WA2
8:45 am – 9:00 am

Modelling of Polymer Thermo-optic Switch with Tapered Input for Optical Backplane

Atef M. Rashed, Ioannis Papakonstantinou and David R. Selviah
Department of Electronic and Electrical Engineering, University College London, Torrington Place
London WC1E 7JE, United Kingdom
a.rashed@ee.ucl.ac.uk, i.papakonstantinou@ee.ucl.ac.uk, d.selviah@ee.ucl.ac.uk

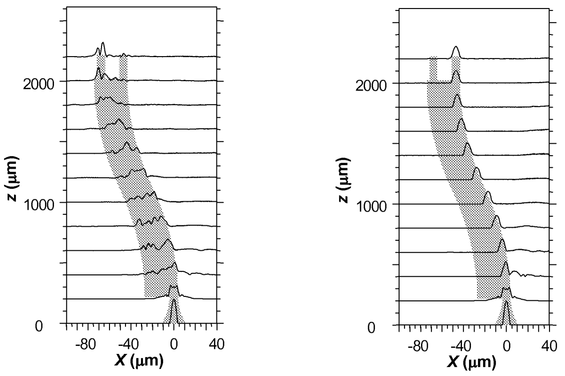
Abstract *A 1×2 thermo-optic switch with tapered input waveguide is modelled using FD-BPM. The tapered section provides greater tolerance for source lateral misalignment. The output power with respect to heating power and source misalignment is investigated.*

Introduction

Electrical interconnects between and within daughter boards and the motherboard backplane in a rack unit are made using copper tracks. At data rates of 10 Gb/s copper tracks can only be used over short distances prompting the need for complex signal shaping to overcome attenuation and distortion due to high frequency parasitics and limited bandwidth [1]. This motivates the investigation of optical interconnects as a solution for these problems. Free space optical interconnects may become misaligned due to vibration and thermal expansion. Optical fibres have a limited bend radius and connector size even though they may be grouped in a ribbon fibre [2]. Polymer waveguides fabricated on or within the electrical FR4 printed circuit boards (PCBs) offer a low cost, compact solution. In these optical backplanes the copper tracks will only remain for supplying power and control signals. However, for low cost optical backplane the laser sources must couple efficiently and reproducibly with the waveguides even in case of misalignment. An additional functionality is introduced to the waveguide interconnect patterns if they are reconfigurable. This could be achieved by implementing optical switches [3] on the backplane. Polymer switches can be realised by making use of the high thermo-optic coefficient and low thermal conductivity of the polymers [4].

Thermo-optic 1×2 switch

We present a one dimensional taper to give tolerance to lateral misalignments of the source followed immediately by an S-shaped multimode interference (MMI) coupler to make a compact structure. The input waveguide tapers quadratically from a cross section of 21×7 to 7×7 μm over a length of 220 μm. The S-shape MMI coupler has a cross section of 28×7 μm and a length of 1.8 mm. The narrow end of the taper waveguide is aligned to the external edge of the lower half of the S-shape. The switch outputs to two straight waveguides each of 200 μm length and 7×7 μm cross section. The two output waveguides are aligned to the side edges of the upper part of the S-shape. An 11.5 μm wide S-shaped thermally conductive stripe aligned with the centre of the left output waveguide lies above the device and acts as a constant temperature element. The waveguides have a channel structure with 0.5% step index and 1.54 core refractive index. The thermo-optic coefficient and the thermal conductivity of the polymer material are -0.0003 K^{-1} and 1.8×10^{-7} W/(μm.K), respectively.



(a) *(b)*

Fig. 1: Thermo-optic switch
(a) Cross-state at P = 0 mW
(b) Through-state at P = 200 mW

The operation of the device results from the principle of field propagation in MMI structures. In this device the length of the MMI coupler is optimised such that the output field is projected to the anti-symmetric position with respect to the input field. This will make the switch operate in its "cross"-state [3].

When heat is applied to the waveguide the core effective index in the heated area decreases to approach that of the cladding. This causes the optical field in the upper half of the S-shape to move towards the higher refractive index region at the right hand side to couple to the right output waveguide when the switch operates in its "through"-state.

A 7 μm aperture VCSEL operating at 850 nm and emitting in its fundamental mode is used to simulate the

0-7803-8557-8/04/$20.00©2004 IEEE

source located at the centre of the input waveguide. Fig. 1 shows a top view of the switch operating in both states at heating power P = 0 mW and 200 mW and the optical field in cross sectional slices.

