POLARISATION OPTICAL TIME-DOMAIN REFLECTOMETRY: EXPERIMENTAL RESULTS AND APPLICATION TO LOSS AND BIREFRINGENCE MEASUREMENTS IN SINGLE-MODE OPTICAL FIBRES

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1. INTRODUCTION

Optical time-domain reflectometry[1,2] is now a well established means of examining the length-dependence of attenuation in multimode optical fibres. Theoretical work[3] has shown that the technique is similarly applicable to monomode fibres and experimental results have lately appeared in the literature[4]. It has recently been noted that in monomode fibres the scatter return contains additional information concerning the local state of polarisation (SOP) in the fibre, since at any point the scattered light mirrors the SOP at that position. A polarisation optical time-domain reflectometry technique (POTDR) has thus been proposed[5], in which the backscattered light is analysed by means of a polariser to reveal the variation of polarisation along a monomode fibre. Such a technique would be invaluable in the study of the properties of polarisation - maintaning fibres for sensor applications (e.g. gyroscopes, hydrophones) and of low-birefringence fibres for the Faraday Current Monitor and telecommunications. In the latter case, information could be obtained relating to the polarisation dispersion in the fibre and to the variation of the SOP with time, an effect which is expected to produce problems when interfacing to integrated-optics devices.

We present here the first measurement to be made using POTDR. Our results clearly establish the feasibility of the technique and, furthermore, show that polarisation effects can cause substantial errors in conventional backscatter attenuation measurements on monomode fibres. Consequently, care must be taken to elliminate the polarisation sensitivity of the measurement and caution exercised in the interpretation of backscatter curves.

2. EXPERIMENT

The experimental arrangement is shown in Fig. 1. An optical parametric oscillator (OPO) pumped by a dye laser produces pulses of ~200w peak power which are truncated to a duration of 10ns by an electro-optic modulator. The light is launched into the fibre via a beamsplitter, a focusing lens and a launching cell. The receiver consists of a Si APD followed by a 15MHz transimpedance amplifier. The signal is fed to a transient recorder where the complete waveform is digitised and sent to a computer for averaging and processing.

This arrangement retains the advantages of the two-channel technique[2] while reducing the measurement time by acquiring samples from many parts of the fibre simultaneously (i.e. a 'multi-channel' technique).

The characteristic feature of the POTDR experiment is the polariser placed in front of the receiver to analyse the time variation of the SOP in the backscatter trace. The analyser converts polarisation information to intensity variations; thus in a fibre having only, say, linear birefringence, the backscatter signal is expected to vary sinusoidally with a period determined by the characteristic polarisation beat length. Note also that the beamsplitter is used at near-normal incidence so that its reflectivity is almost polarisation-independent.

3. POTDR MEASUREMENTS

Measurements were made on the final 150m section of a 450m length of germano-borosilicate fibre having a cutoff wavelength of 860nm. Typical results measured at 885nm are shown in Fig. 2. POTDR traces taken with the receiving polariser parallel (upper curve) and orthogonal (middle) to the input polarisation exhibit strong and rapid fluctuations of power along the length, corresponding to the evolution of the SOP in the fibre. Note that the POTDR traces measured at orthogonal polarisations are precisely anti-correlated and thus sum to a near-constant value; the fluctuations which are observed thus correspond to variations in the polarisation of the received power and are not found in the total intensity of the backscattered light. This is confirmed by a conventional backscatter trace (lower) which was measured without the receiving polariser; the curve is almost featureless by comparison.

A detailed analysis of the POTDR returns is complex since several mechanisms contribute simultaneously to the length-dependence of the SOP. The backscattered light, does, however, contain sufficient information[5] to describe fully the polarisation retardance and rotation characteristics of a particular section of fibre. For example, it can be seen that a characteristic frequency exists in the traces which corresponds to a polarisation beat-length of 10m, a typical figure for this series of low-birefringence fibres.

4. DISTORTION OF BACKSCATTER LOSS BY POLARISATION EFFECTS

Light backscattered in single-mode fibres is almost inevitably polarised. It is therefore of utmost importance that backscatter test equipment designed for single-mode fibres should not contain polarisation-sensitive components. Insufficient attention to this point would lead to spurious features in the loss/distance curves. For example, a semitransparent beamsplitter at an angle of 45° is commonly used in backscatter experiments to separate the forward and backward-travelling light. Figure 3 shows a measurement of the same length of fibre as in Fig. 2 made in this way.

