HIGH-PERFORMANCE COMPOSITE METAL/GLASS FIBRE POLARISERS

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ABSTRACT

Continuous composite metal/glass single-mode fibre polarisers have been fabricated. The devices exhibit an extinction ratio greater than 48dB with an insertion loss of less than 1dB at 830nm. Moreover, an extinction ratio of more than 40dB can be obtained over a 250nm spectral window ~1300nm.

SUMMARY

Introduction: Optical-fibre polarisers are important devices for optical-communications and fibre-sensor systems. Many applications require high extinction ratios [1], together with wide polarising spectral windows. The latter has proved particularly difficult to achieve, despite its importance when LEDs are used, as in the fibre gyro, or when wavelength multiplexing is required.

Existing techniques for fabricating fibre polarisers are based either on the use of polarising fibres[2] or on the interaction between the evanescent field of the core and an external medium. In this case the core evanescent field is exposed by polishing or etching [3-6] the fibre cladding and a birefringent crystal [3] or a metal film [4,5] is used to impart a differential radiative loss or absorption to one of the fibre polarised-modes. However, the fabrication technique is time-consuming and requires considerable skill. In addition, polarisers with both a high extinction ratio and a wide spectral range have proved difficult to achieve.

We describe a fibre fabrication technique which allows continuous access to the core, as well as offering an extremely smooth polished surface close to the core. The fibre design permits the integral incorporation of a metal sector to yield continuous metal/glass composite polarisers with high performance.

Theory: The fibre cross-section is shown schematically in Fig.1. The design incorporates a hollow D-section filled with metal in close proximity to the core. The effect of the metal is to provide a large differential absorption between the x and y-polarised (pseudo TE and TM) modes. The magnitude of this absorption can be calculated by using a slab waveguide model with a metal overlay at distance d from the core. Assuming the metal to be pure gallium (complex permitivity ε=-73-43i at 830nm) and taking the first-order approximate solution [7] for the eigenvalue equation, the results shown in Fig.3 are obtained. Here the ratio of attenuations $\gamma=\alpha_y/\alpha_x$ of the y and x-polarised modes (αy,αx in dB) is plotted as a function of metal-to-core distance d for operation at 830nm. Also plotted is the insertion loss per unit length αx/L for the x-polarised (throughput) mode, where L is the fibre

length.

From Fig. 3 it can be seen that the maximum differential attenuation between x and y-polarised modes is obtained at a metal-to-core distance of ~1μm, where the insertion loss α_x/L is about 1dB/cm. The polariser extinction ratio E is given by

$$E = (\gamma - 1) \cdot \alpha_x \qquad (1)$$

For distances d of greater than 2μm, however, the ratio γ is approximately constant at ~120. Thus for a fixed insertion loss of, say, 1dB an extinction ratio of 119 dB can be theoretically obtained for a variety of values of d and L. Therefore, for the same performance, a choice can be made of fibre length by varying the distance d. For example, at d = 4μm a length of 1 metre is required to give an insertion loss of 1dB and an extinction of 119dB, while at d = 2.5μm, 10 cm is sufficient. Thus great flexibility is available; moreover, for a given fibre virtually any extinction ratio can be obtained at the expense of increased insertion loss by simply cutting the fibre to an appropriate length.

Experiment: A fibre containing a hollow-D section was fabricated by grinding and polishing a flat onto the side of a preform. The preform was then sleeved and drawn into a fibre. Gallium was pumped into the hole in the fibre in lengths of several metres, although experiments have also shown the feasibility of drawing metal/glass fibres as a unit. A typical fibre cross-section is shown in Fig 3.

A number of fibres have been made by the above technique, the parameters for two of which are given in Fig.1. It was found that the loss of the fibres was only a few dB/km before metal insertion despite the close proximity of the flat surface to the core. Surface scattering was therefore negligible, indicating an extremely-smooth surface. A further advantage of the fabrication process is that the fibres were found to be birefringent as a result of asymmetric internal stresses and ellipticity of the core. The birefringent axes are automatically aligned to the metal surface, so that the device both maintains polarisation and polarises. This is an important point if a long device is envisaged, where mode coupling due to twist and bends is inevitable.

