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DESIGN OF HELICAL-CORE CIRCULARLY-BIREFRINGENT FIBRES

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ABSTRACT

Helical-core polarisation-maintaining fibres have been fabricated with very high circular birefringence (Beat length = 4.9mm). Owing to the helical structure, the fibres exhibit single-mode propagation up to V-values of 25.

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Circularly-birefringent fibres have several important potential applications ~~in coherent detection~~ schemes and as the sensing fibre in electric-current monitors[1] and magnetic-field detectors. Recently we have reported[2] a novel fibre based on the rotation of the polarisation state which occurs when light is constrained to follow a helical path. Fibres fabricated with helical cores have already exhibited circular birefringence which is an order of magnitude higher than has been obtained previously by twisting the fibre.

We report here an improved fibre design which is both easier to manufacture and has still higher circular-birefringence. A construction which eliminates the hollow centre used previously has yielded an optical rotation length (i.e. 2 x beat length) of only 9.7 mm (modal birefringence $B = 1.31 \times 10^{-4}$), a figure which does not differ greatly from the linear birefringence found in normal polarisation-maintaining fibres. In addition, helical-core fibres exhibit a number of interesting propagation effects. For example, we show here that, as a result of the continuous bend experienced by the light, effectively single-mode propagation is possible at V-values as large as 25.

A helical-core fibre is shown schematically in Fig.1. The optical rotation length L_r is given by[2]

$$L_r = \frac{SP}{S-P} \simeq \frac{P^3}{2\pi^2 Q^2} \quad , \quad P >> Q \qquad (1)$$

where P is the pitch, S the arc length and Q the core offset. For high circular birefringence we therefore require a large core offset Q and a short pitch P. In practical designs the continuous bend radius experienced by the core is then sub- mm and care must be taken to minimise bend loss.

By using a ray argument involving the characteristic angle of a mode, it can be shown that modes propagating in a helical path have a cut-off V-value given by

$$V = \frac{U}{1 - \frac{\pi Q}{P}\left[\frac{2}{\Delta}\right]^{\frac{1}{2}}} \quad , \quad P >> Q, \quad V >> 1 \qquad (2)$$

where Δ is the core relative-index difference and the normalised propagation constant U for the second and higher-order modes takes values of 3.84, 5.14 etc, assuming V>>1. Thus in typical designs the second-mode cut-off, given by (2) with U = 3.84, is dependent on both pitch and offset and can be at a V-value which is an order of magnitude higher than in an equivalent straight fibre.This fact can be exploited to both minimise the bend loss of the HE_{11} mode and to obtain a core diameter/index difference combination much larger than usual.

A preform was assembled by inserting a 2mm diameter pre-drawn MCVD preform (Δ = 2.1%) into an off-centre hole ultrasonically drilled in a 30mm-diameter silica rod. The composite preform was spun during fibre drawing to give a helical core with an offset of 170 m and a pitch of 1.5mm. The cross-section of the fibre is shown schematically in Fig.2, while Fig.3 clearly shows the helical core. The optical rotation length L_r was measured to be 9.7mm,(i.e. a beat length of 4.9 mm) in good agreement with eqn.(1), and represents the largest circular birefringence ever reported.

In another experiment, a similar helical-core fibre was made (= 0.94%, offset 200 m) with a pitch which varied continuously from 1.5mm to several cm. The fibre had V = 25 at = 633nm, as determined from the drawing ratio required to make conventional single-mode fibre from the same preform. According to eqn.(2), the helical-core fibre should be single-moded for a pitch less than 10.8 mm. When linearly-polarised light from a He-Ne laser was launched into the fibre at the long-pitch end, several bright bands were observed along the fibre length and the output was observed to be single mode. Clearly, the fibre is multimode for large pitches and gradually supports fewer modes as the helix becomes tighter. Thus each bright band indicates where a particular mode reaches its effective cutoff. The fibre was found to be low loss and single mode for pitch lengths between 9 and 1.8mm, below which the fundamental mode became lossy. This is in good agreement with the predicted pitch of 10.8mm for the second-mode cutoff.

In conclusion, we have fabricated an all-solid helical-core fibre which exhibits very-high circular birefringence. Despite having a V-value of around 25, these fibres are able to support only the lowest-order mode.

References.

