NOVEL POLISHING TECHNIQUE FOR OPTICAL FIBRES

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Introduction

Tapers in optical fibres are very easy to implement simply by stretching the fibre in a flame with the result that tapers and taper based components had proved to be very popular. The unique cladding-mode nature of the taper makes it a very versatile element in all-fibre devices. For instance completely different fibres can be spliced together with low loss simply by tapering the splice joint. Similarly, low loss couplers can be fabricated from completely dissimilar fibres to provide wavelength flat, normal or WDM type couplers. The taper even allows for a wavelength independent y-function device to be implemented in single-mode fibres.

However, a fundamental limitation of the taper in the construction of all-fibre devices is that FIBRES WHICH DO NOT HAVE A MATCHED CLADDING CANNOT BE TAPERED WITH LOW LOSS. With the result that some of the more important fibres for telecommunications and sensors, such as the W-fibre and the Bow-Tie or elliptical cladding polarisation-maintaining fibres are ruled out as suitable candidates for taper based components.

The question then arises - can an alternative mechanism for field access be implemented for single-mode fibres which has the same facility and appeal as tapering but which can be applied to all fibre categories?

The main option which has been explored is the removal of the cladding by polishing. The fibre is fixed in an specially prepared groove in a glass block. The fibre and the block are then polished to achieve an optically flat surface extending over both the fibre and the glass block, and creating a length of exposed core or interaction length of typically 1-2mm. This polishing process is both elaborate and time consuming and treats the fibre as if it belongs in the same category as, for instance, bulk glass lenses which have to be polished in a very laborious manner.

In this paper we also propose the polishing of the fibre to achieve field access but now in such a manner that treats the fibre as a fibre! We exploit the fibres strength and its stringy characteristics in our new polishing approach. An approach which is at least as easy to implement as the taper and that we expect will find widespread use in the construction of all-fibre components, devices and sensors.

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Fibre Polishing Method

The fibre (locally stripped) is suspended under slight tension over a lubricated polishing wheel as shown in Fig. 1. The polished length can be altered by changing the contact angle of the fibre on the wheel, or by using a polishing wheel of different diameter. Under our polishing conditions, where the wheel rotates at 50-100 RPM, the tension on the fibre is approximately 0.2N and the wheel is lubricated with liquid paraffin, the radial force on the wheel from the fibre is essentially uniform over the contact length and the fibre polishes uniformly over that length. Fig. 2 shows the longitudinal profile of two polished flats on a single-mode fibre for two different contact lengths produced on a wheel of 2.5cm diameter as measured under a travelling microscope. It is found that, indeed, the polished flat is uniform except for the transitions at each end of the polished region.

On examining Fig. 2 in more detail it is found that the length of the end transition regions are the same irrespective of the overall polished length. For the 125μm diameter silica fibre used, this transition length was 2mm at each end. So that for an overall polished length of 12mm the optical interaction length would be approximately 8mm while for an overall polished length of 7mm the optical interaction length would be approximately 3mm. The abrasive wheel used was a Van Moppes IDP diamond impregnated resin polishing wheel with particle sizes of 2-6μm.

Optical Measurements

As the fibre is being polished the wheel is lubricated with a high index liquid paraffin which plays the additional role as mode stripper when the polished flat approaches the core. The measured loss of power as a function of distance from the fibre axis is shown in Fig. 3 for two different overall polished lengths. The fibre in this case was single-moded with a cutoff wavelength of 1.2μm, a core radius of 4μm and an outer diameter of 125μm. A laser diode operating at 1.3μm and a Germanium photodetector were used to monitor the loss.

To measure the polished depth the fibre was cleaved and the cross-section examined under a microscope. The curves in Fig. 3 represent an exponential "best fit" to the experimental data which are also shown. Fig. 3 provides a useful calibration, in practice, it would be the "level of interaction" or loss for a given length which would provide the deciding factor as to whether the polished depth is satisfactory for a specific application. One example of a polished flat which had been polished for 1 minute on the polishing wheel exhibited a throughput loss of 10 dB in liquid paraffin and approximately 0.4 dB with the liquid paraffin removed. The residual loss is a result of scattering due to surface imperfections. The scatter loss can be reduced by further polishing with a finer polishing paste on the wheel or by fire polishing. Other similar polished flats which had been further polished for up to five minutes on a wheel impregnated with Cerium Oxide showed surface improvement to the extent that scatter losses of less than 0.1 dB could be routinely achieved. SEM photographs of different stages of polishing will be shown at the meeting.

Advantages and Applications

The advantages of this new method over the polished block approach are:

(i) Polishing times of approximately 1-5 mins.
(ii) Polished lengths can be arbitrarily long e.g. we have repeatedly achieved a length of 3cm with a 6cm diameter wheel, with no difficulty.
(iii) The polished fibre can be further processed at high temperature yielding an added flexibility in device design.
(iv) The polished flat opens up the possibility for fused evanescent multiport elements yielding stable devices in depressed cladding fibres and in HiBi fibres as well as matched cladding fibres.

