MEMS WDM Routers Using Analog Micromirror Arrays

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ABASTRACT: We report on the recent progresses in our MEMS wavelength-division-multiplexed Routers with a 1D array of analog micromirrors for wavelength-selective switching among multiple fibers.

There have been increasing interests in programmable optical add-drop multiplexers (OADM) and wavelength-selective switches in wavelength-division-multiplexed (WDM) networks. Conventional OADM has one input and one output channels, in addition to an add and a drop channels [1]. It is also called 1x1 OADM. Dynamic OADM with more than one output ports offers greater flexibility and functionality for WDM networks [2,3]. We call this type of devices WDM Routers. They are also called 1xN wavelength-selective switches or multi-port OADM. They enable new network topologies. For example, meshed rings that offer greater capacity and higher level of protection can be realized using WDM Routers. In this paper, we report on our recent experimental results of the WDM Routers employing a novel analog micromirror array. Using a hidden comb drive actuator with high force density, large scan angles are achieved with at low voltages. We also report on the stability and repeatability of the WDM Router. Less than ±0.0035 dB variations in system insertion loss have been achieved over three hours of open-loop operation [4].

The key device for the WDM Router is a linear array of analog micromirrors with large continuous scan range, and high fill factor. Digital micromirrors similar to Texas Instruments' Digital Micromirror Devices (DMD) were used in 1x1 OADM [1]. To address more input/output ports, more than two discrete angles are needed for the micromirror array. High fill factor is required to reduce the gap between WDM channels and achieve flat-top spectral response. Electrostatically actuated parallel plate micromirror scanners have been used for multi-port OADM [3], however, they suffer from high actuation voltage, limited scanning angle due to unstable pull-in effect, and high crosstalk between adjacent mirrors. A double-hinged micromirror has been used to amplify the scan angle (14° at 57 V), however, the scan range is asymmetric and the rotation axis is offset to the edge of the mirror, which results in out-of-plane displacement of the mirror when it rotates [5].

Recently, we have developed a novel analog micromirror array with hidden vertical comb drive actuators. The micromirror is implemented by a five-polysilicon-layer surface-micromachining process offered by Sandia National Lab (SUMMiT-V) [6]. The process includes two chemical-mechanical planarization (CMP) processes, which were used to (1) separate the lower and upper vertical combs; and (2) completely cover the actuators with flat mirror surface. The force density in vertical comb drive actuators is inversely proportional to the gap spacing between the upper and the lower comb fingers. Using SUMMiT-V, we achieved a gap spacing of 0.5 μm, which is much smaller than what bulk micromachining can produce. Our vertical comb drive actuator has 240 times higher force density than the corresponding parallel plate actuator with the same

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mirror height, thanks to the submicron finger gap spacing. This enables us to achieve low operating voltage and large scan angle, while still maintaining a high resonant frequency.

Experimentally, we have successfully demonstrated 1x10 and 1x30 analog micromirror arrays. The mechanical scan range is measured to be ± 5.9° and the bias voltage is as low as 6 V. In comparison, micromirrors with parallel plate actuators that are fabricated on the same chip has a scan range of ± 4° at a much higher voltage of 22 V. We have constructed a WDM Router using this micromirror array. The experimental setup is shown in Fig. 1. The spectral response shows a flat-top shape with extinction ratio of 35 dB. The switching time is less than 400 μsec. One of the most critical issues for practical operation is the stability of the micromirror. It is known that many electrostatically driven micromirrors suffer from drifting of mirror angle due to dielectric charging. In our vertical comb structure, we have carefully designed the structure to eliminate most exposed dielectric areas and grounded all the conducting structures around the mirror. Extremely low drift has been achieved for both the device (± 0.00085°) and the WDM Router (fiber-to-fiber loss variation < ± 0.0035 dB) over three hours of continuous operation without any feedback control (Fig. 2). This suggests the WDM Router can operate in open-loop conditions, which has enormous cost benefits. More detailed results will be presented at the conference.

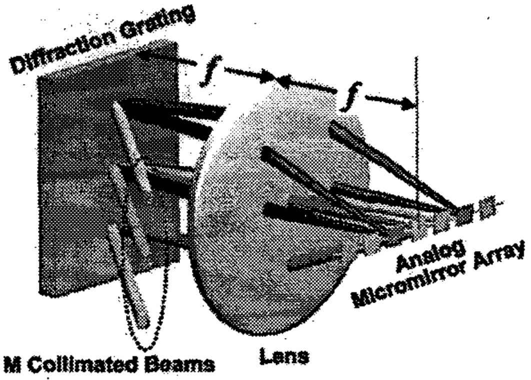

Fig. 1. Schematic of MEMS WDM Router with analog micromirror array.

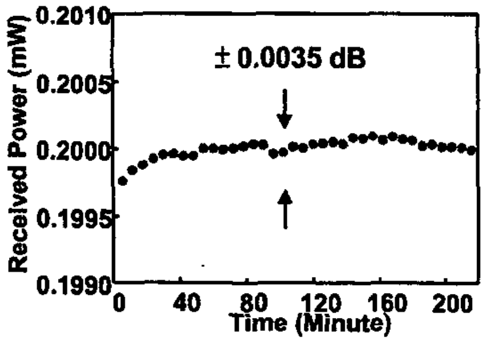

Fig. 2. Variation of received optical power of MEMS WDM Router in open loop condition.

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