HELICAL-CORE CIRCULARLY-BIREFRINGENT FIBRES

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Abstract

A new type of circularly-birefringent fibre is demonstrated based on the optical rotation which occurs in a helical core fibre. The birefringence is an order of magnitude higher than that obtained with previous fibres.

Introduction

Polarisation-maintaining fibres are well known to preserve linear polarisation. It is less well known that by making a fibre highly-circularly birefringent, it could be made to preserve circular polarisation. Highly circularly-birefringent fibres have several important applications in communication and sensor systems. Two main areas of interest are (i) as polarisation-maintaining fibres in coherent detection systems[1], and (ii) as the sensing fibre in electric-current monitors[2] and magnetic field detectors. In both cases the high circular-birefringence swamps the unwanted effects of linear birefringence caused by bending and cabling the fibre.

As in a linearly-birefringent fibre, it is necessary to have a polarisation beat length of the order of mms in order to preserve polarisation. Previously, circularly-birefringent fibres[3] have been based on the photoelastic effect, which is induced by twisting the fibre after the draw. This imparts an optical rotation $\alpha = g\xi$, where ξ is the twist rate in rads/m, and g (=0.07) is the stress-optic rotation coefficient. Therefore, fibres need sub-mm twists to obtain mm beat lengths. This is clearly impractical, since the fibre would break.

In this paper we report a new method of fabricating highly circularly-birefringent fibres which uses geometrical birefringence. The fibres are based on the optical rotation which occurs when light is constrained to follow a helical path. These fibres have already achieved optical rotation lengths $L_r = 2\pi/\alpha$ as low as 15mm, a figure which is an order of magnitude better than ever previously reported.

Theory

It is not well known[4] that when light follows an isotropic helical path, (inset Figure 1), it experiences a rotation Θ of the plane of polarisation per unit pitch P, given by:

$$\Theta = 2\pi(1 - P/S) \qquad (1)$$

where S is the arc length of the helix.

Thus, the dependence of the optical rotation length $L_r = 2\pi P/\Theta$ can be plotted versus P for different values of core offset Q. Thus from Figure 1, we would expect a fibre with P = 2mm and Q = 80μm to have a geometrically-induced optical rotation length of 78mm. Similarly, we would expect another fibre with P = 2mm and Q = 184μm to have L_r = 13mm.

Experiment

Figure 2 shows two helical-core fibres which were made with the above dimensions. These fibres were fabricated from composite rod and tube preforms, the helix being formed by spinning the preform during the fibre drawing process. This results in a torsion-free circularly-birefringent fibre, in which the spinning process averages to zero any net linear birefringences caused by core non-circularity and stresses[5]. A photograph of the helical-core fibre is shown in Figure 3, where the helical waveguiding region is clearly visible.

The optical rotation lengths were measured by launching linearly-polarised light into the fibre after preparing the fibre end as shown in Figure 4. Here the fibre has been locally heated and tapered, a process which stretches the helix and enables light to be launched into the fibre on axis. The values are plotted in Figure 1 and were found to be L_r = 90mm and 15mm respectively, in good agreement with theory. These fibres have at least an order of magnitude more circular birefringence than previously reported.

For experimental purposes, acrylate coated helical-core fibres have so far been produced in lengths of tens of metres and appear to exhibit low losses. The intrinsic radiation losses due to the curvature experienced by the helical core can be calculated from conventional bend-loss formulae[7]. For an NA of 0.2, and the above experimental parameters, we expect losses of about 10dB/km, which could be reduced by increasing the numerical aperture. These losses are in accordance with our experimental observation that the loss is already acceptable for sensor applications.

Conclusions

We have demonstrated the first geometrically-induced circularly-birefringent fibre. The design has already exhibited the highest circular birefringence reported to date. Work is now underway to produce a solid fibre with a helical core.

Acknowledgements

Thanks are due to British Aerospace plc for assisting this work.

