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Open-Loop Operation of MEMS WDM Routers with Analog Micromirror Array

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ABSTRACT

We report on the optical performance for a reconfigurable WDM router implemented by a low-voltage analog micromirror array. The system exhibits an optical insertion loss of 5 dB and a flat-top spectral response. Both the device and the system exhibit excellent repeatability (<0.12%) and stability (<0.16%) for open-loop operation.

INTRODUCTION

Wavelength-division multiplexed (WDM) switches and routers that support individual wavelengths switching are of great interest for transparent optical networks [1-3]. A 1×1 optical add-drop multiplexer (OADM) has been demonstrated using a digital micromirror array in conjunction with a grating spectrometer [1]. WDM Routers, or multi-port OADM's, provide more functionality for the optical networks. This can be realized by employing an analog, instead of digital, micromirror array [2,3]. Recently, we have proposed and demonstrated a novel analog micromirror array with hidden vertical comb drive actuators [2,4]. Large continuous scan range and high fill factor have been achieved, which are important for high channel count and flat spectral response. In addition, the high force density of the vertical comb drive also greatly reduces the operating voltage and power consumption of the actuator and the drive electronics [4]. In this paper, we report on the optical performance of the MEMS WDM Routers. In particular, we experimentally characterized the repeatability and stability of both the MEMS device and the WDM Router. The excellent stability suggests that our MEMS WDM Router could operate in open loop, which dramatically reduces the overall system cost, size and power consumption.

WDM ROUTER SYSTEM

Fig. 1 shows the schematic diagram of the WDM router system. This router can handle multiple spatial and multiple wavelength channels at the same time. The optical beams from input/output fibers are first collimated and then dispersed by a grating spectrometer. Each wavelength is focused onto a corresponding micromirror by a focusing lens. The wavelength can be routed independently to any of the fibers by tilting the corresponding micromirror.

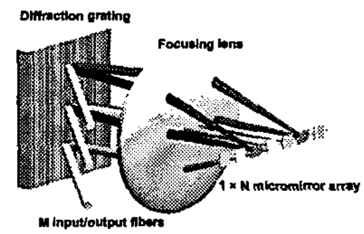

Fig. 1. Schematic diagram of the MEMS WDM router.

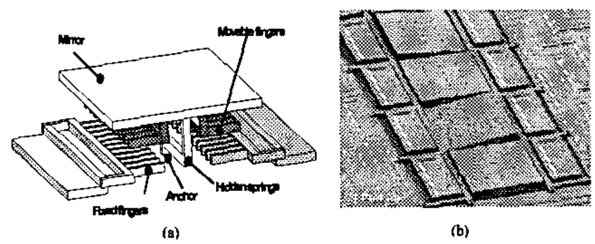

Fig. 2. (a) Schematic diagram and (b) scanning electron micrograph of the analog micromirror array with hidden vertical comb drive actuator.

The WDM Router is realized by a 1-D analog scanning micromirror array with hidden vertical comb-drive actuators. The micromirror shown in Fig. 2 exhibits low operating voltage (6 V), wide scan range (23.6° optical), high fill-factor (91%), high resonant frequency (3.4 kHz), and good uniformity (< ±3.2%) [2]. The fiber-to-fiber optical insertion loss is measured to be 5 dB. Fig. 3 shows the spectral response of a switched and a dropped channels, respectively. The channel exhibits a broad flat-top response. An extinction ratio of 35 dB has been achieved. The rise time and the fall time are measured to be 100 μsec and 380 μsec, respectively.

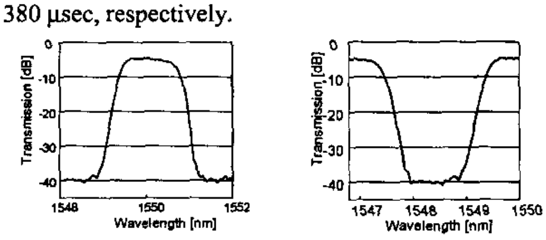

Fig. 3. (a) Typical passed channel when adjacent channels dropped. (b) Typical rejection of a channel when adjacent channels are transmitted.

