An Optical MEMS Cross-bar Switch

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Abstract—**We present preliminary findings regarding an optical cross-bar switch concept based on integrated silicon photonics waveguides and a MEMS device. Finite difference time domain simulations were performed were performed at a wavelength of 1550 nm to validate the initial design. Simulations indicate that there is a 9 dB difference in output optical power that can be achieved between the two waveguides.**

I. Introduction

The past few decades have witnessed an explosion in the demand for high telecommunications throughput. This demand shows no sign of diminishing, as increasingly higher resolution video transmission, the internet of things, and various other networking applications utilize all available communications bandwidth. This has led to the need for research into improvement in all manner of optical communications components such as lasers, waveguides, wave division multiplexers, optical attenuators and optical switches. A number of technologies have been proposed for optical switching, however switching technology based on microelectromechanical systems (MEMS) particularly provides a number of useful features related to price, compactness and robustness.

Most MEMS optical switching technology is fundamentally based on a movable mirror which reflects laser input to the required output [1]. By increasing the numbers of mirrors into arrays, more complex NxN optical switching can be achieved [2].

Here we present a novel optical switching technology which utilizes an out of plane mirror movement. The technology is based on a combination of silicon photonics and MEMS, and can be easily fabricated at the wafer level using standard foundry techniques.

II. Proposed Design

The switch design is based on a device made from two stacked silicon photonics waveguides as shown in Fig. 1. Both waveguides have diffraction gratings etched into them, for coupling light out of plane. Input light is supplied to the top waveguide. An overhanging cantilever mirror is used to select the proportion of light leaving each of the silicon waveguide outputs by creating an optically resonance cavity which uses interference to couple light into either the top or bottom waveguide based on the cantilever mirror position. The gratings and waveguides are designed for optimal performance in the infrared C-band (1530-1565 nm). This range was chosen as it is the most widely used wavelength band for fiber optic communications.

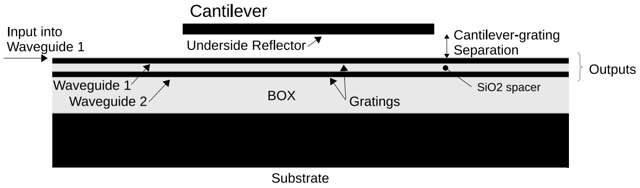

Fig. 1. Cross-section of proposed device.

Such a design could be fabricated through a standard combination of silicon photonics and surface micro-machined MEMS processing [3]. Specifically:

1) start with a silicon-on-insulator (SOI) wafer and pattern the gratings and waveguides into the epitaxial silicon layer using photolithography
2) deposit the silicon dioxide spacer and silicon top layer through a techniques such chemical vapour deposition (CVD)
3) pattern the gratings and waveguides into the top silicon layer
4) Fabricate the cantilever with an underlying reflector using surface micromachining

III. Modelling Results

Finite difference time domain modelling was performed using MEEP open source software developed by MIT [4]. Simulations were run to determine the optical field strength through the structure for light input to Waveguide 1, as the position of the cantilever mirror was moved from 0.1 to 3.5 μm. The simulations also quantitatively determined the optical power propagating through the output of each waveguide. Optical power is quoted in dB referenced to an initial simulation run through the waveguides which does not include gratings or cantilevers. Simulations were run over the range from 1340 nm to 1835 nm to determine the optical bandwidth of the device.

Fig. 2 shows the results of FDTD modelling of the structure for 1550 nm light. Fig. 2(a) shows the light output from each

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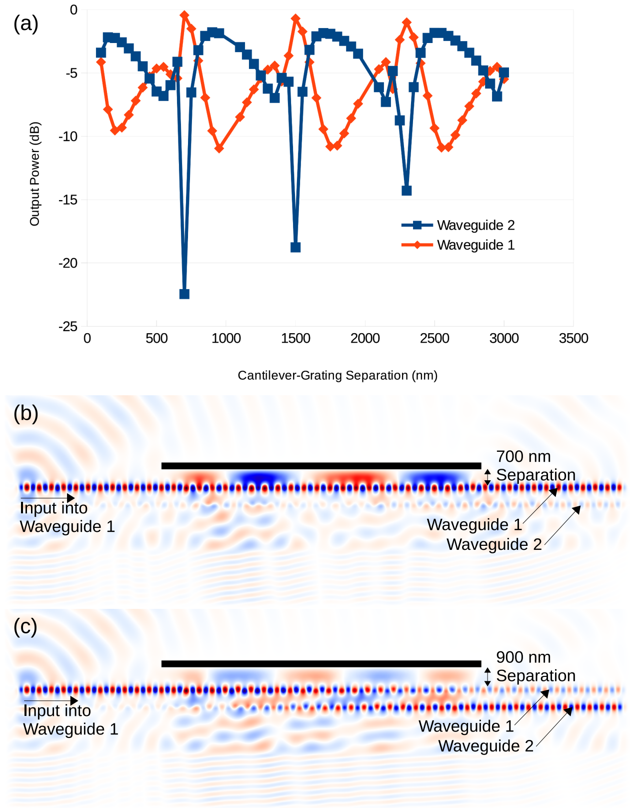

