BIREFRINGENCE CHARACTERIZATION OF FIBRES WITHOUT POLARIZER

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Abstract

Two new simple interferometric methods for birefringence measurements are described applying to either low- or high-birefringence fibres and to any kind of birefringence, the set-up being free of polarizing device.

Introduction

In actual single-mode fibres the polarisation state degeneracy of the fundamental mode is usually raised by either residual or induced anisotropies and internal stresses within the fibre. In classical transmission system birefringence gives rise to polarisation mode dispersion (PMD) and must therefore be minimized. However in coherent transmission system the polarisation state must be well defined and stationnary and this can be achieved with high-birefringence fibres. Both situations require the knowledge of the birefringence characteristics of the fibre. Many methods have been developpped for birefringence measurements using either frequency domain [1] or interferometric techniques [2,3]. All these methods involve linear polarisers and the search of birefringence axes, so that a complete measurement requires great care and time. In this paper we describe a set-up and the associated measurement techniques which allows an easy characterisation of either high- or low-birefringence fibres without any polarizing device and parallel beam optics.

Description of set-up

The set-up is an all-fibre Michelson interferometer whose one arm is a reference non-birefringent fibre, the measured fibre sample being the other arm. When white light filtered by a monochromator is launched into this interferometer and reference arm length is varied, interferences are detected within a coherence length when group delays in both arms are equal. Group delays with extreme resolution (< 2 fs) on meter-length samples were performed with this set-up [4].

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Measurement technique for high-birefringence fibres

When the fibre sample is highly birefringent interferences of each polarisation mode occur at distinct locations owing to their very different group velocity (fig 1). Polarisation mode dispersion is then simply deduced by dividing the group delay difference between the polarisation modes by sample length. Group delay spectrum of each polarisation mode can be independently measured yielding PMD as a function of wavelength (fig 2). Furthermore chromatic dispersion of each polarisation mode can be independently calculated from the same data set [5]. Neglecting wavelength dependence of PMD and thus assuming group velocities difference between polarisation modes equal to phase velocities difference, birefringence can be straightforwardly deduced from PMD.

Resolution is limited by the overlap of the fringe patterns of each mode and is given approximately by

$$\mathrm{PMD}_{\mathrm{min}} = \frac{2\,\lambda^2}{\Delta\lambda\ L\ c}$$

where λ is the wavelength, $\Delta\lambda$ the spectral width of the source and L the fibre sample length. With our set-up (λ=1300nm, $\Delta\lambda$=8nm, L=3.5m) it is therefore possible to measure PMD greater than 0.4 ps/m with an experimentally determined accuracy of 0.02 ps/m. Thus this technique may be applied only for high-birefringence fibre measurements. Nevertheless the phase relationship between polarisation modes may be measured when interference patterns overlap by using a more complex data processing technique involving non-linear numerical fits [6]. This can improve the resolution by an order of magnitude.

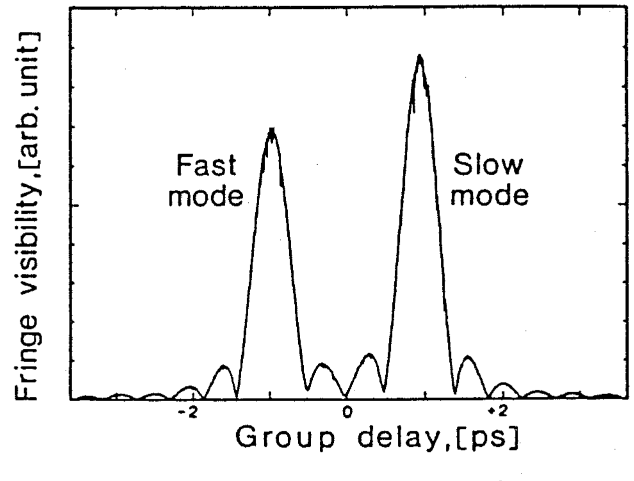

Fig.1 Direct measurement of fringe visibility of high-birefringence fibre at λ=1.3 μm.

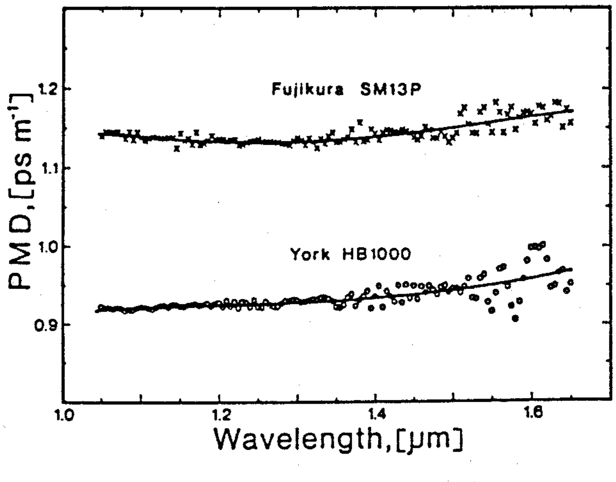

Fig.2 Polarisation mode dispersion spectra of two different high-birefringence fibres.

