7.4 LOW-COST METAL/GLASS FIBRE POLARISERS PRODUCED IN CONTINUOUS LENGTHS

Luksun Li, George Wylangowski, David Payne and Robin Birch.
Department of Electronics and Information Engineering
University of Southampton, Highfield, Southampton SO5 9NH
United Kingdom.
Telephone: (0703) 559122, Ext. 3583.

SUMMARY

Fibre polarisers are essential devices in optical fibre communication and sensor systems whenever the control of polarisation is needed. They are particularly important in fibre-gyro systems where low insertion-loss and high extinction-ratio polarisers are required[1]. A wide polarising spectral-window is another important requirement, since in many practical fibre systems broad-spectrum LEDs are used as the light source. Wide-bandwidth polarisers are also needed in wavelength-multiplexing systems.

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

We report here a new approach 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 design has been used to make metal/glass fibre polarisers in which a metal is incorporated directly into the fibre close to the core, as shown in Figure 1. The result is a high-performance metal/glass fibre polariser which can be produced in continuous lengths and whose extinction ratio can be adjusted to requirements by cutting to a given length.

The metal-section fibre polariser described here exploits the large differential attenuation between the x- and y-polarised (pseudo TE and TM) modes which can be obtained when a metal surface is placed close to the core. It can be shown that the ratio of $\gamma = \alpha_y/\alpha_x$ of the attenuations of the y- and x-(throughput) polarised modes (α_y , α_x in dB) is approximately constant provided that the distance d, between core and the metal surface is greater than a few μm. In this case the extinction ratio between the x- and y- polarised modes is given by

$$\eta = \alpha_x (\gamma - 1)$$

where

$$\alpha_x \simeq c_1 e^{-c_2 d} \cdot L$$

Here c_1 and c_2 are constants and L is the interaction length with the metal. Values of the ratio γ depend on the metal chosen.

We see that both the extinction ratio and insertion loss are proportional to the length and it is 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, extinction ratio is critical while one or two dB of insertion loss is acceptable. The fibre polariser reported here allows this choice to be made by simply cutting the fibre to the required length. Moreover, the fibre can be designed to provide a given extinction ratio for lengths of a few cm to several metres by adjusting the core to metal distance d.

The metal/glass fibre polarisers were made as follows. A fibre containing a hollow section (Fig 1) was fabricated by grinding and polishing a flat onto the side of a preform. The preform was then sleeved with a close-fitting tube and drawn into a fibre. The acrylate-coated fibre had an N.A. of ~0.16, a cut-off wavelength of ~1.25μm and the distance between core and hollow-section was ~3μm. Fibre dimensions are given in Fig.1. The fibre was then bonded to a stainless steel syringe containing a Tin (48%) Indium (52%) alloy (m.p.~ 120°C) as shown in Figure 2. The syringe and the fibre were heated to ~130°C and gas pressure of~4bar was introduced above the metal through a stainless steel tube. Filling a two metre length took about one minute. The resultant composite metal/glass fibre could be handled, cleaved and spliced in a similar manner to a conventional fibre. The extinction ratio η and insertion loss α_x of a 48cm length of polariser fibre is given in Fig.3 as a function of wavelength. An extinction ratio greater than 37dB was found over wide spectral window from 1300nm to 1600nm.

Figure 4 shows a measurement of the extinction ratio and insertion loss for various metal lengths, made using a 1.3μm semiconductor laser as the light source. The experiment was limited to a maximum measurable extinction ratio of about 50dB and for lengths greater than 6cm no accurate results could therefore be obtained. However, it is reasonable to assume that the extinction ratio continues to increase for lengths longer than 6cm. Comparison of the insertion loss and extinction ratio for lengths less than

4cm reveals an attenuation ratio γ of 63, which is a credible value for the metal alloy used.

Temperature stability measurements were carried out using a fibre with a 3.5cm metal section. The results are shown in Figure 5, and indicate that the device is temperature insensitive over wide temperature range from -40°C to 100°C. Maximum use temperature is limited to 120°C by the melting point of the alloy. Higher temperature operation can be obtained by using alternative alloys.

In conclusion, a low-loss, high extinction-ratio composite metal/glass fibre polariser has been fabricated. The device is rugged, temperature insensitive, compact and operates over a wide spectral range. Since it can be produced in continuous lengths, inexpensive high-performance fibre-polariser sections can be cut and spliced to conventional fibres. Moreover, the fabrication technique can be extended to make other evanescent-field devices.

REFERENCES

1. E.C. Kintner, Opt. Lett., 16 154-156, 1981
2. R.A. Bergh, H.C. Lefeure and H.J. Shaw, Opt. Lett., 5, 479-481, 1980.
3. D. Gruchmann, K. Peterman, L. Standigel and E. Weidel. ECOC 83, 305-308 Elsevier Science Publishers B.V. (North-Holland) 1983.