Fig. 2. FDTD modelling at 1550 nm. (a) Optical power in output waveguides as a function of cantilever-gap separation. Simulation performed for 1550 nm light. (b) Optical field strength through structure for 1550 nm light for a cantilever-gap separation of 0.7 μm. This separation distance represents the point of peak power through the top waveguide. (c) Optical field strength through structure for 1550 nm light for a cantilever-gap separation of 0.9 μm. This separation distance represents the point of peak power through the bottom waveguide.

waveguide as a function of the cantilever to top grating separation. It can be clearly seen that optical power in waveguide 1 is at a maximum at separations of 0.7 μm, 1.5 μm, and 2.3 μm. Optical power in waveguide 2 is at a maximum at separations of 0.9 μm, 1.7 μm, and 2.5 μm. For the 0.9 μm separation, there is approximately a 9 dB difference in optical power between waveguide 1 and waveguide 2. Note that for this point of maximum power in waveguide 2, there is an approximate 1.8 dB drop.

Fig. 2(b) shows the optical field strength of 1550 nm light for a cantilever-grating separation of 0.7 μm, the majority of power can be seen to be travelling through the top waveguide (waveguide 1). Fig. 2(c) shows the optical field strength of 1550 nm light for a cantilever-grating separation of 0.9 μm, here the majority of power can be seen to be travelling through the bottom waveguide (waveguide 2). More optical power appears to be escaping through the substrate for this case that for the case of the 0.7 μm simulation.

In order to investigate the optical bandwidth of the system, simulations were run for a wavelength range from 1340 nm to 1835 nm. Fig. 3 indicates that the effect appears to be broadband enough for use across the entire optical C-band (1530 – 1565 nm).

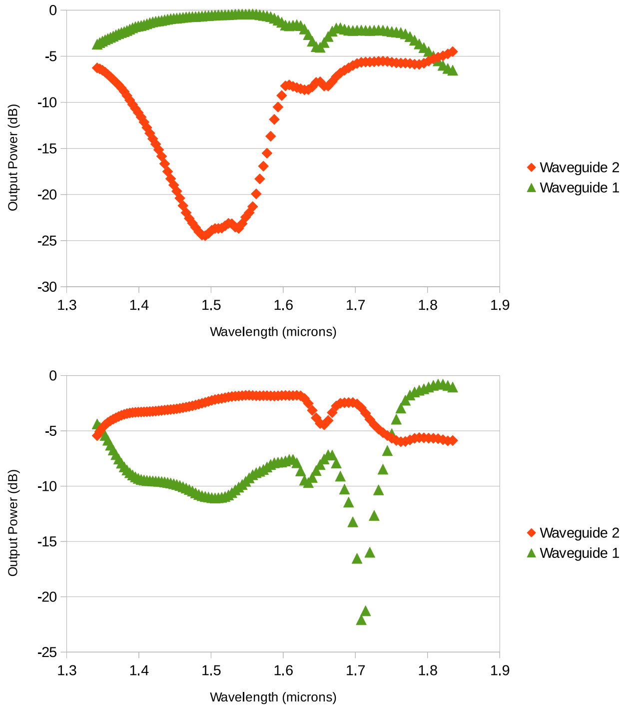

Fig. 3. FDTD modelling from 1340 nm to 1835 nm. Top: Optical power in output waveguides as a function of optical wavelength when the cantilever-grating separation is 700 nm. Bottom: Optical power in output waveguides as a function of optical wavelength when the cantilever-grating separation is 900 nm.

IV. CONCLUSION

We have presented a novel design based on MEMS and silicon photonics which can be used as a cross-bar switch. At an operating wavelength of 1550 nm, simulations show that the light is switched into the receiving waveguide with a power efficiency of 1.8 dB, and that the difference in power in the two output waveguides is 9 dB. Further simulations show that the switch should comfortably operate in the optical telecommunications C-band of (1530 – 1565 nm).

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