BROADBAND METAL/GLASS SINGLE-MODE FIBRE POLARISERS

Indexing terms: Optical fibres, Polarisation, Polarisers

Continuous metal/glass fibre polarisers incorporating Ga or In/Sn alloy have been fabricated. An extinction ratio of greater than 37 dB with an insertion loss of less than 1 dB can be obtained over a 250 nm spectral window around 1300 nm. Extinction ratios as high as 52 dB have been measured at 830 nm.

Introduction: Fibre polarisers play an important role in optical fibre communication and sensor systems. Many applications require high extinction ratios[1] as well as 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.

During the last few years, several approaches[2-6] for fabricating fibre polarisers have been proposed and demonstrated. Most have been based on polishing the fibre to expose the optical field. Among these, high extinction ratios have been demonstrated using an overlay of a birefringent crystal[3] or a metal film.[6] However, the fabrication technique is time-consuming and requires considerable skill. In addition, a high extinction ratio in combination with a wide spectral range has not been reported.

In this letter we describe a fabrication technique which yields continuous lengths of polariser fibre and provides a practical low-cost solution. The technique is based on a fibre fabrication process which allows continuous access to the core optical field, as well as providing an extremely smooth, low-scatter surface at which interactions can be obtained. The fibre design permits the integral incorporation of a metal sector to yield a continuous polariser whose extinction ratio can be selected by cutting to length.

Design considerations: The glass/metal fibre polariser described here incorporates a hollow section filled with metal in close proximity to the core (Fig. 1). The effect of the metal is to provide a large differential attenuation between the x- (throughput) and y-polarised (pseudo-TE and -TM) modes.

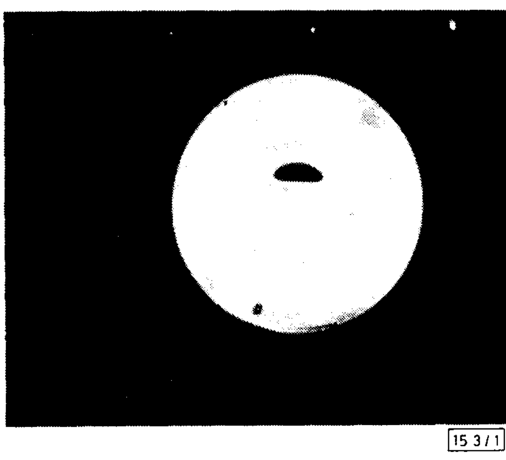

Fig. 1 *Cross-section of a metal/glass composite fibre polariser (polariser A)*

It can be shown that the attenuations α_x, α_y (in decibels) of the x- and y-polarised modes decrease exponentially as the distance d between the core and metal surface increases, provided that d is greater than a few micrometres. In this case the attenuation ratio $\gamma = \alpha_y/\alpha_x$ is approximately constant at a level which depends on the choice of metal, fibre parameters and operating wavelength, but is typically of the order of 100. Moreover, the polarisation extinction ratio $\eta = \alpha_y - \alpha_x$ (in decibels) increases linearly with the metal length, since the values of α_x and α_y are both proportional to the interaction length. It is therefore theoretically possible to design a polariser with virtually unlimited extinction ratio at the expense of increased insertion loss. This is important, since in many applications (particularly the fibre gyroscope) the extinction ratio is critical, whereas 1 or 2 dB of insertion loss is acceptable.

The fibre polariser reported here allows the extinction ratio to be chosen by simply cutting the fibre to the required length. Moreover, the fibre can be designed to provide a given extinction ratio for lengths ranging from a few centimetres to several metres by adjusting the core-to-metal distance d.

Experiments: A fibre containing a hollow D-section was first fabricated using a conventional MCVD preform with a flat ground on one side. The preform was then sleeved with a silica tube and drawn into a fibre. The cross-section of the fibre is shown in Fig. 1. A low melting point metal was melted and subsequently pumped into the hole in the fibre. Experiments have also shown the feasibility of drawing metal/glass fibres as a unit. Pure Ga (melting point 29·8°C) or an In/Sn alloy (m.p. 117°C) were used as the metallic materials. The latter provided an all-solid polariser structure with a high temperature performance adequate for most applications.

Table 1 FIBRE PARAMETERS FOR FIBRE POLARISERS A, B AND C

Fibre	NA	Fibre diameter	d	λ_c	Metal composition
		μm	μm	nm	
A	0·16	140	3	1200	In/Sn
B	0·16	140	3	1200	Ga
C	0·2	120	2·5	780	Ga

Parameter d is core-to-metal distance and λ_c is measured second-mode cutoff wavelength

A number of fibres have been made by the above technique, the parameters for three of which are given in Table 1. It was found that the loss of the as-drawn 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 slight ellipticity of the core. Since the birefringent axes are automatically aligned to the metal surface, the device both maintains polarisation and polarises.

