WAVELENGTH-FLATTENED COUPLERS: PERFORMANCE OPTIMISATION BY TWIST-TUNING

Indexing terms: Optical fibres, Optical couplers

The twisting of an asymmetric fused tapered single-mode fibre coupler is found to decrease the maximum coupled power, in addition to the usual shift in the wavelength response. This effect can be used to optimise a wavelength-flattened coupler's performance during or after coupler elongation.

Introduction: Asymmetric fused tapered single-mode fibre couplers can be fabricated which have a 'flattened' wavelength response,[1] with a maximum coupled power of less than 100% (typically near 50%). The asymmetry can be introduced by pretapering,[1] pre-etching[2] or prepolishing[3] one fibre prior to coupler fabrication, or even by using two dissimilar fibres.[2,4,5] However, the maximum splitting ratio (MSR) has been shown to depend both on the asymmetry between the two fibres[1,2] and also on the degree-of-fusion of the fibres in the coupler.[5] Both effects need to be carefully controlled and balanced *a priori* to produce a coupler with a desired specification.

In this letter it is shown that axial twisting[6] can yield an *a posteriori* optimisation mechanism in asymmetric couplers. It is found that as an asymmetric coupler is twisted, not only do the wavelength positions of the maxima in the spectral response change (as for a symmetric coupler[6]), but the heights of the maxima change as well.

Experiment: An asymmetric coupler was fabricated from a pair of dissimilar single-mode fibres, which had cladding diameters of 80 μm and 100 μm. The coupler exhibited the flattened wavelength response typical of such couplers, with a maximum coupled power of about 50%. The variation of the height of this maximum in the spectral splitting ratio (i.e. the MSR), as its wavelength position was changed by the coupler elongation process, is drawn in Fig. 1. The coupler was elongated until the splitting ratio was a maximum at a wavelength

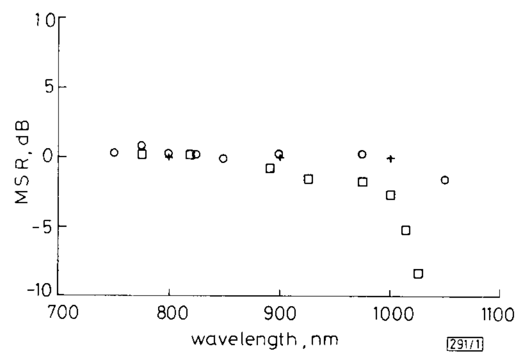

Fig. 1 *MSR of asymmetric coupler against wavelength position of MSR*
○ as coupler is being tapered
□ as fully tapered coupler is subsequently twisted through 0·5, 1, 1·5, 1·75, 2, 2·25, 2·5 and 2·75 twist revolutions from neutral position

of 750 nm, and the spectral splitting ratio curve of the final coupler is drawn in Fig. 2. The splitting ratio is defined here to be

$$\text{splitting ratio} = 10\log_{10}\left(\frac{P_b}{P_a}\right)\text{dB} \qquad (1)$$

where P_a and P_b refer to the throughput and coupled output powers, respectively.

The fully elongated coupler (with its spectral splitting ratio peak centred at the wavelength of 750 nm) was then subjected to varying degrees of axial twisting. As has been demonstrated with symmetric couplers,[6] the wavelength position of the splitting ratio peak was found to move towards longer wavelengths as the coupler was twisted. However, the height of the peak (the MSR) was also found to change with twisting, and the variation of the MSR with the peak's wavelength position is also drawn in Fig. 1. It is evident from the Figure that the MSR decreases as the peak's wavelength (and hence the amount of twist) increases. Indeed, at the right-most twist-tuned point in the Figure (corresponding to 2·75 revolutions of twist) the maximum coupled power has fallen to less than 15% of the input power. The splitting ratio graph for the coupler with 2·75 revolutions of twist is drawn in Fig. 2, for comparison with the graph for the untwisted coupler.