FD-BPM numerical model

The switch is modelled by solving Helmholtz wave equation (1) using FD-BPM by creating a mesh in 3D with corresponding step sizes of $\Delta x = \Delta y = 0.5\ \mu\text{m}$ and $\Delta z = 5\ \mu\text{m}$.

$$\frac{\partial u}{\partial z} = \frac{i}{2\beta}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \left(\frac{4\pi^2 n^2}{\lambda^2} - \beta^2\right)u\right) \qquad (1)$$

Where u is the propagating field, β is the propagation constant, n is the refractive index, λ is the wavelength and x, y and z are the coordinates in the lateral, transverse and propagation direction, respectively.

Results and discussion

Fig. 2 shows the ratio of the output to the input power as a function of the heating power. Excellent switching behaviour is observed starting from a very low heating power, P of 60 mW with large power difference between the two outputs in the two operating states. This difference representing the cross talk between the two channels reaches its optimum value at P = 60 mW. The cross talk is at its lowest level of –42 dB at that heating power.

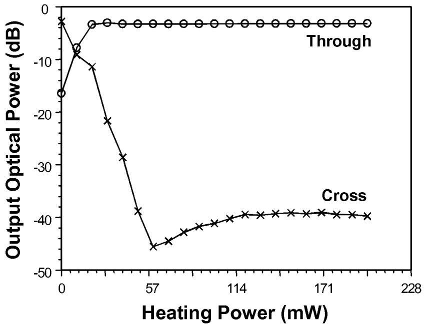
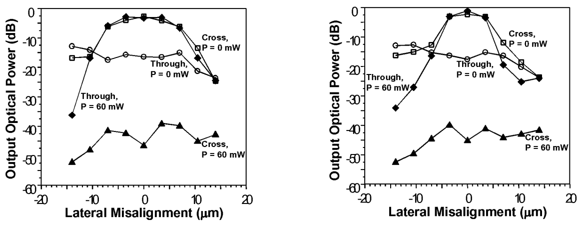


Fig. 2: Output power ratio versus heating power

We compared the taper input with a straight waveguide input of 7 μm width and 220 μm length in terms of the switching behaviour and the tolerance to misalignment for both input waveguides.

Fig. 3 shows the ratio of the output to the input power at P = 0 mW and 60 mW as a function of the source lateral misalignment in the case of a tapered input waveguide (a) and a straight input waveguide (b). The cross talk between the two channels of the switch at P = 0 mW and 60 mW for both input waveguides at different values of lateral misalignment can be derived by subtracting the power of the cross-state from the corresponding value of the through-state. Fig. 4 shows this cross talk as a function of misalignment for each case.



(a) *(b)*

Fig. 3: Output power ratio versus lateral misalignment

(a) Tapered input waveguide

(b) Straight input waveguide

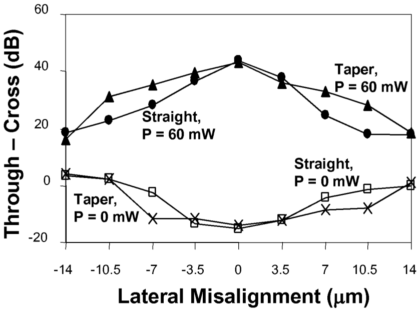


Fig. 4: Cross talk versus lateral misalignment

At P = 0 mW, the taper outperforms the straight waveguide by cross talk difference up to 9 dB over ±7 μm of lateral misalignment. At P = 60 mW the taper also shows better switching behaviour indicated by cross talk difference up to 10 dB over ±10.5 μm of lateral misalignment.

Conclusions

A compact, low power, low cross talk, highly lateral misalignment tolerant thermo-optic switch has been modelled. The tapered input waveguide provides greater tolerance to lateral source misalignment.

Acknowledgement

The authors are grateful to UK EPSRC, DTI and Xyratex, Havant for support through the Storlite project.

References

1 Stach, Annual Report, Optoelectron. Dept., Univ. of Ulm, (2002)
2 Moisel, IEEE Proc. LEOS, Vol. 2 (2000), pp. 567
3 Shu et al, Proc. CLEO, (2002), pp. 200
4 Hida et al, IEEE Photon. Technol. Lett., Vol. 5 (1993), pp. 782