$1xN^2$ Wavelength-Selective Switch With Telescope-magnified 2D Input/Output Fiber Collimator Array

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Abstract

A 2D (6x6) fiber collimator array with a telescope beam expander is incorporated into a $1xN^2$ wavelength-selective switch (WSS) to achieve high port count. The $1xN^2$ WSS is realized using two cross-scanning 1-axis analog micromirror arrays in a 4-*f* optical system. We have achieved a 1x9 WSS with a channel spacing of 160 GHz, a fiber-to-fiber insertion loss of 14 dB and a switching time of < 1 msec.

Introduction

Wavelength-selective switches (WSS) have received a great deal of attention because of their ability to route different wavelength channels independently in the WDM networks. Several 1xN WSS with linear fiber arrays have been reported [1-3]. The maximum number of output ports reported to date is four, which is limited by optical diffraction.

Larger port count (≥ 10) WSS is desired for high capacity networks. The port count of WSS can be increased from N to N^2 by using two-dimensional array of fiber collimators. Previously, we proposed to use two 1D arrays of 1-axis micromirrors with orthogonal scanning directions to implement the 2D beam steering function [4,5]. We have demonstrated a 1x8 WSS using discrete collimators to simulate the 2D collimator array. However, the large housings of discrete collimators reduce the practical port count, and the alignment of individual collimators is a cumbersome process. A monolithic 2D fiber collimator array can overcome the above disadvantages. In this paper, we report on optical performance of the first $1xN^2$ wavelength-selective switch with monolithic 2D fiber collimator array.

Wavelength-Selective $1xN^2$ Switch

The schematic diagram of the $1xN^2$ wavelength-selective switch is shown in Fig. 1. The inset shows the photograph of the 2D fiber collimator array. Two focusing lenses are arranged in a 4-*f* confocal configuration to image the first micromirror array in Plane A to the second micromirror array in Plane B. The grating is inserted between the lenses in the upper half of the system. The 4-*f* configuration ensures that the optical beam focused on any mirror in the first array is always directed to the corresponding mirror in the second array, and vice versa, irrespective of the tilting angle of the mirrors. Thus each wavelength is steered by two micromirrors in orthogonal directions and directed towards the desired collimator in the 2D array. The telescope expands the laser beams emerging from the 2D fiber collimator array.

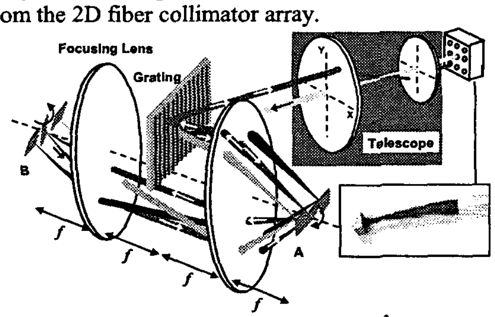

Fig. 1. *Schematic setup of the $1xN^2$ wavelength-selective switch. The two orthogonally scanning micromirror arrays enable the fibers to be arranged in two dimensions, which increase the output port from N to N^2. The telescope is used to expand the beam size.*

Analog Micromirror Arrays

The analog micromirror arrays are similar to those used in our previous demonstration [5]. Figure 2 shows the schematic of the analog micromirror arrays. The hidden vertical combdrive actuators permit low operating voltage and high fill factor. The fill factors are 97.5% for Array A (156 μm mirror on 160 μm pitch) and 96.25% for Array B (154 μm mirror on 160 μm pitch). The maximum mechanical scan angles are ±5° (7V) and ±6.3° (7.5V) for arrays A and B, respectively [5]. They are limited by lateral pull-in between the comb fingers.