1. A.M. Smith, Appl. Opt. 17, 52 - 56, 1978.

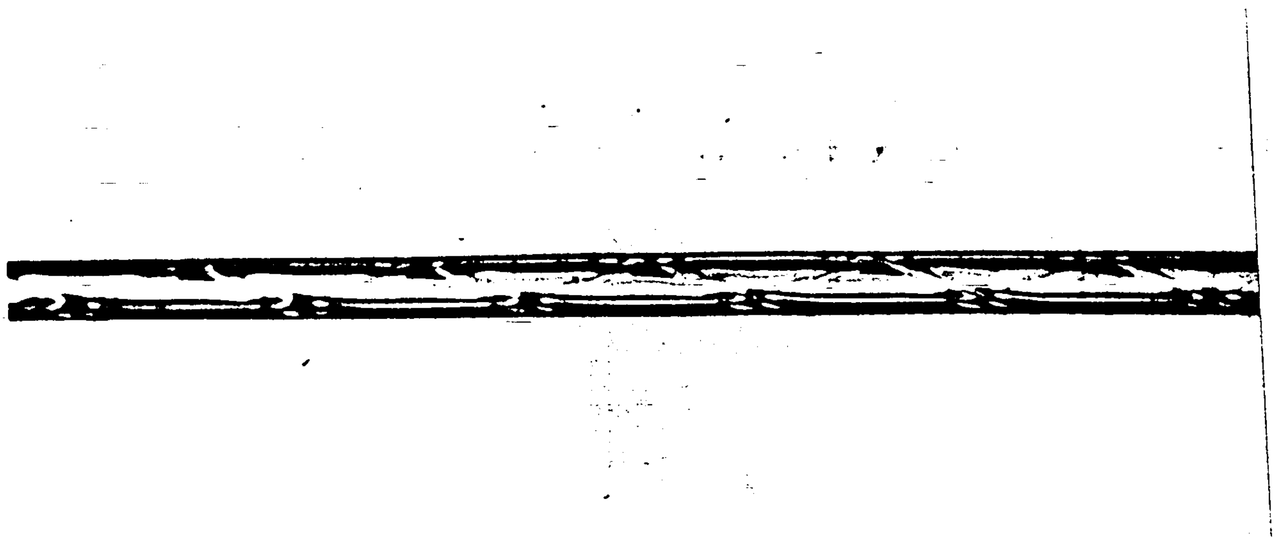
2. M.P. Varnham, R.D. Birch and D.N. Payne, IOOC - ECOC, Venice, Oct 1 - 4, 1985.

FIGURE CAPTIONS

Fig. 1. Schematic of helical-core fibre.

Fig. 2. Practical fibre structure.

Fig. 3. Transverse view of helical-core fibre.



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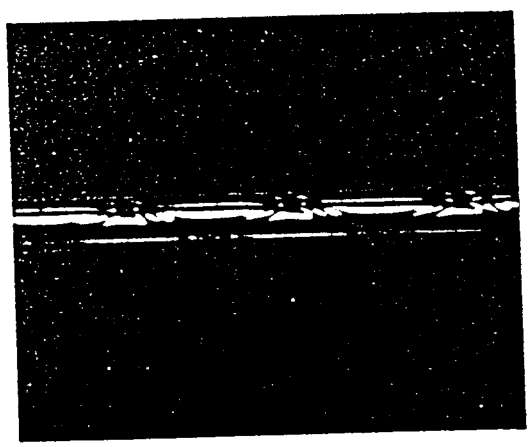