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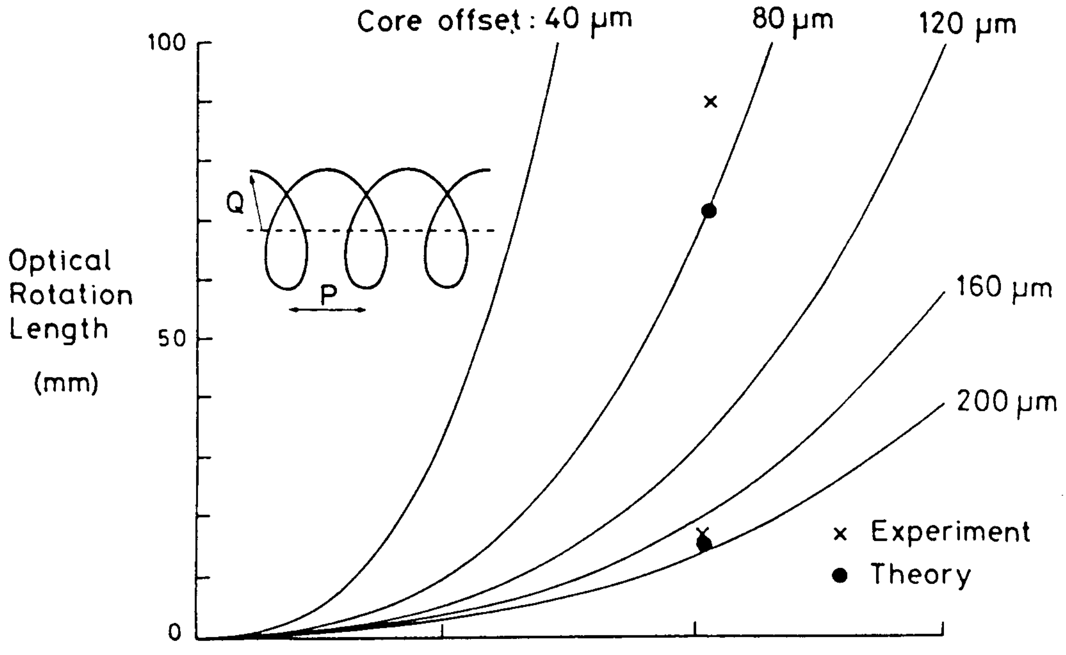

Fig.1. Optical rotation in helical-core fibres calculated for various pitch and core offsets.

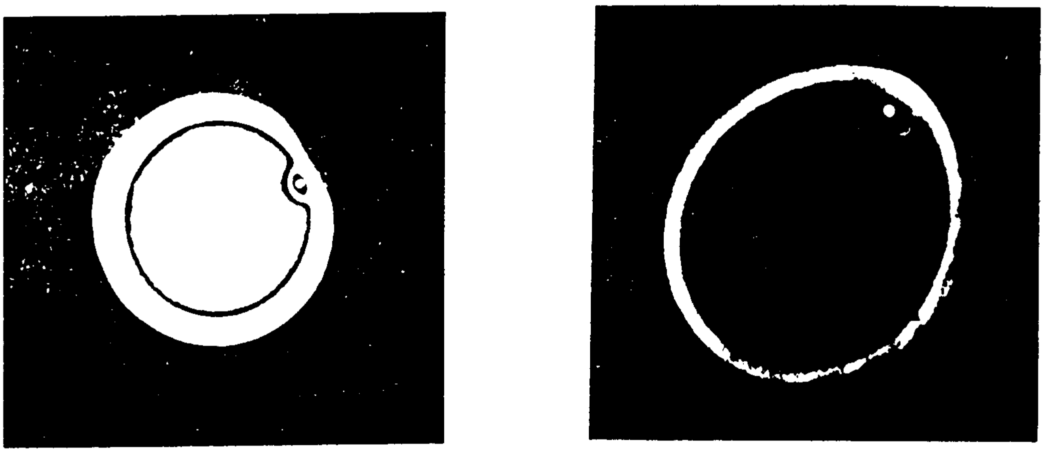

Fig.2 Helical-core fibre cross-sections showing hollow tube and core structure.

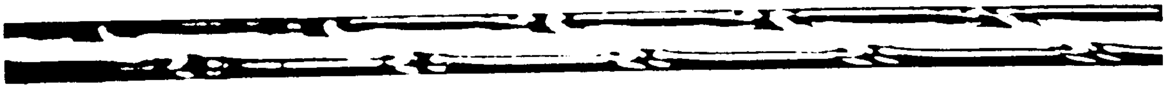

Fig.3 Transverse view of helical-core fibre.

Fig.4 Tapered fibre end to assist launching.