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ALL-FIBRE 3 × 3 ACOUSTO-OPTIC SWITCH

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Abstract

We report an all-fibre 3 × 3 acousto-optic switch. The maximum drive power required is 4 mW, the switching time is 100 μs and the insertion loss is less than 0.5 dB.

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We have previously made an all-fibre 2 $\times$ 2 acousto-optic switching element from a fused coupler[1]. Here we describe a similar 3 $\times$ 3 switch. Two of three identical fibres are narrowed (pre-tapered) by different amounts, before all three are fused and elongated together to form the coupler. If the three diameters are sufficiently different, the result is a "null" coupler; light of any wavelength entering in a particular fibre will leave the coupler from the far end of the same fibre.

Light in each fibre excites just one distinct mode in the coupler waist, Fig. 1. A flexural acoustic wave can couple light between these modes if the acoustic wavelength matches the appropriate intermodal beat-length. Light coupled into a mode will emerge from the fibre associated with that mode. All the light can be coupled if the amplitude and frequency of the acoustic wave are suitably adjusted. This being so, the switch can have the three states shown in Fig. 2, depending on the presence and frequency of the acoustic wave. The favoured fibre is the one of intermediate diameter; for symmetry reasons, light cannot be routed directly between the widest and narrowest fibres. The advantages of the 2×2 switch are retained, namely low drive power, low insertion loss, and monolithic construction with identical fibre ports.

A 3×3 coupler was made from three lengths of standard 125 μm single-mode fibre. Two were pre-tapered to about 3/4 and 1/2 the initial diameter, respectively. In the passive state with $\lambda = 1550$ nm the excess loss was 0.22 dB, and the maximum power coupled from any fibre to any other fibre was 1:400 (a good null coupler). The acoustic wave was imposed via a horn fixed to the unstretched fibres[1]. Light was coupled from the intermediate fibre to the widest and narrowest fibres, respectively, for drive frequencies of 0.8 MHz and 1.6 MHz, with maximum coupling fractions of 94 % and 97 % for RF drive powers of 2 mW and 4 mW. The switching speed was about 100 μs for both. The power simultaneously coupled to the remaining fibre did not exceed 1 %. Fig. 3 is a graph of coupled power versus RF drive voltage for the higher frequency; the lower frequency gave a similar response. Larger values of maximum coupling, hence better channel isolation, would be expected by using a more broadband acoustic transducer, and closer polarisation control.

Optical routing arrays are usually designed with 1×2 switching elements in mind[2]. The availability of efficient 1×3 (and maybe higher order) switching elements should prompt the design of new array topologies with fewer elements per channel.

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References

1. T. A. Birks, S. G. Farwell, P. St.J. Russell, C. N. Pannell: Optics Letters, **19**, 1994, pp. 1964-1966.

2. C.-C. Lu, R. A. Thompson: IEEE Transactions on Lightwave Technology, **12**, 1994, pp. 1482-1489.

Figure captions

1. Sketches of the modes excited in the coupler waist by light waves in each fibre.

2. The three possible states of the switch: (a) bar state (no acoustic wave); (b) first cross state (acoustic wave at lower resonant frequency); (c) second cross state (acoustic wave at upper resonant frequency).

3. Optical powers in the intermediate (○) and narrowest (□) output fibres versus RF drive voltage at 1.6 MHz, for input light in the intermediate fibre. Output in the third fibre was less than 1 % at all times. The first maximum corresponds to an RF drive power of 4 mW.

Fig 1
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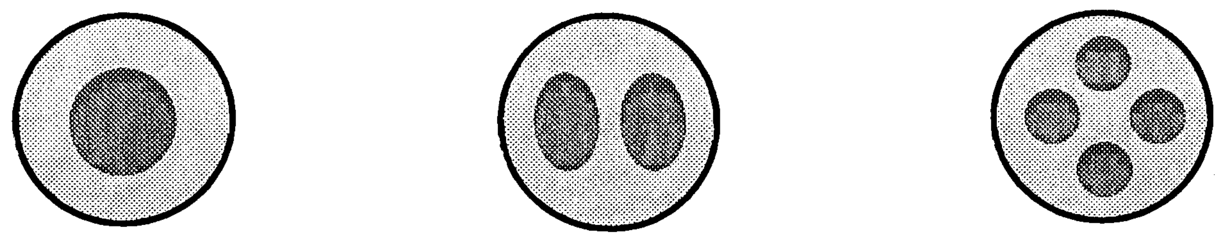

LP_{01} excited by widest fibre

LP_{11} excited by intermediate fibre

LP_{21} excited by narrowest fibre

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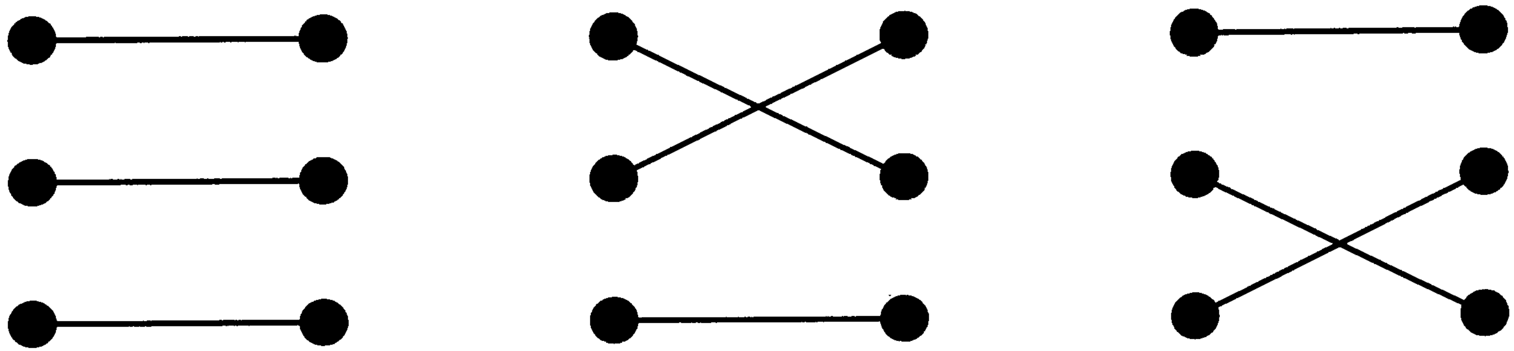

(a) (b) (c)

Fig 3
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