Attenuation measurements for the x and y-polarised modes in polariser A (d~3μm) were made as a function of metal-section length using an 830nm semiconductor laser and prism polarisers. The results are shown in Fig.4, where it is seen that at a length of 10cm an extinction ratio of 48dB could be obtained for an insertion loss of less than 1dB (i.e. γ ~ 49). This is an extremely creditable result, although less than half the predicted value for γ of 120. The reasons for the discrepancy are probably associated with a very small degree of residual coupling between polarised modes. Note that for longer lengths of metal, where even higher extinction ratios are expected, the measurement was limited to 52dB.

Polariser B was fabricated for operation at ~1300nm. Spectral attenuation plots for the x and y-polarised modes were obtained using a white-light source and a double monochromator. Figure 5 shows the

results for a metal-section length of 5 cm. The extinction ratio is extremely flat over a wide spectral range, being greater than 40dB between 1350 and 1600nm. Again, this figure represents the limit of our measurement equipment. Note also that at 1200nm, where the measurement is not limited, the value of γ ~106 is improved over polariser A. Insertion loss over the whole spectral region is around 1dB.

Conclusions: Continuous lengths of composite metal/glass fibre have been made from which potentially large numbers of low-cost high-performance polarisers can be cut. The polarizers have high extinction ratios, low insertion losses and operate over a wide spectral range. The devices are rugged, temperature insensitive and can be readily spliced to conventional fibres. Moreover, the fabrication technique can be readily applied to make other exposed-field devices.

REFERENCES

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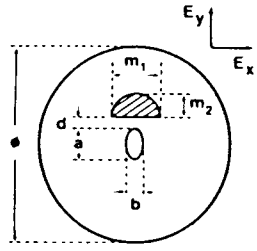
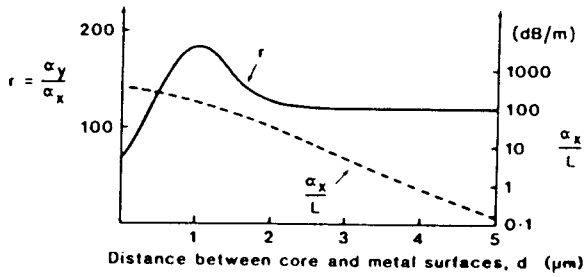
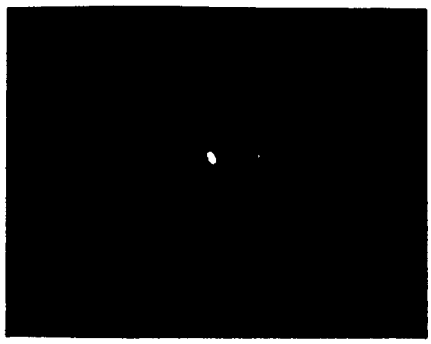


	Polarizer A	Polarizer B
NA	0.2	0.16
a/b	2	1.2
$m_1 \times m_2$	30 × 20 μm	40 × 25 μm
ϕ	120 μm	135 μm
d	3 μm	2 μm
λ_c	750 nm	1200 nm

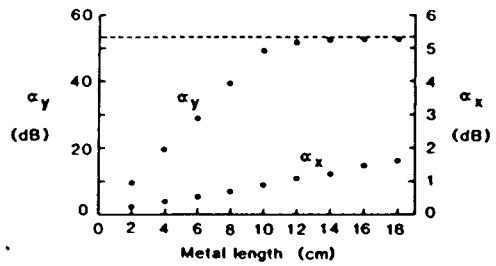
1. Composite metal/glass fibre construction.



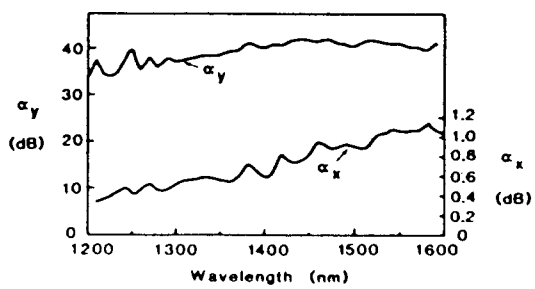
2. Calculated ratio of attenuations of x and Y-polarised modes as a function of core-to-metal distance d. Also shown is the insertion loss per unit length of the x-polarised mode.



3. Cross-section of fibre polariser showing D-section containing metal. Fibre diameter is 120μm and core-to-metal distance is 3μm.



4. Measured attenuation of x and y-polarised modes for polariser A for various lengths of the metal sector.



5. Measured spectral attenuation of x and y-polarised modes for polariser B. Metal length is 5cm.