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POLARISATION INDEPENDENT (<0.01 dB) SWITCHING IN A 2×2 FUSED FIBRE NULL COUPLER USING ASYMMETRIC DUMBBELL CROSS-SECTION

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Abstract

Polarisation independent (<0.01 dB) switching at 1.55 μm is achieved in a strongly guiding tapered fibre null coupler acousto-optic switch. A strongly fused asymmetric dumbbell cross-section gives the form birefringence required to render the null coupler polarisation insensitive.

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High performance optical networks require polarisation independent switches. To date, planar technology using polymer [1] or lithium niobate [2] substrates have resulted in high performance devices but still exhibit significant polarisation sensitivities (~0.5 dB). Recently we have described an all-fibre acousto-optic switch at 1.55 μm [3] which outperforms these devices in terms of insertion loss and drive power and compares favourably in terms of switching speed. However, this early device still showed significant polarisation sensitivity. The device relies on the acoustic wavelength matching the beatlength ($L_B = 2\pi/(\beta_e - \beta_o)$) between the even and odd modes of the coupler waist to give resonant coupling. The fact that $L_B^x \neq L_B^y$ in a circularly fused device gives rise to polarisation dependent coupling and therefore polarisation splitting.

To overcome the polarisation dependence of this fibre device several methods have been devised, which rely on meeting the resonance condition separately for each polarisation. Overlapping the two coupled spectra results in polarisation insensitivity for a small range of wavelengths. These techniques include driving the device with two acoustic frequencies [4], varying the waist radius until the optical bandwidths of the orthogonal polarisation states overlap [1], or employing two regions of different waist radius. However all these techniques give large sidebands, require increased drive powers and suffer from polarisation crosstalk. Recently we have reported a device [5] with a circular cross-section and with <0.2 dB twist-induced polarisation insensitivity. It is only this and the present device we are now reporting that switch a single notch filter range of optical wavelengths, as opposed to merely masking the polarisation sensitivity at specific wavelengths. They are also the only configurations requiring the minimum RF drive power.

In this paper we demonstrate for the first time that it is possible to eliminate the polarisation sensitivity in a null coupler by precisely controlling the cross-section of the waist to give zero form birefringence [6,7]. Polarisation insensitive acousto-optic switches driven at 1 MHz (operation described in [3]) were fabricated with a 25mm interaction region. Figure 1 shows the "isotropic" ($L_B^x = L_B^y$) cross-section of the coupler's waist. Precise heating was needed to achieve this degree of fusion, and was accomplished using our newly developed computer-controlled coupler rig. In figure 1, the ratio of major to average-minor axes is 1.77:1.

The switching curve for a 25 mm interaction length device having an excess loss of 0.05 dB and passive crosstalk of -42 dB is shown in figure 2. The device has an experimental switching time of 40μs compared to the theoretical switching speed of 37μs (equation 2 in [3] where $B = 4.938 \times 10^{-9}\text{m}^{-2}\text{s}^2$). The device has an extremely low polarisation sensitivity of <0.01 dB at 96% coupling efficiency and uses only 0.25 mW of electrical power. This is the best reported performance to date. Preliminary results for 8mm interaction lengths give 11 μs switching times with similar polarisation suppressions.

The polarisation sensitivity of the device was examined using a polarised tunable laser.

The wavelength separation of the polarisation peaks was 3.1 nm, compared to 49.8 nm [8] expected from a circularly fused device driven at the same frequency. The optical bandwidth of the device is shown in figure 3 and reveals a single peak as would be expected from a polarisation insensitive device. The -3 dB bandwidth was 19.5 nm and compares favourably with the theoretically calculated value of 16.5 nm. This discrepancy is due to the residual polarisation peak separation, but is also a strong indication that there is a very uniform degree of fusion along the interaction length.

In summary, the asymmetric dumbbell method overcomes the polarisation dependence of the device in one step. The device gave an extremely low polarisation sensitivity of <0.01 dB at 96% coupling efficiency, using only 0.25 mW of electrical power. Further work will involve tuning the fusion parameters to give exactly zero form birefringence and applying the twisted waist method to an asymmetric dumbbell cross-section in order to further improve repeatability of fabrication.