FIG 3 VARNHAM et al

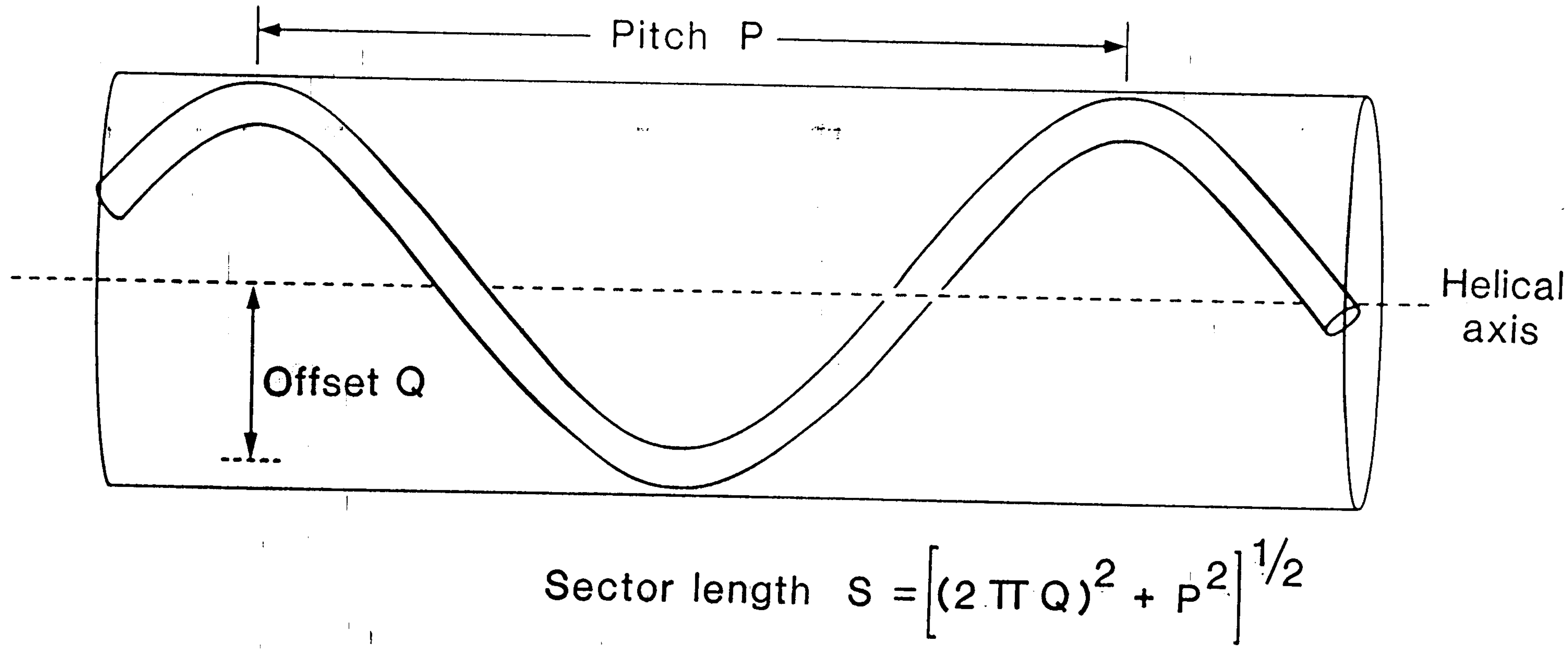

Fig 1 Varnham et al.

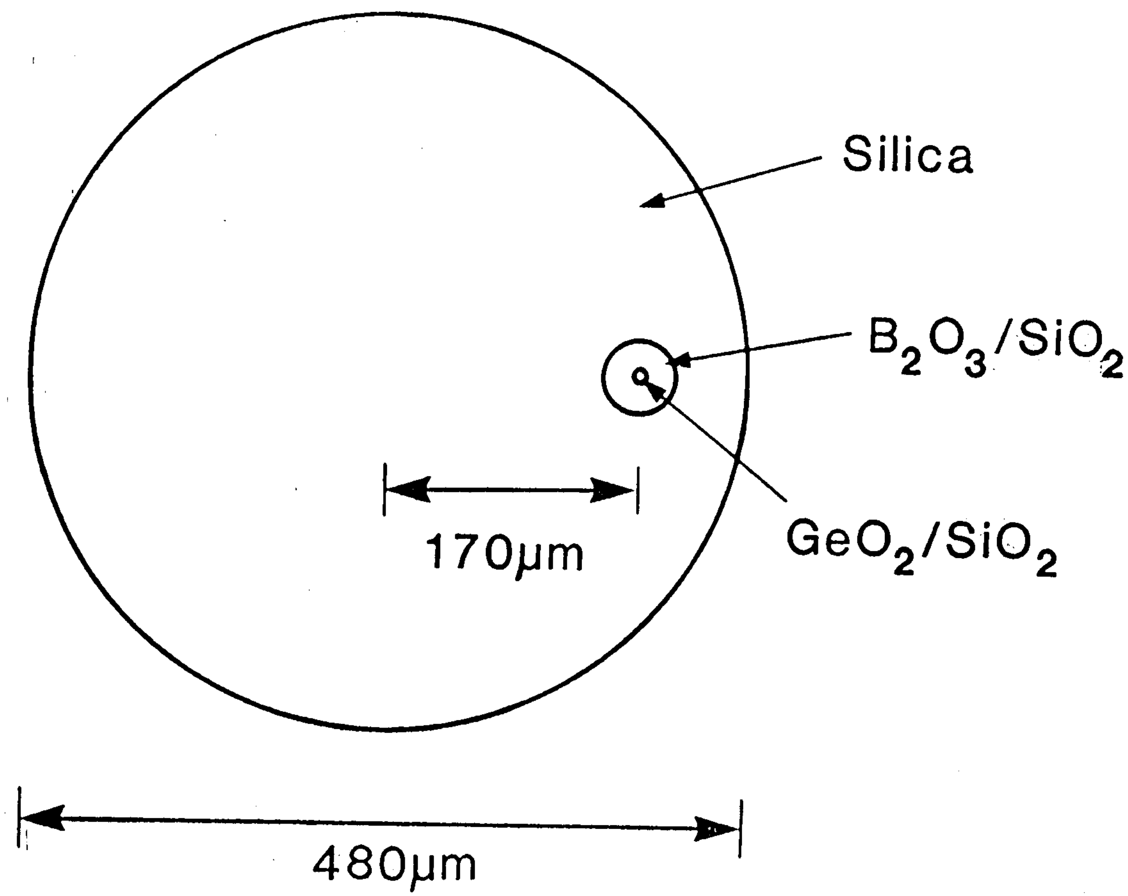

FIG 2 VARNHAM et al