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MEASUREMENTS OF FIBRE POLARISATION PROPERTIES USING A PHOTO-ELASTIC MODULATOR

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INTRODUCTION

Single-mode fibres with controlled polarisation properties are required for many fibre applications. For example, high-birefringence fibres are able to transmit linearly-polarised light, a property which is useful in interferometric fibre sensors and in coherent transmission systems. Low-birefringence fibres, on the other hand, have negligible intrinsic birefringence and are suited to conventional communications, polarisation-control devices and polarimetric sensors.

Precise measurements of fibre polarisation properties are an essential prerequisite for the development of fibres which exhibit extremes of birefringence. Conventionally, measurements are made using standard polarimetric techniques (polariser and analyser) or, in the case of very high birefringence fibres, by visual observation of the beat pattern. Neither technique is entirely satisfactory, since for low-birefringence fibres with retardations of $<10^{\circ}/m$ the sensitivity is low, whereas for high-birefringence fibres, measurements are inaccurate and are limited to the visible region.

A dramatic improvement in measurement sensitivity can be obtained by employing dynamic photoelastic modulation of the birefringence, rather than static measurement. We report here the details of the technique and its use in the development of fibres with both the highest and the lowest birefringence yet recorded. Furthermore, the sensitivity of the measurement has permitted an accurate determination of the wavelength dispersion of the stress-optic coefficient in fibres, together with its temperature dependence. These parameters are of considerable importance in the interpretation of birefringence measurements and in the design of fibre devices which employ bends or twists to achieve controlled birefringence.

MEASUREMENT TECHNIQUE

The photo-elastic modulator consists of a glass plate element vibrated at a frequency f by an acoustic transducer. The acoustic vibration sets up an oscillatory photo-elastically induced retardation in the plate. As shown in figure 1, linearly-polarised light is launched into the fibre and the output polarisation state is analysed by the combination of the photoelastic modulator and an analyser, which rotate as a unit. A demodulator provides d.c. signals proportional to the amplitude of the light-intensity modulation at frequencies f and 2f(S_1 and S_2 respectively). These relate directly to the fibre birefringence properties.

In use, a Soleil compensator (Fig.1) is adjusted to null the fibre retardation, as shown by a zero modulation component S_1 and a maximum in S_2. In this way, direct birefringence measurements are obtained with a high sensitivity. The use of the modulation permits much faster and more accurate measurements than existing polarimetric methods, and considerably less dependence on polariser extinction efficiency when measuring ultra-low birefringence values. The lowest measurable birefringence is in fact limited largely by the finite birefringence of the input lens.

RESULTS

1) Low-birefringence fibre measurements.

Ultra-low birefringence fibres can be reproducibly manufactured using the fibre spinning technique.[1] The residual birefringence present in a spun fibre is extremely small (typically <1°) and its variation with temperature is negligible. The modulator system has been used to perform several measurements which confirm the properties of these fibres. Furthermore, since the fibres are virtually polarisation transparent they can be used to perform a number of measurements of fundamental polarisation parameters without fear of interference from intrinsic birefringence. As an illustration of this and of the accuracy obtainable with the photo-elastic modulator technique, we have performed a series of measurements of the stress-optic coefficient and its dispersion in germanium-doped spun single-mode fibres. The stress-optic coefficient is of importance in several forms of fibre birefringence, such as the thermal-stress birefringence used to advantage in high-birefringence fibres[2], and the bending birefringence used in the fibre isolator[3].

The technique used is to measure the rotation of the plane of polarisation produced by twisting a vertically-hung fibre. When a fibre is twisted at a rate ξ, a stress-optic rotation $\alpha = g'\xi$ is introduced, where g' is the photo-elastic rotation constant and is directly proportional to the stress-optic coefficient C. The measured values of g' as a function of wavelength λ are shown in Fig. 2, with the computed value for pure silica shown for comparison. From the fibre curve we calculate a value of the stress-optic coefficient C(1 µm) in doped silica of $-3.23 \times 10^{-11} m^2 kg^{-1}$ and its wavelength dispersion $dC/d\lambda = 2.4 \times 10^{-15} m^2 kg^{-1} nm^{-1}$. The dispersion in C is significant and can contribute substantially to polarisation mode dispersion (∿ 10%) and to measurements of high-birefringence fibre beat length as a function of wavelength.

The variation of g' with temperature T is shown in Fig. 3 and leads to a value for dC/dT of $-4.31 \times 10^{-15} m^2 kg^{-1} K^{-1}$. This is sufficient to cause a change in fibre bending birefringence with temperature of 0.01% K^{-1}, an effect which limits the stability of fibre birefringent filters or sensor devices which use controlled bend birefringence.

2. High-birefringence fibre measurements.

The modulator technique is also useful in measurements on fibres with very high birefringence, where, for example, it can be used to determine very small changes due to temperature or aging. In Fig. 4, the variation of fibre beat-length with temperature is shown for a fibre whose birefringence resulted primarily from core ellipticity. From the slope of the curve it is evident that about 15% of the birefringence was produced by thermal stress. From measurements such as these, an understanding of the birefringence-producing mechanisms in the fibre has been obtained and this has led to the development of a fibre with a novel stress-inducing structure. Beat lengths as low as 0.6 mm at a wavelength of 0.633 µm are now regularly obtained. Measurements of the properties of these fibres, as a function of temperature and wavelength will be reported.