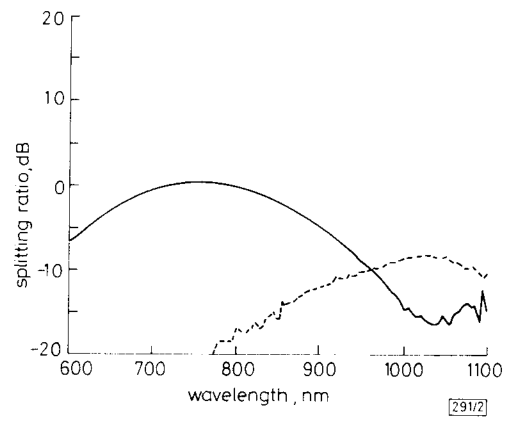

Fig. 2 *Spectral splitting ratios of asymmetric coupler*
——— untwisted
– – – – when twisted through 2·75 revolutions

That this change is due to the twisting process and is not merely a purely spectral effect is demonstrated by the constancy of the MSR over the wavelength range as the coupler was being tapered. The coupler's initial insertion loss of 0·1–0·2 dB suffered no more than a 0·1 dB increase during the twist-tuning process. A similar experiment was conducted on a different asymmetric coupler, and the trends in performance described above were confirmed.

Discussion: It has been demonstrated elsewhere[6] that the twisting of a tapered coupler induces decoupling, i.e. a reduction in the coupling coefficient. This is the result of a redistribution of the modal fields in the coupler away from the longitudinal axis, causing a reduction in the coupling strength. The effects of this field redistribution on the MSR of an asymmetric coupler can be understood very easily, since twisting produces a situation analogous to a reduction of the degree-of-fusion of the coupler; this also causes a decrease in the MSR.[5]

Twist-induced tuning of the MSR can be used to optimise the performance of wavelength-flattened couplers during or after taper elongation, despite the complications due to the simultaneous movement of the wavelength position of the MSR. For example, suppose it is necessary to fabricate a 50%-splitting coupler with a wavelength-insensitive band centred on a wavelength λ_0. The asymmetric pair of fibres is fused and elongated until the first peak in the splitting ratio lies at λ_0, and if this peak is greater than 50% the coupler can be tapered further and then twisted until the peak again lies at λ_0. If the twist-tuning effect has not reduced the peak sufficiently, the coupler can be untwisted, tapered further and then twisted again, and the procedure can be repeated until a splitting ratio peak of about 50% lies at λ_0.

Conclusions: A new degree of freedom has been introduced for the fabrication of wavelength-flattened couplers. The twisting of an asymmetric coupler causes a decrease of the maxima in the spectral splitting ratio response; this is in addition to the wavelength shift previously reported for symmetric couplers. Both effects are due to the twist-induced reduction of the coupling strength in the coupler. The MSR decrease can be employed to optimise the performance of wavelength-flattened couplers during or after fabrication, and it is thus possible to dispense with the close control over the fibre preparation and elongation processes normally necessary for such couplers.

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T. A. BIRKS*
C. D. HUSSEY*

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Optical Fibre Group
Department of Electronics & Computer Science
University of Southampton
Southampton SO9 5NH, United Kingdom

* Now with Lightwave Technology Research Centre, National Institute of Higher Education, Limerick, Ireland

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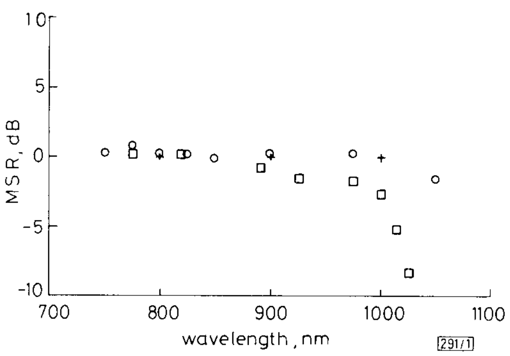

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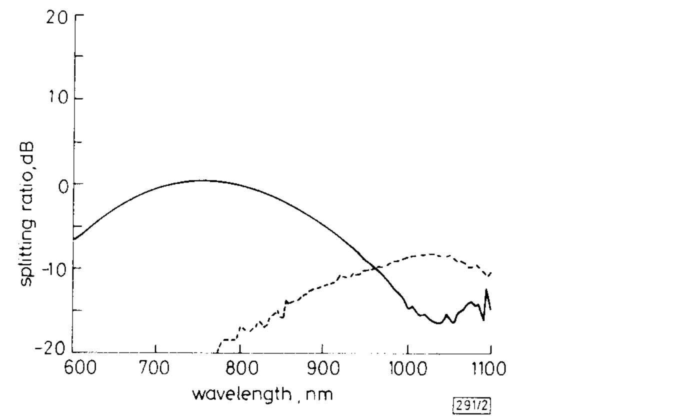

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