POLARISATION IN FUSED SINGLE MODE FIBRE COUPLERS

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Introduction

The first polarisation beam splitter based on a single-mode fused-taper coupler has been recently demonstrated. (1-3). In the device it was shown that the frequency response of the coupling of unpolarised light exhibits a modulated oscillatory behaviour as shown in Fig.1. The modulation occurs because the coupling strengths of x- and y- polarised light are slightly different, resulting in different beat lengths for the two polarisations (2,3). Potentially there are many important applications which can exploit this effect. These include wavelength filters, multiplexers, modulators, and wavelength tuneable couplers. The ease and simplicity of fabrication of the fused coupler is an added advantage when considering such applications.

In this paper we present further results which demonstrate that the polarisation splitting ability arises predominantly from geometrical birefringence in the coupling region. This conclusion is supported by a detailed analysis of the birefringence which is in good agreement with our experimental measurements.

Experimental Results

Birefringence in the coupling section can occur as a result of stress or geometrical shape. To investigate which of these mechanisms is responsible for the observed behaviour, measurements were made on several fused couplers with very long interaction lengths fabricated from matched-cladding single-mode fibres. The spectral response of a coupler with a 300mm long interaction length is shown in Fig.1. The response shows two main features. Firstly, the power splitting ratio oscillates rapidly with a channel spacing $\Delta\lambda$ of about 3nm. Secondly, this power splitting is modulated by a slower period $\delta\lambda$ which decreases with increasing wavelength. This latter observation is an important one and confirms that geometrical birefringence is the dominant effect in the coupler. Stress birefringence has a dependence of $1/\lambda$ in the difference in coupling strengths of the x- and y- polarisations. Consequently if stress birefringence proved dominant we would find an increase of the modulation period with increasing wavelength.

Analysis

To investigate the extent to which the observed behaviour is dominated by geometric birefringence we have carried out a detailed analysis of the birefringence of the coupling section.

For strongly-fused couplers the cross section of the interaction region is approximately oval, as in Fig.2(a) For weakly-fused couplers the cross section is composed of two fibres just touching, as in Fig.2(b). In both cases the effect of the tapering has made the core diameters almost vanish, so that the electromagnetic field propagates in a waveguide consisting of the entire coupler cross section, shown shaded in Fig.2.

For both cases shown in Fig.2., the ratio of the modulation period to channel spacing can be shown to be given by

$$\frac{\delta\lambda}{\Delta\lambda} = G \cdot \frac{V}{\left(1 - \frac{n_2^2}{n_1^2}\right)} \qquad (1)$$

where $V = 2\pi a/\lambda(n_1^2 - n_2^2)^{1/2}$ and G is a geometric factor which has the value $G = \frac{1}{4}$ for the strongly fused case of Fig.2(a) and $^{10}/_{14}$ for the weakly fused case of Fig.2(b)

Discussion

The cross sectional shape of the coupler measured in Fig.1 corresponds closely to Fig.2(b). Equation (1) predicts that ratio $\delta\lambda/\Delta\lambda$ of modulation period to channel spacing should decrease as $1/\lambda$ with increasing wavelength, which is consistent with experiment. In Fig 3 we have plotted this ratio against $1/\lambda$ using the coupler whose response is shown in Fig.1.

Using eq (1) with the appropriate G for the weakly fused case together with the slope of the straight line found from Fig.3, we find that the cross sectional dimension of this coupler should have $a \approx 2\text{-}3\mu m$. This is in close agreement with the measured cross section for our couplers.

Conclusions

The polarisation properties of fused taper couplers have been shown to result from geometrical birefringence in the coupling section. Our detailed analysis of this birefringence is in excellent agreement with experimental measurements.

This quantitative understanding of the polarisation behaviour will be very important in the design of opto-electronic components exploiting the polarisation properties of tapered couplers.