STABILITY CHARACTERIZATION

Electrostatically actuated MEMS devices often exhibit drift under constant DC biases due to charging effect. Our device is designed to minimize this undesirable effect. Extensive grounding and shielding have been incorporated in our scanner device to increase its stability. We have experimentally characterized the repeatability and stability of both the MEMS scanner and the WDM Router. Fig. 4 (a) shows the variation of the output power from the MEMS WDM Router over a five-minute period when a constant voltage was applied to one fixed comb electrode while the other fixed comb electrode is grounded. The output power was very stable and no drift was observed. However, if the counter electrode was left floating, significant drifting was observed in the output power, as shown by Fig. 4 (b). This demonstrates the importance for controlling the potential of all adjacent electrodes/structures around the mirror.

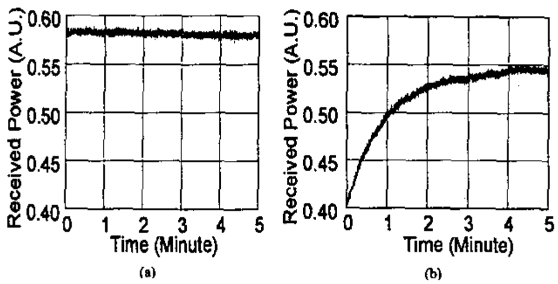

Fig. 4. Variation of output power from WDM router when the free electrode of MEMS mirror is (a) grounded, (b) floating.

The long-term stability is measured by sampling the output power. A constant 6.2V is applied to one electrode while the other fixed electrode of the micromirror is grounded. Measurement was performed over a period of 3.5 hours. The results are shown in Fig. 5. The measured long-term drift is less than 0.16%.

To measure the repeatability, we turn on the voltage to 6.2V (ON) right before the measurement starts, and collect data for 1 minute, after which the voltage is returned to 0V (OFF) for five minutes. This ON-OFF process has been repeated over 3-hour period. The measured data are as shown in Fig. 6. The total power variation is less than 0.12%.

CONCLUSION

We have characterized the open-loop system performance of our WDM router employing a low-voltage analog micromirror array with hidden vertical comb-drive actuators. The experimental results show excellent stability (<0.16%) and repeatability (<0.12%).

ACKNOWLEDGEMENTS

This project is supported by DARPA/SPAWAR under contract N66001-00-C-8088. The authors would like to thank Hung Nguyen, Hsin Chang, and Sagi Mathai for technical assistance.

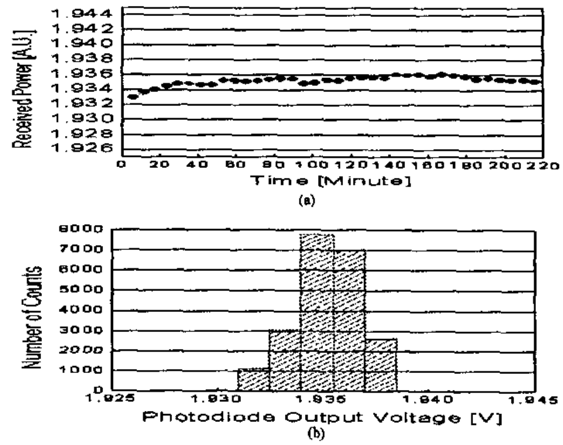

Fig. 5. (a) Long-term drift of the system over 3.5 hours and (b) histogram of signal power variation.

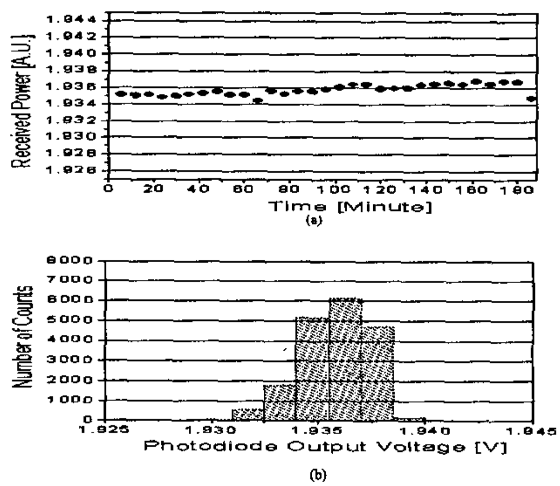

Fig. 6. (a) Repeatability of the system over 3 hours and (b) histogram of signal power variation.

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