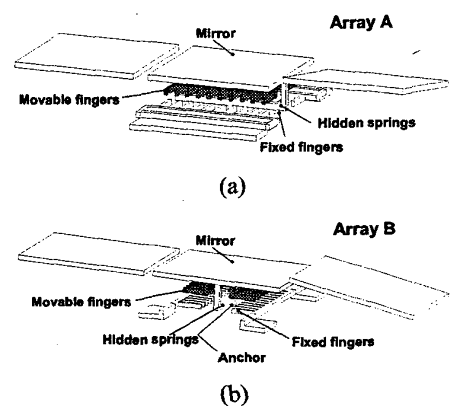

Fig. 2. *Schematic of the analog MEMS mirrors arrays with hidden vertical comb-drive actuators. The scan directions of the mirrors are (a) perpendicular to, and (b) in parallel with the array directions.*

System Performance

A commercial 6x6 fiber collimator array is used in our setup. The pitch of the array is 1 mm, with a beam radius of 125 µm. A 6x telescope expands the optical beams before they are spatially dispersed by the grating. The beam expander reduces the optical spot size on the MEMS mirror. A 600-grooves/mm grating and two lenses with 15-cm focal length are selected for our system. 10 of the 36 (6x6) spatial channels are covered by the effective lens area in our current setup. Therefore, it functions as a 1x9 WWS. The port count can be increased by improving the fill factor of the 2D collimator array. The microlens diameter-to-pitch ratio of our current collimator array is relatively low (50%).

The fiber-to-fiber insertion loss is measured to be 14 dB when the light is coupled back to the input port. When the light is switched to another spatial channel, the insertion loss is 16.5 dB. The measured insertion losses are higher than our previous result of 6 dB using discrete collimators. The reasons for the increased loss are two folds: first, the commercial collimator array we used is not optimized for our setup and the beam spot size at MEMS mirror is larger than the mirror size, which results in clipping loss. Second, the alignment tolerance is tighter since we cannot adjust angular misalignment of individual collimators.

Figure 3 shows the temporal response when the light is switched from the input port to another output port. The switching time is less than 1 msec. Figure 4 shows the spectral response of 4 wavelength channels with 160-GHz channel spacing. The 1550-nm channel is switched to the output port, while the other 3 channels are coupled back to the input port. The extinction ratio can be improved by reducing the focused spot size on the device plane.

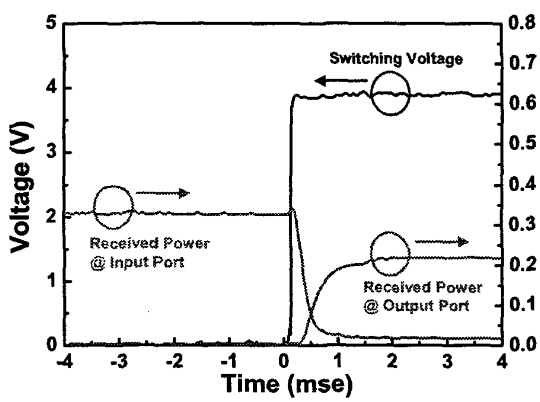

Fig. 3. *Temporal response during switching.*

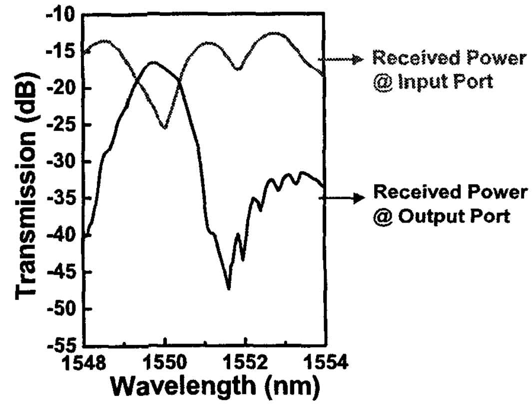

Fig. 4. *Spectral Response: the 1550-nm is switched to another output port.*

Conclusion

We have successfully integrated a telescope-magnified 2D (6x6) fiber collimator array into a $1xN^2$ wavelength-selective switch. A 1x9 WSS with a channel spacing of 160 GHz is successfully demonstrated. The insertion loss of our wavelength-selective switch is measured to be 14 dB, and the switching time is < 1 msec.

Acknowledgement

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