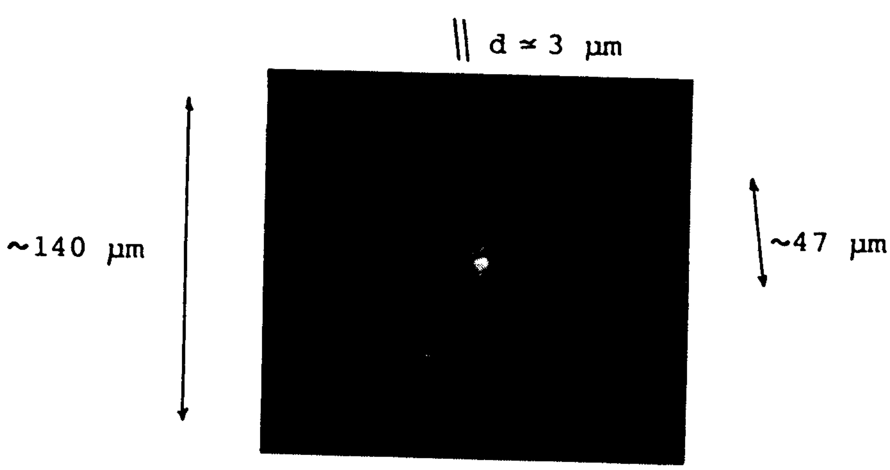

Figure 1. Cross section of a metal/glass composite fibre-polariser.

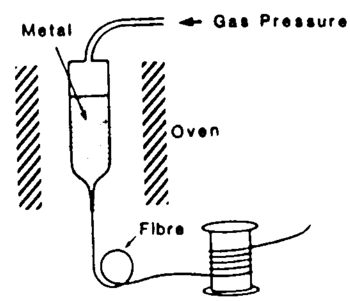

Fig. 2. Syringe pump for fibre filling.

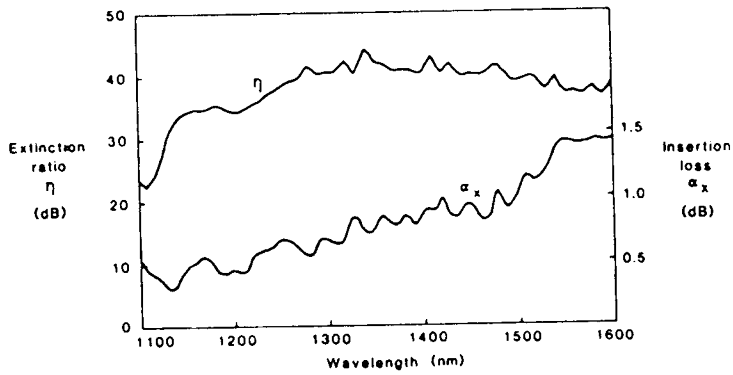

Fig. 3. Extinction ratio and insertion loss measured as a function of wavelength. The metal length is ~4.8cm.

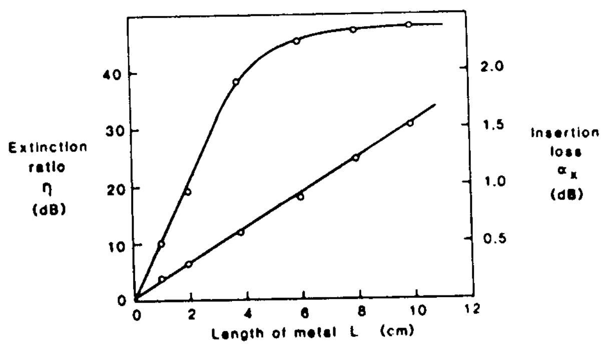

Fig. 4. Attenuation measurements at 1300nm of x- and y-polarised modes for various lengths of metal section.

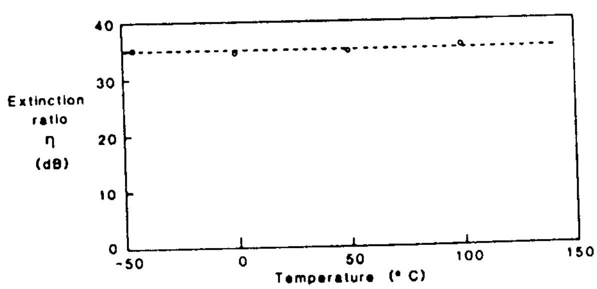

Fig. 5. Temperature stability measurement for a metal length of 3.5cm made at a wavelength of 1300nm.