The result (upper) shows a large number of spurious features which are not real attenuation features (e.g. Fig. 2 lower curve) but which are associated with the variation of reflectivity of the beamsplitter with the SOP of the incident light. This interpretation is confirmed by the correlation which exists between these features and those of the POTDR curve (Fig. 3 lower curve).

5. CONCLUSIONS

We have demonstrated the feasibility of POTDR and have presented the first measurements using the technique. In addition to revealing the potential of POTDR for polarisation studies, our measurements show that extreme care must be exercised in interpreting conventional OTDR loss measurements on monomode fibres owing to the presence of polarisation effects.

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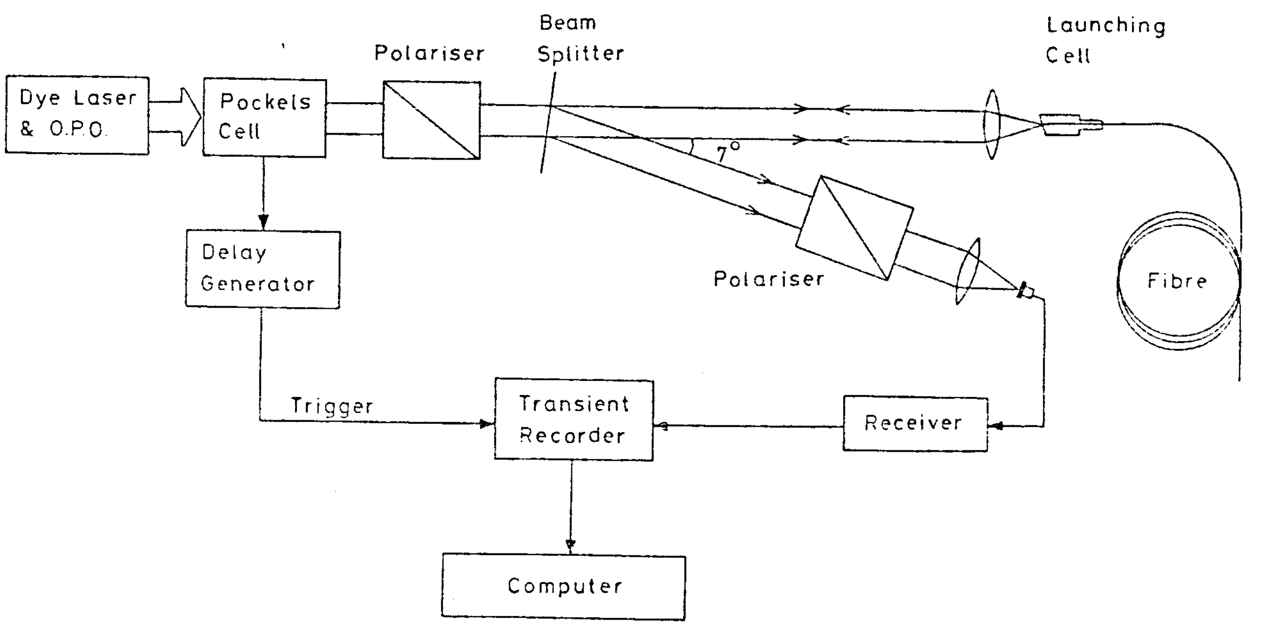

