MEASUREMENT OF TRANSMITTED POWER IN UNTAPERED MULTIFIBRE UNIONS: OSCILLATORY SPECTRAL BEHAVIOUR

Indexing terms: Optical fibres, Optical measurement, Optical filters

In the letter we show a new structure, the untapered multifibre union, with similar oscillation behaviour to that of tapered single-mode fibres. As a consequence conical regions are not relevant to the final results. This oscillatory behaviour opens the way to low-cost all-fibre devices such as optical filters.

Introduction: As has been shown in several previous papers, biconically tapered single-mode fibres allow power transmission with a quasisinusoidal dependence on wavelength, elongation and surrounding medium refractive index.[1,2] Tapered fibres have particular advantages for sensor and wavelength filters applications[3,4] with a prescribed response. The biconic tapered structure is composed of a multimode region located between two single-mode regions[5] with conical transition zones.

Untapered multifibre unions. A subject that needs to be studied is the influence of the conical tapered zones on the transmitted power. This point is important because the repeatability of these zones depends very much on the manufacture. A structure where these regions are nonexistent, is presented in this letter. The configuration we have adopted is shown in Fig. 1. No transition regions between single-mode and multimode zones appear. This passive device has been made with just a multimode fibre (50/125 μm) spliced between two single-mode fibres (9/125 μm). Moreover, a simple connector (with a matched liquid index to avoid reflection interfaces) can be employed to couple single-mode and multimode fibres without any fusion. Both configurations have been employed by us and similar results have been obtained.

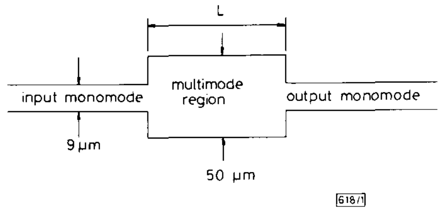

Fig. 1 *Structure of untapered multifibre union*

This structure comprises multimode region located between two single-mode regions without any transition zones. L is multimode zone length

A further difference from previous structures is the number of excited modes in the central region. At tapered fibres, this region is considered few-mode, normally two-mode.[5] Our present configuration gives a multimode region where the two-mode approximation is not correct. This structure has been called the untapered multifibre union.[6]

Large oscillations in the power transmission, obtained with abruptly tapered slopes and with our structure, have been shown to be related to the interference process[5,6] between the excites modes of the multimode zone.

Experiment: Our experimental set-up to measure wavelength transmission is composed of a white light halogen lamp source, a spectrum-analyser system which uses a Ge detector and a Michelson interferometer. The resolution is better than 1 nm. A cladding mode-stripper ensures that only the transmitted fundamental-mode power (HE_{11}) reaches the detector.

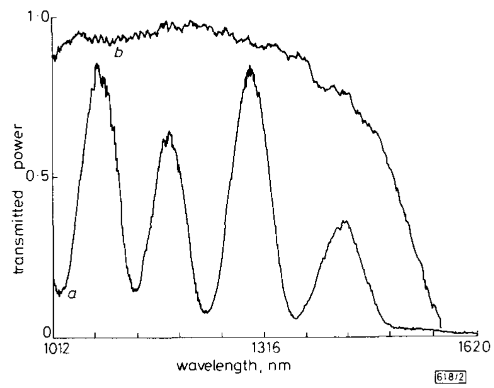

Fig. 2

a Transmitted power against wavelength for untapered multifibre union structure with $L = 3{\cdot}5$ cm
b System response

Transmitted power against wavelength is shown in Figs. 2–4, for different multimode fibre lengths L. The obtained results are for $L = 3{\cdot}5$ cm (Fig. 2*a*), $L = 12$ cm (Fig. 3*a*) and $L = 28$ cm (Fig. 4*a*). Lines *b* show the overall system response (light source, single-mode fibre and cladding mode-stripper). As can be seen, it decreases for $\lambda > 1400$ nm. In this case $\Delta\lambda_p$, defined as

$$\Delta\lambda_p = \lambda_p - \lambda_{p-1} \tag{1}$$

where λ_p, the centre wavelength of the pth peak, depends on the wavelength and is inversely proportional to L (see Table 1). The obtained behaviour shows oscillations similar to the results reported for tapered fibres,[3] but with nonperiodic oscillations. This behaviour is because our working range extends to longer wavelengths and our index difference is smaller than in previously reported work. In our case, for a given L, $\Delta\lambda_p$s increase with the wavelength. This result is similar to the one reported in a more recent paper[7] which studied the tapered-fibre interferometric wavelength response. This fact gives proof that conically tapered regions are of very little importance.

Table 1 PEAK SEPARATION FOR DIFFERENT WORKING WAVELENGTHS

Multimode zone length L	Peak separation $\Delta\lambda_p$ for working wavelength λ, μm				
	1·1	1·2	1·3	1·4	1·5
cm			nm		
3·5	—	105	115	133	—
12	30	35	40	42	54
28	13	15	19	21	23
39	9	10	12	13	14

As can be seen in Figs. 2–4, the power oscillation has a modulation indicating the existence of more than two modes. Some numerical calculations have indicated there are three principal modes carrying most of the energy. Because every pair of modes has a distinct propagation constant difference, different oscillation amplitudes are obtained.