CONCLUSION

We have implemented a sensitive technique for birefringence measurement which uses a photo-elastic modulator. A range of measurements of fibres with extremes of birefringence have been conducted.

REFERENCES

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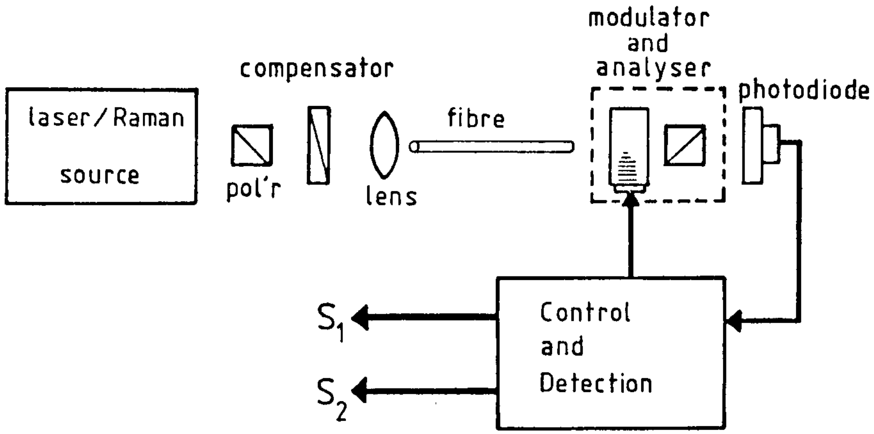

Fig. 1. Experimental arrangement

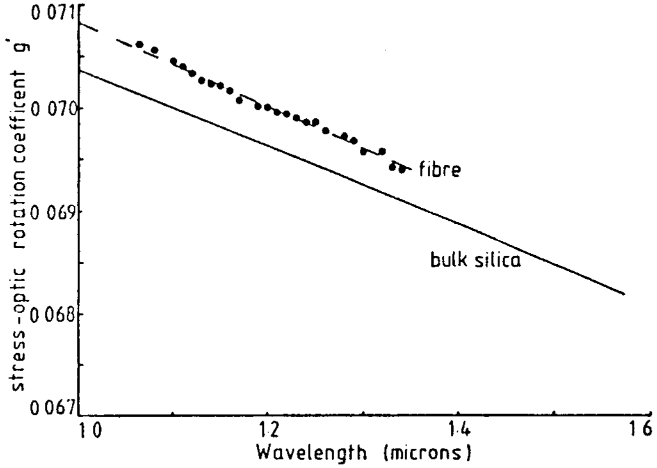

Fig. 2. Variation of stress-optic rotation coefficient with wavelength in a twisted fibre

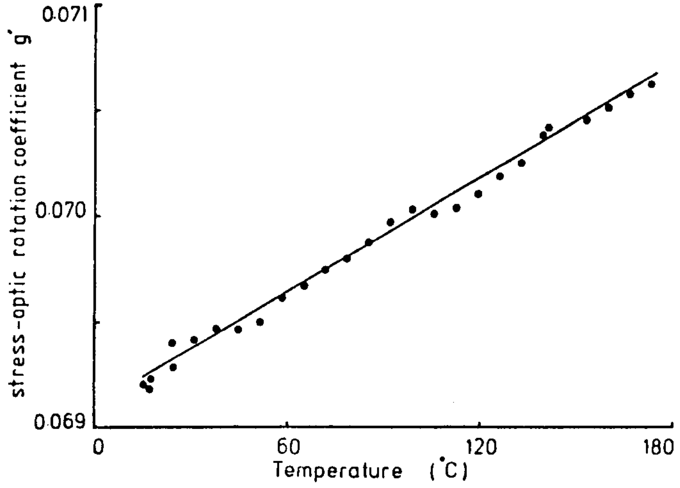

Fig. 3. Variation of stress-optic rotation coefficient with temperature in a twisted fibre

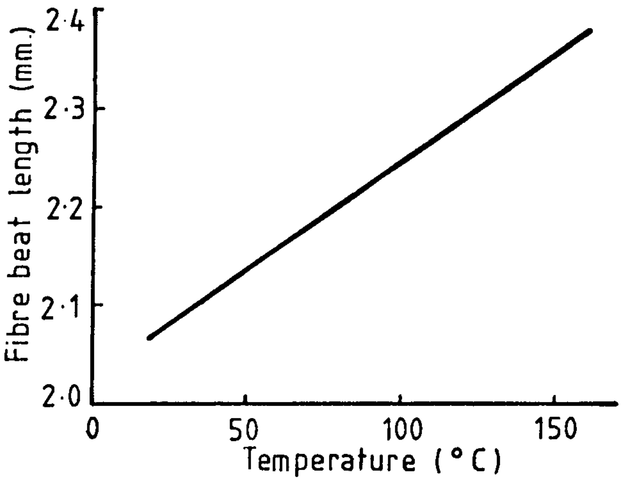

Fig. 4. Temperature dependence of polarisation beat length in a high-birefringence fibre.