376

# TWIST-TUNING OF FUSED-TAPERED SINGLE-MODE FIBRE COUPLERS

T. A. BIRKS.
OPTICAL FIBRE GROUP,
DEPARTMENT OF ELECTRONICS AND COMPUTER SCIENCE,
UNIVERSITY OF SOUTHAMPTON,
SOUTHAMPTON,
SO9 5NH.
UNITED KINGDOM.

## ABSTRACT

The axial twisting of a tapered coupler causes optical decoupling which can change its power-splitting ratio. An environmentally stable package is implemented which allows a coupler's response to be tuned through all possible values.

## INTRODUCTION

The fused-tapered single-mode fibre coupler is an important component in many fibre applications and is simple to fabricate and environmentally stable[1]. However, no practical method of adjusting the power-splitting ratio of tapered couplers after their fabrication has been found. It is known that an induced bend in a tapered coupler will affect its splitting ratio[2,3] but this effect has not been successfully exploited. This is in contrast to the polished coupler, which finds wide laboratory use as an adjustable power-splitter[4]. We have found that the splitting ratio of a tapered coupler can also be tuned by inducing an axial twist in the coupler, and that this tuning is the result of a decoupling effect. We have assembled a simple prototype packaging container for fused-tapered couplers which allows the power-splitting of the coupler to be readily tuned from 0% to 100% at the operating wavelength, and which is temperature and vibration insensitive.

## TWISTING A COUPLER

A fused-tapered single-mode fibre coupler was made in the conventional manner[1] and was tapered through one complete coupling cycle at 870nm, ie, the optical power returns completely to the throughput fibre at 870nm. After fabrication, but without being packaged, the coupler was subjected to varying degrees of twisting and was characterised. To avoid the effects of bends care was taken to ensure that the coupler remained taut, and by positioning adhesive tabs along the untapered fibres we confirmed that all of the twisting was absorbed by the tapered region alone.

Fig.1 shows the variation of the logarithmic splitting ratio of the output powers of the coupler with the amount of twist, at a wavelength of 870nm. The splitting ratio is seen to vary across all possible values, from no power coupled to all the power coupled, over 480° of twist. This variation was reversed when the coupler was untwisted. The coupler insertion loss of 0.1dB suffered no significant change at any stage.

Fig.2 shows the spectral power-splitting ratio of the coupler the amount of twist increasing from curve a to curve c. The features of the graph shift towards the longer wavelengths with increasing twist, which is the opposite of what happens as tapering proceeds during coupler fabrication. We conclude that twisting a coupler induces decoupling rather than further coupling. It is notable then that the coupling strength at 870nm is halved as the power transfers from one fibre to the other over the 480° twist.

The coupler suffered many 480° twisting-untwisting cycles without degradation. Tested to destruction, the coupler was finally destroyed after approximately eight consecutive revolutions of twist in the same sense.

## THE TUNABLE COUPLER PACKAGE

A number of similar couplers were twisted and all exhibited similar properties to the coupler described above, demonstrating the reproducibility of the tuning effect.

In particular, one such coupler was fabricated and packaged in a prototype cylindrical container consisting of a silica tube with plastic end-pieces. In each end-piece a 1mm hole was drilled through which the fibres were threaded. After coupler fabrication the package was assembled around the coupler, and the coupler ports were fixed in the end-pieces with epoxy adhesive while the coupler was kept taut between them (Fig.3). The end-pieces were free to rotate on the silica tube, and this provided the twisting mechanism.

This coupler had been fabricated under a larger tapering tension than was the unpackaged coupler described earlier, resulting in a longer taper. In this case the coupler required two revolutions of an end-piece to tune across the full range of splitting ratios at the operating wavelength of 850nm.

To test the environmental stability of the packaged coupler, the coupler was tuned so that power emerged from both output ports, and was then subjected to changes in external temperature. A change in temperature from 0°C to 60°C gave rise to a 0.45% change in the fraction of the input power coupled, and the coupler insertion loss of 0.2dB suffered negligible change. The packaged coupler was struck vigorously and dropped onto the bench from a height of 20mm, and suffered a coupled-power variation due to vibration of the coupler, with an amplitude of typically 0.4% and at no stage greater than 0.9%.

A further coupler was mounted in a similar package which was then filled with a viscous uncured silicone elastomer (Dow-Corning Sylgard 182) to assist in the mechanical protection of the coupler. The tunability of the coupler was little changed by the addition of the elastomer; however, the temperature sensitivity of the coupler was increased to a 0.8% change in the fraction of power coupled per 20°C change in temperature. This increased temperature sensitivity is almost certainly due to the thermally induced change in the elastomer refractive index.