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Figure Caption

1. Cross-section of a 25 mm "isotropic" null coupler taken using a scanning electron microscope. The ratio of the major to average minor axis is 1.77:1.

Figure Caption

2. Switching curve for a device of length 25mm, driven at an acoustic frequency of 1.026 MHz. both polarisation states are shown. The polarisation suppression was <0.01 dB at 96% coupling. Response shown for light initially launched in the pretapered fibre.

Figure Caption

3 Optical bandwidth of a device with a 25 mm interaction region taken using unpolarised light. Only one coupling peak is seen since both polarisation peaks are overlapped.

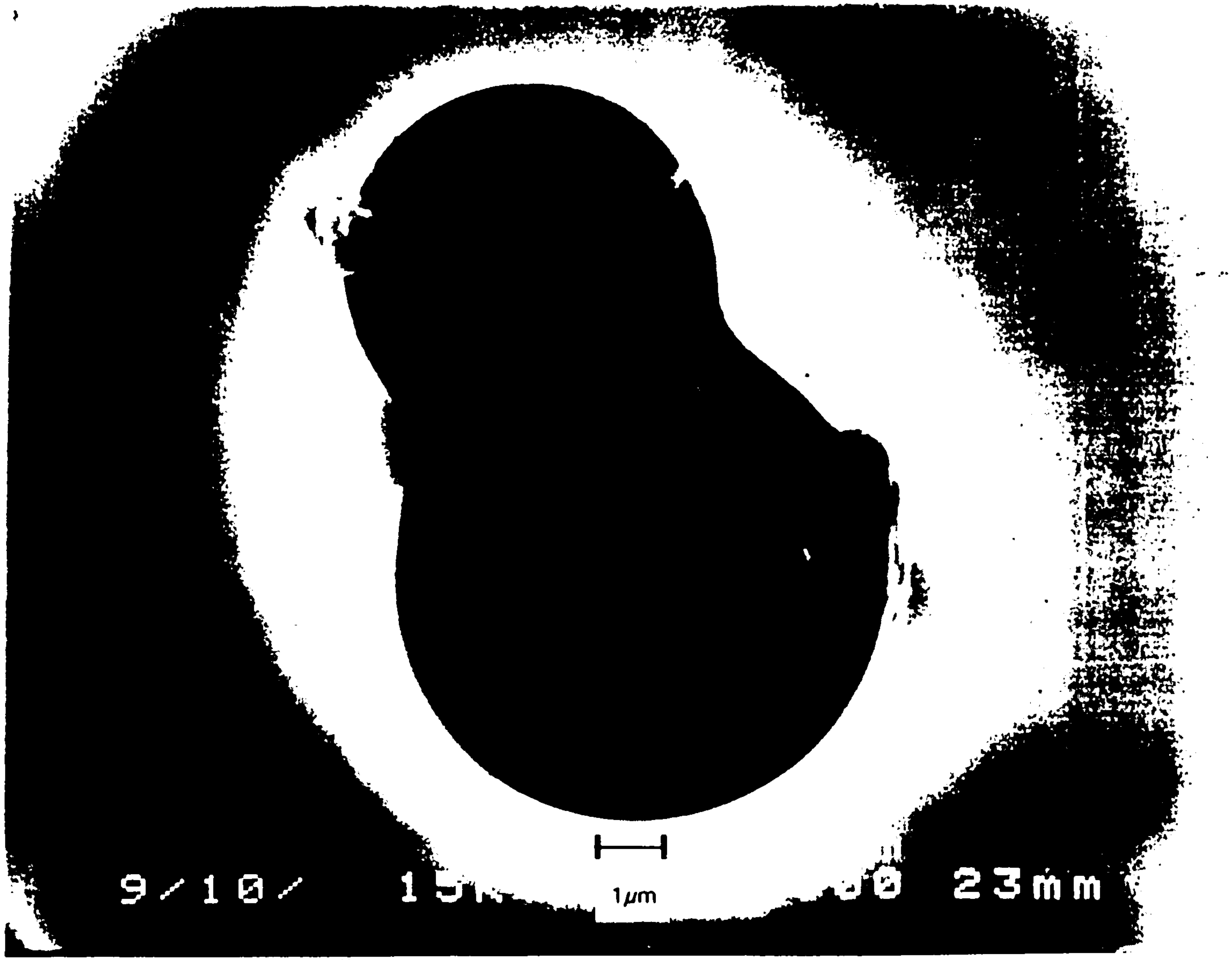

Figure 1

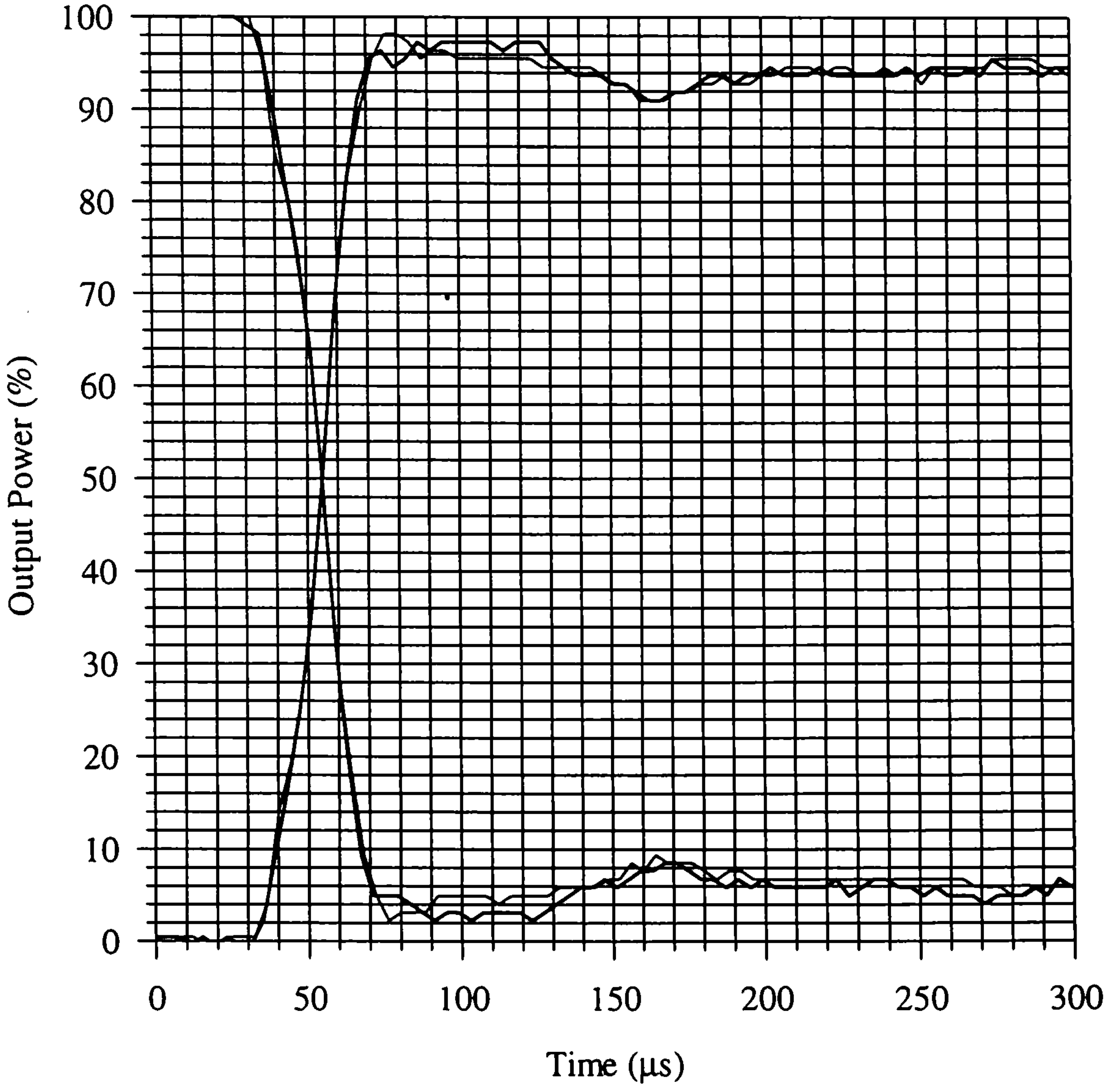
100
90
80
70
60
50
40
30
20
10
0
Output Power (%)
0
50
100
150
200
250
300
Time (μs)