Perhaps the easiest device to implement on the polished fibre is the fibre polariser which requires only that the polished region be covered with a metal. We hope to report on some of our latest results on polarisers at the meeting.

Conclusion

In this paper we have described a new polishing process for optical fibres. We have demonstrated the process on a single-mode fibre but clearly it is also suitable for multimode fibres.

There are numerous applications of polished fibres in evanescent devices and couplers, however, our purpose here is not to present a shopping list of components but to present this new polishing approach as an additional technique for the construction of fibre devices.

We expect this new technique to complement the use of polished blocks, tapers and etching for field access in optical fibres.

References

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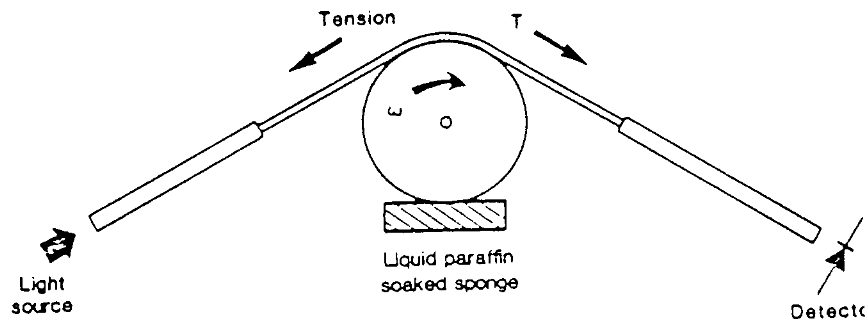

Fig. 1. Schematic of the fibre polishing arrangement.

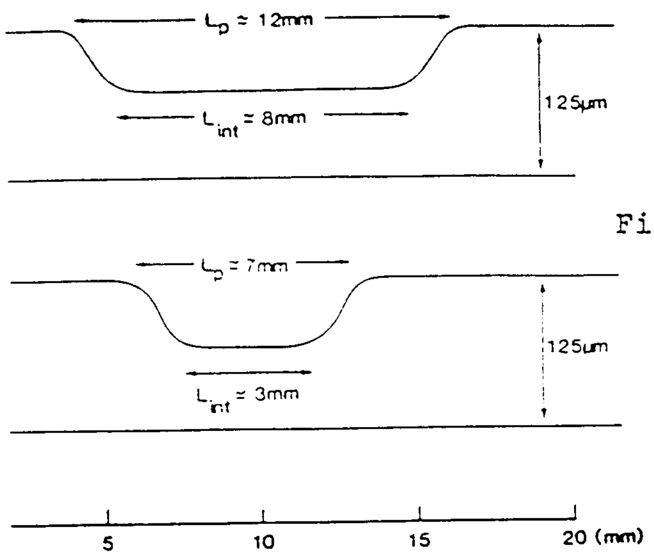

Fig. 2 Longitudinal profile for two polished flats.

a) polished length approximately 12mm.

b) polished length approximately 7mm.

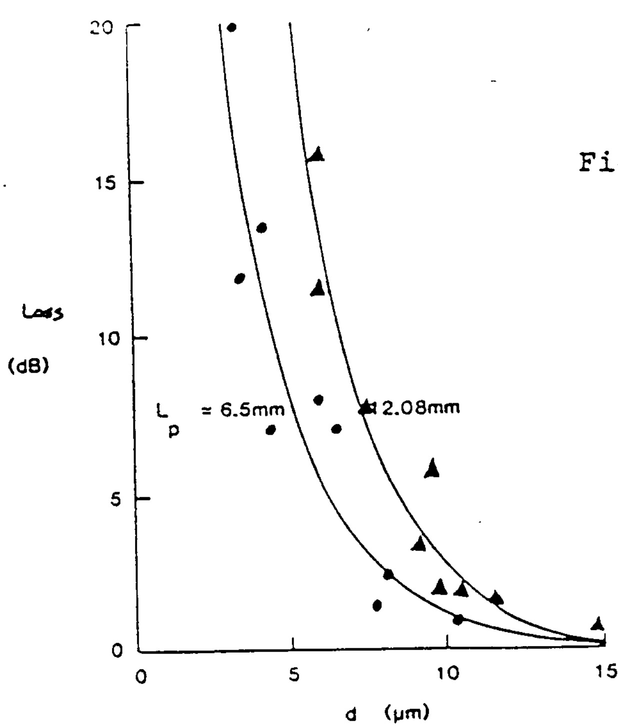

Fig. 3 Loss calibration curves (for the fibre mentioned in the text) as a function of distance from the fibre axis for two different polished lengths. Shown also are the experimental points.