## DECOUPLING MECHANISM IN TWISTED COUPLERS

Twisting induces a change in the effective refractive index in the cross-section of the coupler which is similar to the familiar effective refractive index change induced in a fibre as the result of a bend[5]. This effective index change can account for the decoupling observed in twisted couplers, since the effective index induced by the twist increases with distance from the longitudinal axis of the coupler. The relative increase in the effective index at the edges of the coupler causes a redistribution of the modal fields in the coupler away from the axis. This reduces the field overlap between the two sides of the coupler, and hence a degree of decoupling takes place.

Calculations show that though this effective index change is small, it is sufficient to account for the halving of the coupling strength observed in the twisted couplers described above.

## CONCLUSION

We have demonstrated that fused-tapered single-mode fibre couplers can be tuned with low loss across all splitting ratios by twisting. This process is reversible and repeatable without degrading the coupler performance. A simple, controllable and environmentally stable tuning package has been described which should provide the basis for the design of a practical tunable tapered coupler.

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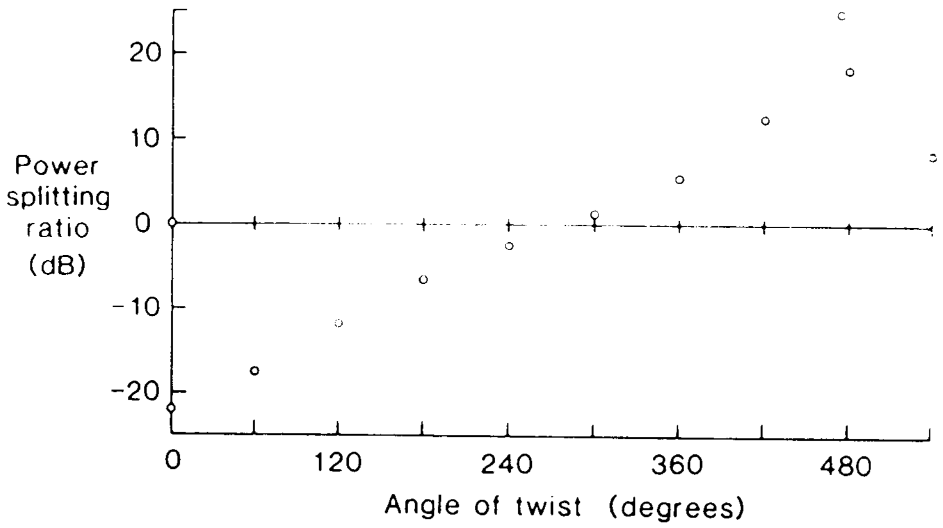

Fig. 1 : The variation of the power-splitting ratio at 870nm of a fused tapered coupler, as a function of the axial twist angle.

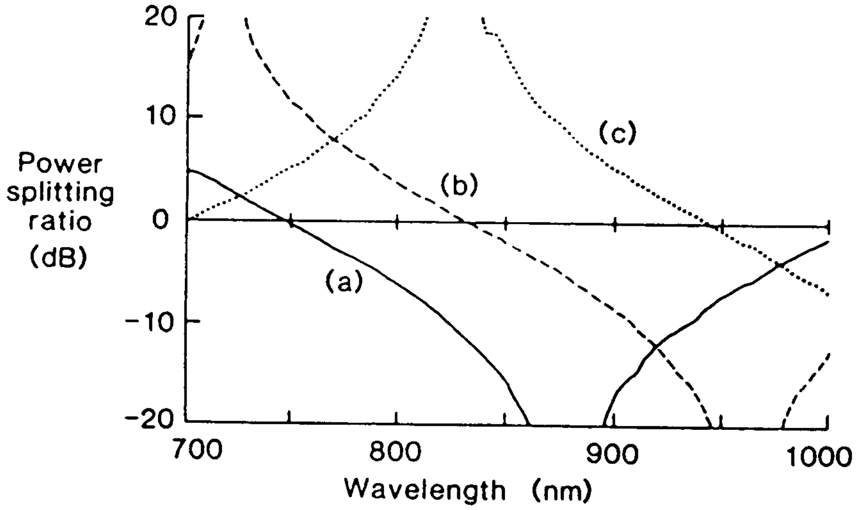

Fig. 2 : The spectral power-splitting ratio of a fused coupler under progressively increasing amounts curve a for 0°, curve b for 240° and curve c

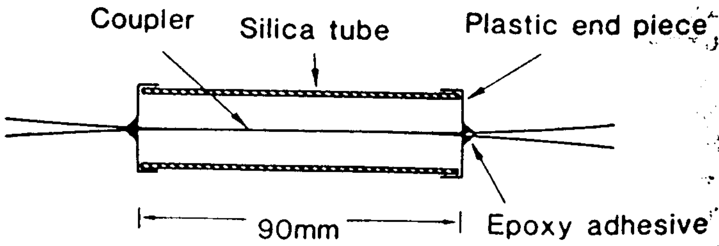

Fig. 3 : The construction of a simple tunable coupler