Figure 2

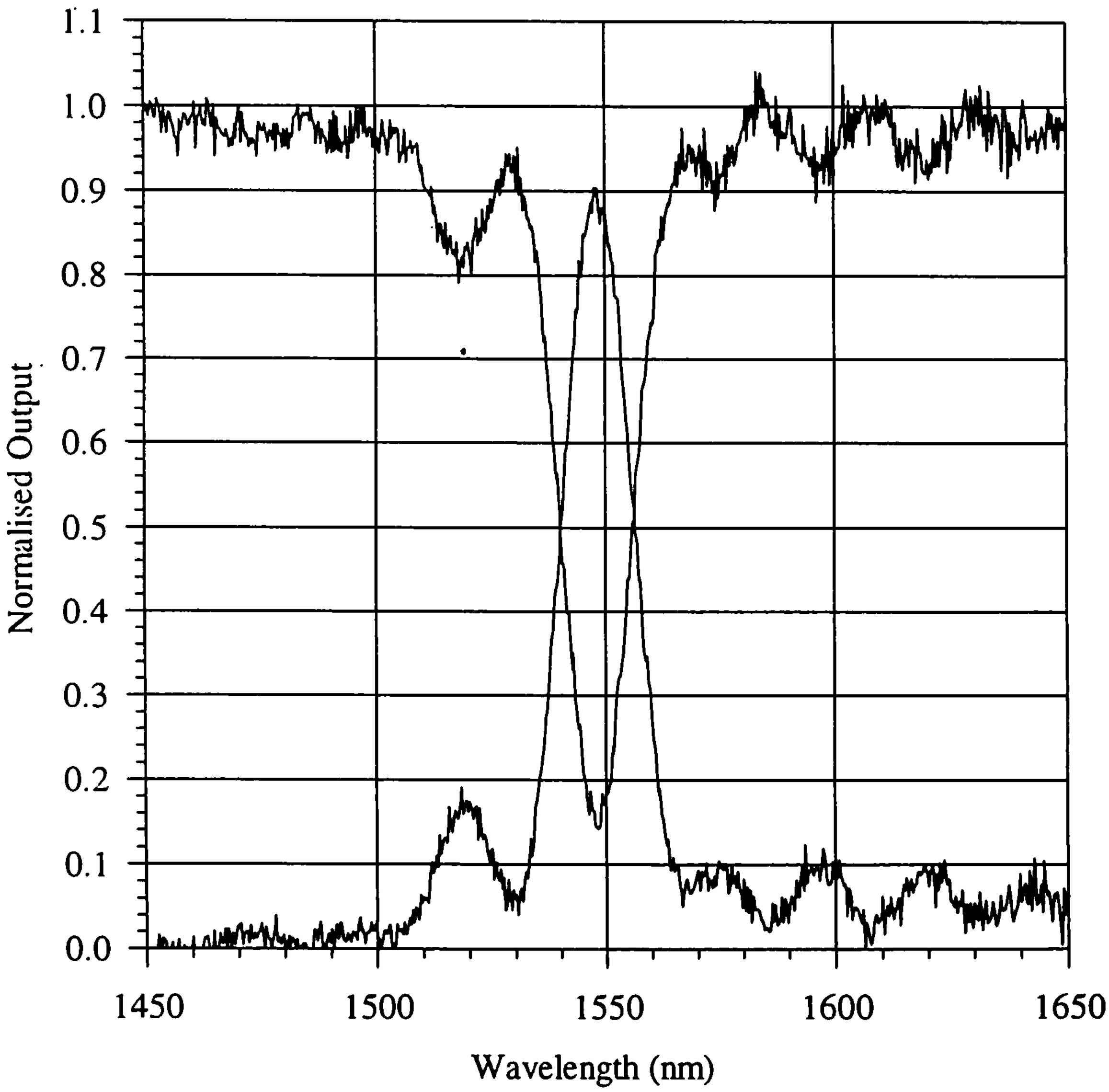
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Normalised Output
1450
1500
1550
1600
1650
Wavelength (nm)

Figure 3