Measurement technique for low-birefringence fibres

Accidentally induced birefringence during manufacturing is usually too low to make distinct fringe patterns. But owing to their orthogonality polarisation modes independently interfere with their own phase shift. When their phase shifts are equal the interference signals add leaving a high overall contrast. Contrary the contrast is poor when the phase difference is π [6]. Change from in-phase to out-of-phase situation can be performed by properly changing the wavelength of the light source (fig 3). As the phase difference between polarisation modes depends linearly on wavenumber, birefringence and sample length, the interference contrast varies periodically when wavelength is scanned, the period being directly related to birefringence (fig 4). This period is easily found by performing the Fourier transform of the contrast as a function of wavenumber. Figure 4 shows the measurement of an ordinary depressed-cladding single-mode fibre with unexpected internal stresses. Calculated PMD is 0.023 ps/m and is quite greater than chromatic dispersion in ordinary fibre link (< 0.015 ps/m). Thus systematic birefringence check-up is very important although PMD effective value is probably reduced by random mode coupling.

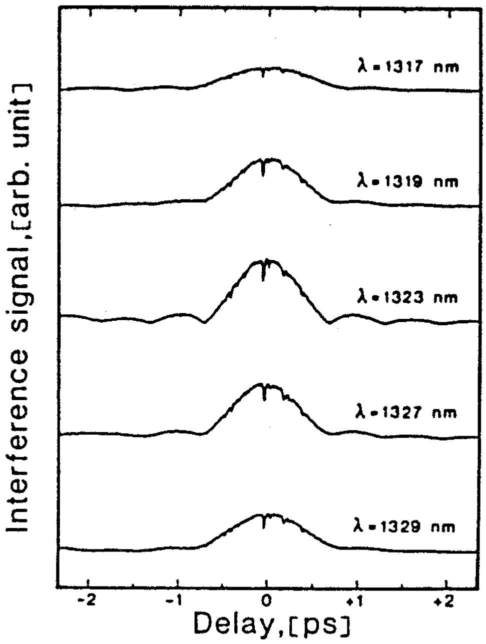

Fig.3 Direct measurement of fringe visibility of low-birefringence fibre at different wavelengths showing different contrast situations.

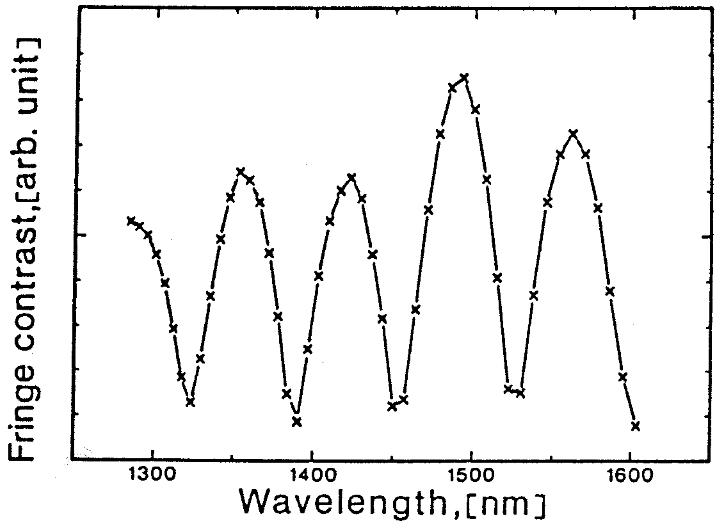

Fig.4 Contrast spectrum of a low-birefringence fibre.

Here resolution is limited by the spectral range because a full oscillation must be recorded to measure the period. Hence,

$$PMD_{min} \simeq \frac{B}{c} = \frac{\lambda_{min} \cdot \lambda_{max}}{L\ c\ (\lambda_{max} - \lambda_{min})}$$

where B is the birefringence, λ_{min}, λ_{max} are the lower and upper bounds of the investigated spectrum and L is the fibre sample length. With our set-up (λ_{min}=1100nm, λ_{max}=1700nm, L=3.5m) the resolution is 0.003 ps/m, more than two orders of magnitude better than the previous method. The drawback is the spectral dependence of PMD cannot be known but is usually approximately constant, photoelastic effects being mostly predominant.

Conclusion

Owing to the easy handling these two methods are particularly suitable for systematic birefringence characterization and check-up of fibres. Furthermore chromatic dispersion can be simultaneously measured. The light being fully unpolarized the methods apply to any kind of birefringence (linear or circular).

References

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