Figure 1 Experimental arrangement

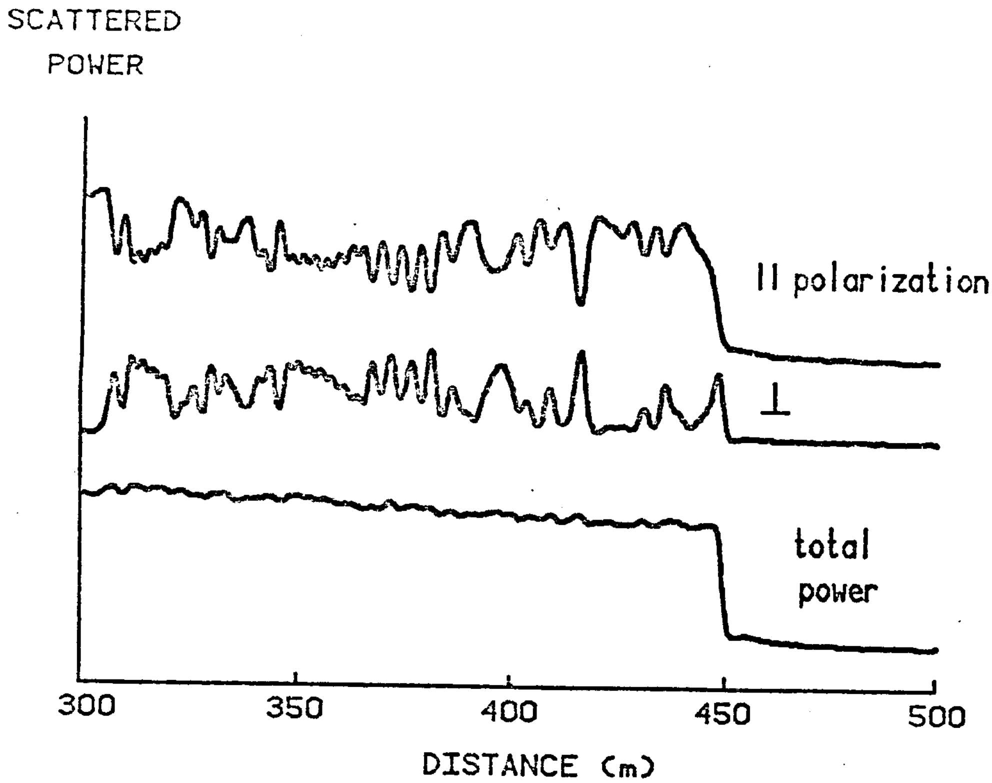

Figure 2 POTDR traces recorded with two Orthogonal orientations of the receiving polariser (upper and middle curves) and measured total scattered return (lower curve)

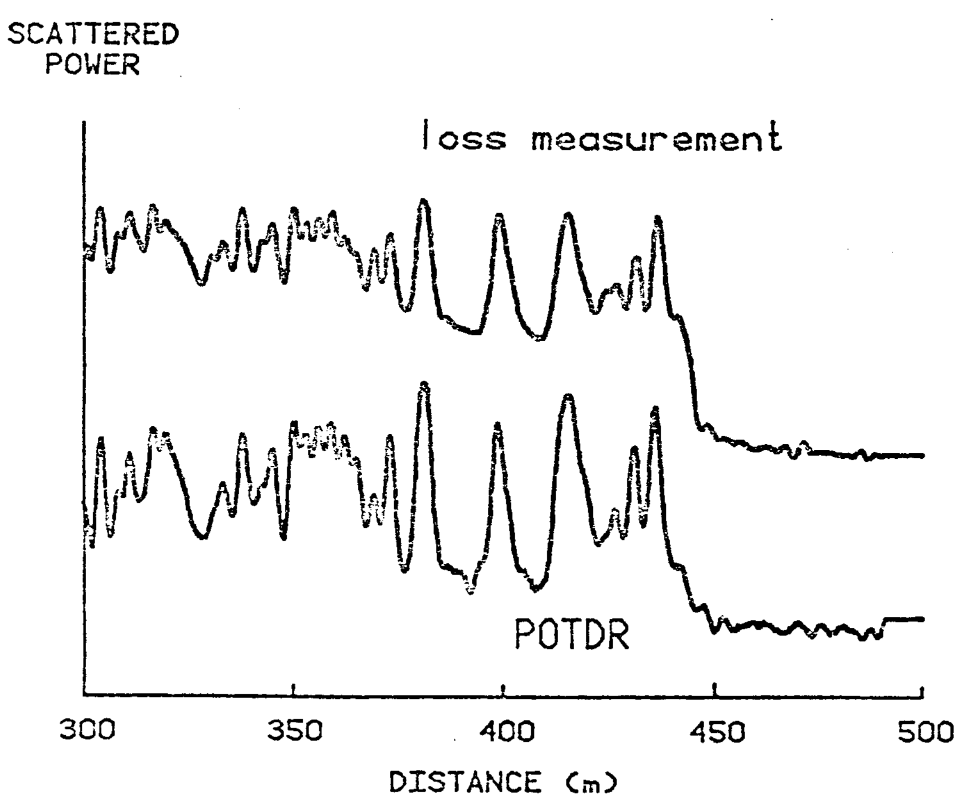

Figure 3 Effect of polarisation-sensitive components on backscatter loss measurements in monomode fibres. Upper curve: total received power, lower curve: corresponding POTDR trace.