350X350 MODULAR OPTICAL CROSS-CONNECT WITH CLOSED-LOOP CONTROLLED MEMS MIRRORS

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Abstract: *We describe a modular MEMS based optical cross-connect switch. Each module has 16 ports with closed-loop servo-controlled mirrors. We have achieved switching times of < 10 ms, excellent optical power stability, and immunity to stochastic vibrations.*

EXTENDED ABSTRACT

MEMS technology has emerged as a clear technology of choice for building high-port-count optical switches. A popular approach is to make use of large monolithic mirror chips, fiber bundles, and lens arrays. However, the drawbacks of such a monolithic approach are numerous, including high cost-per-port due to component yield, high installation (and replacement) cost, and the necessity for overbuild. In this paper, a modular optical architecture is demonstrated to solve these challenges. A modular switch has a number of distinct benefits: 1) The system imposes no component yield bottleneck; 2) The system allows in-service installation and replacement of individual modules instead of the whole switch fabric; 3) The system reduces start-up cost and enables pay-as-you-grow cost structure.

Fig. 1 illustrates the basic modular optical system. The switch fabric comprises arrays of identical 24 input and 24 output modules mounted in vertical slots inside a card cage. An attached optical chassis with four folding mirrors direct light from the input ports to output ports. Each module assembly contains 16-ports with supporting optics and electronics. Each optical port comprises a lens fused to the tip of the fiber, a folding mirror, a MEMS mirror, and a collimating lens. An auxiliary optical sensing system for the MEMS tilt angle is incorporated into each port. A fully populated system would ideally yield a 384 (16×24) by 384 non-blocking switch. The gold-coated silicon mirrors are electro-statically actuated with less than 85 volts, employing a closed-loop servo control system that provides immunity to stochastic vibrations, and long-term mechanical and electronic drift. The nonlinear controller is based on a new torque-to-voltage conversion technique and classic linear controller techniques with full-state feedback, state estimator, and reference input with feed-forward. Long-term angular noise of less than 150 μrad is achieved.

Fig. 2 shows a typical switching event with less than 8ms switching time even when mirrors tilt between 2 extreme positions. The use of closed-loop controlled mirrors provides excellent noise rejection and pointing stability. The fiber-to-fiber coupled power under normal operation shows power fluctuations within +/– 0.15 dB. Coupling power for each connection is maximized using an optimization method based on a 4-dim (arising from the 2 tilting axes of the input and output mirrors) peak-search algorithm. A typical automatic power-peaking process takes less than 70 steps to reach peak power from around –30dB below peak. These optimization algorithms ensure the feasibility of in-service module installation and long-term connection stability.

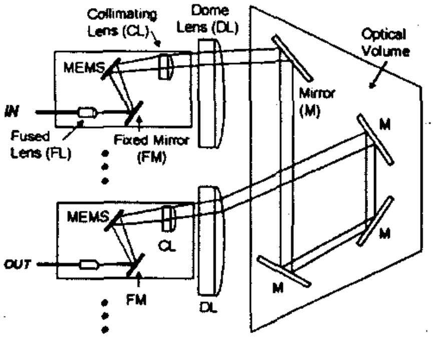

Fig. 1: Schematic of modular optical system.

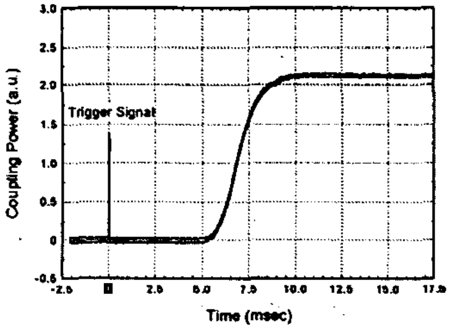

Fig. 2: A typical switching event.