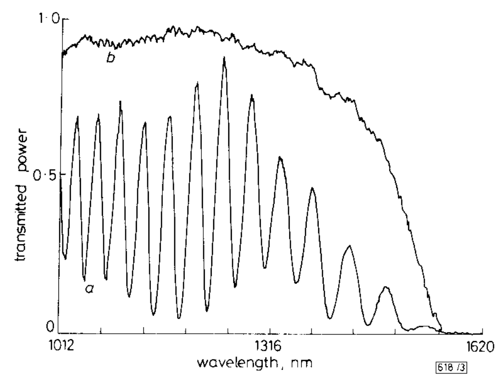

Fig. 3

a Transmitted power against wavelength for $L = 12$ cm. Peak separation $\Delta\lambda_p$ is smaller than in Fig. 2, and larger than in Fig. 4
b System response

It is interesting to note that the output power is independent of the input light polarisation.

In summary, we have shown that untapered multifibre unions have behaviour similar to tapered single-mode fibres. Hence, the previous assumption that the biconically tapered regions are of no importance to the final results is correct.

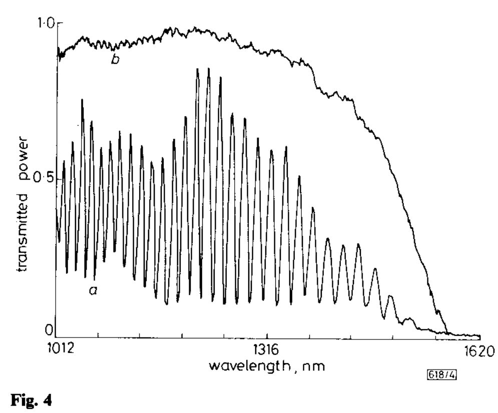

Fig. 4

a Transmitted power against wavelength for $L = 28$ cm. Peak amplitude is not constant. Modulation shown is due to more than two modes at multimode zone
b System response

Moreover, we have proposed a new structure with similar applications to tapered fibres. The advantage of our structure lies in their low cost, as a result of the simple fabrication method. The polarisation insensibility, temperature stability and very low cost offer a way to practical devices.

P. R. HORCHE
M. A. MURIEL
J. A. MARTÍN-PEREDA

Dpto. Tecnologia Fotonica
ETSI Telecomunicación
Universidad Politecnica de Madrid
28040 Madrid, Spain

13th March 1989

References

1 CASSIDY, D. T., JOHNSON, D. C., and HILL, K. O.: 'Wavelength-dependent transmission of monomode optical fibre tapers', *Appl. Opt.*, 1985, **24**, pp. 945–950
2 DE FORNEL, F., RAGDALE, C. M., and MEARS, R. J.: 'Analysis of single-mode fused tapered fibre couplers', *IEE Proc. H*, 1984, **131**, pp. 221–228
3 LACROIX, S., GONTHIER, F., and BURES, F.: 'All-fibre wavelength filters from successive biconical taper', *Opt. Lett.*, 1986, **11**, pp. 671–673
4 LAWSON, C. M., KOPERA, P. M., HSU, T. Y., and TEKIPPE, V. J.: 'In-line single-mode wavelength division multiplexer/demultiplexer', *Electron. Lett.*, 1984, **20**, pp. 963–964
5 GONTHIER, F., LAPIERRE, J., VEILLEUX, C., LACROIX, S., and BURES, J.: 'Investigation of power oscillations along tapered monomode fibres', *Appl. Opt.*, 1987, **26**, pp. 444–449
6 HORCHE, P. R., and MURIEL, M. A.: 'Spectral behaviour of untapered multi-fibre unions'. Proc. optical fibre communication conference, OFC' 89, 1989, Houston, paper number WQ11
7 LACROIX, S., GONTHIER, F., BLACK, R. J., and BURES, J.: 'Tapered-fibre interferometric wavelength response: the achromatic fringe', *Opt. Lett.*, **13**, pp. 395–397

THREE-BEAM AMPLIFICATION IN BSO CRYSTALS

Indexing terms: Optics, Holography, Optical properties of substances

It is shown that by applying the right detuning to two pump beams incident upon the BSO crystal from the same side, a third signal beam may be amplified. The maximum amplification was 12 000 for a 1 cm-thick crystal which represents the highest value ever measured in BSO. It is further shown that the amplification strongly depends on the input power of the signal beam and full amplification is achieved for a beam ratio in excess of 10^7.

There has been considerable interest in the last 15 years in the coupling of optical beams incident upon a photorefractive crystal (see e.g. Huignard *et al.*).[1] There is a 'traditional' amplification mechanism (see e.g. Kukhtarev *et al.*)[2] in which two beams are incident, and one of the beams is amplified at the expense of the other one. The power transfer is in one definite direction depending on the orientation of the crystal. It has been suggested recently[3] that another amplification mechanism exists in which the direction of power transfer is inwards, from the outer beams towards the inner beams. In particular, a weak beam, situated between the strong beams may be amplified. An experimental proof of the existence of this new amplification mechanism has been provided[4] by exciting power in a ring resonator in the presence of two pump beams. That method however, relying on external feedback, could not provide figures for the gain.

In this letter we report measurements of gain when 3 beams are incident on the crystal. The basic experimental set-up is shown in Fig. 1. Beams 1 and 2 are the pump beams with