolded model of single channel; b) simulation.

Figure 3. a) Unfolded model with single curved mirror; b) simulation for different curvatures.

Figure 4. a) Unfolded model with two curved mirrors; b) simulation for different curvatures.

Figure 5. a) Variation of efficiency with curvature; ideal throughput with curved mirrors.