Acknowledgements

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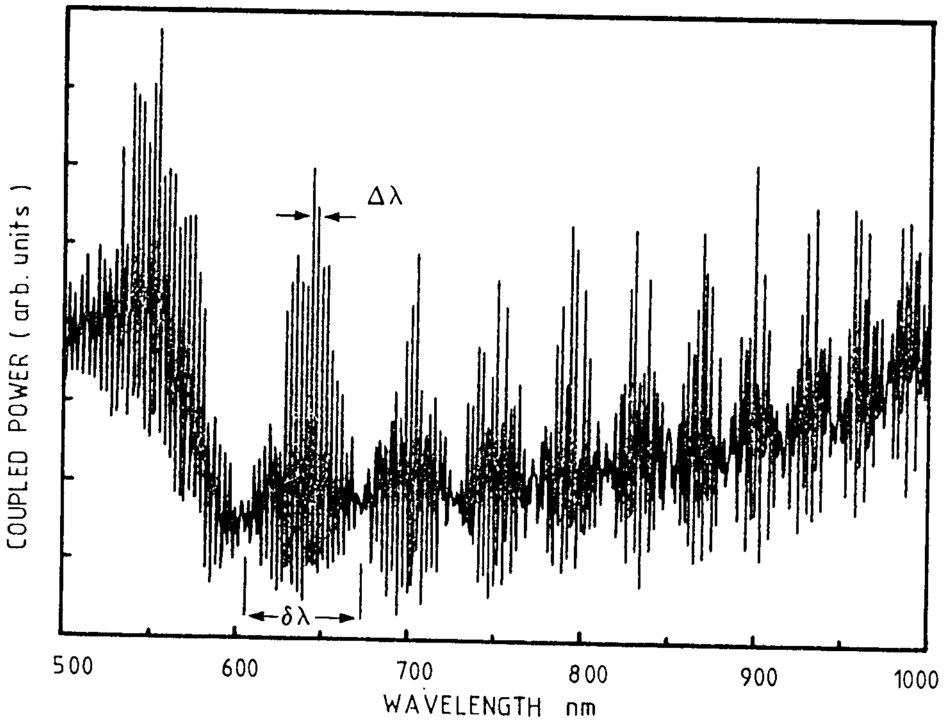
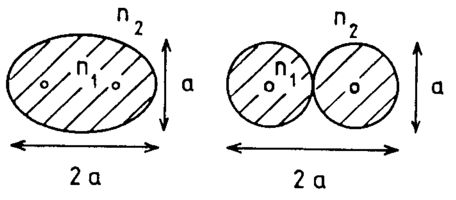
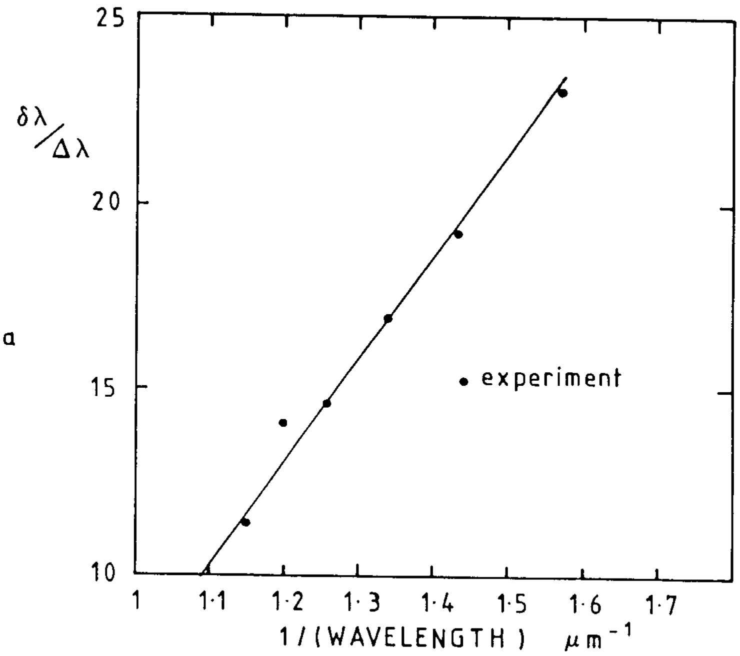


Fig·1 Variation of coupled power with wavelength for a fused-taper coupler with a 300 mm long coupling section.



(a) (b)

Fig·2 Coupler cross section for (a), well fused couplers and (b), for weakly fused couplers.



Fig·3 Experimental results for the variation of the ratio of modulation period δλ over the channel spacing Δλ. Equation 1 predicts a straight line dependence against 1/λ.