The spectral attenuation plots for the x- and y-polarised modes were obtained for fibres A and B using a white-light source and a double monochromator. These fibres were identical but contained different metals, In/Sn alloy and Ga, with metal-section lengths of 4·8 and 5 cm, respectively. The results are shown in Fig. 2. An extinction ratio of greater than 37 dB was found for both fibres over a wide spectral window from 1300 nm to 1550 nm, this figure being the limit of our measurement equipment. The insertion losses were less than 1 dB in both cases.

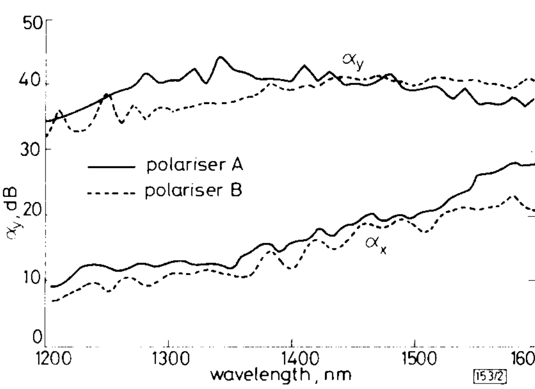

Fig. 2 *Measured spectral attenuation of x- and y-polarised modes for two polarisers*

Polariser A had a metal length of 4·8 cm and polariser B 5 cm

Attenuation measurements for the x- and y-polarised modes in polarisers A and C were made as a function of metal length, using 1·3 and 0·83 μm semiconductor lasers and prism polarisers. Care was taken to avoid mode coupling due to

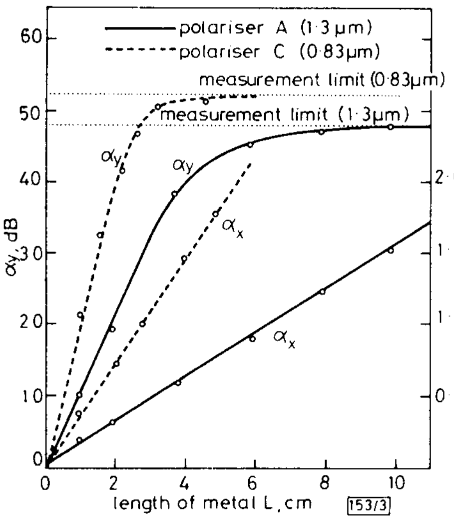

Fig. 3 *Attenuation of x- and y-polarised modes for polarisers A and C for various lengths of metal section*

Note measurement limits

twisting, bending and lateral pressure. The results are shown in Fig. 3. As expected, a linear increase in loss with length for both polarised modes was found. Polariser A reached the limit of our loss measurement capability (see curve) at a length of 7 cm (48 dB extinction), whereas polariser C required 3 cm (52 dB extinction). In both cases, insertion losses at these values of extinction ratio were around 1 dB. It is reasonable to assume that the extinction ratio continues to increase beyond our measurement limits for longer metal lengths. Taking the point where the extinction ratio is about 20 dB and the measurement is not therefore equipment-limited, the ratio $\gamma = \alpha_y/\alpha_x$ was found to be 63 and 48 for polarisers A and C, respectively. These values are somewhat less than the calculated values, presumably as a result of polarisation crosstalk.

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 device is rugged, temperature-stable, compact and can be spliced to conventional fibres. Moreover, the fabrication techniques can be readily extended to make other evanescent-field fibre devices.

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References

1 KINTER, E. C.: 'Polarisation control in optical-fibre gyroscopes', *Opt. Lett.*, 1981, **16**, pp. 154–156
2 VARNHAM, M. P., PAYNE, D. N., BIRCH, R. D., and TARBOX, E. J.: 'Single-polarisation operation of highly birefringent bow-tie optical fibres', *Electron. Lett.*, 1983, **19**, pp. 246–247
3 BERGH, R. A., LEFEVRE, H. C., and SHAW, H. J.: 'Single-mode fibre-optic polariser', *Opt. Lett.*, 1980, **5**, pp. 479–481
4 EICKHOFF, W.: 'In-line fibre-optic polariser', *Electron. Lett.*, 1980, **16**, pp. 762–764
5 HOSAKA, T., OKAMOTO, K., and MODA, J.: 'Single-mode fibre-type polariser', *IEEE J. Quantum Electron.*, 1982, **QE-18**, pp. 1569–1572
6 GRUCHMANN, D., PETERMAN, K., STANDIGEL, L., and WEIDEL, E.: 'Fibre-optic polarisers with high extinction ratio'. ECOC '83 (Elsevier Science Publishers B.V. North-Holland, 1983), pp. 305–308