Distributed Fibre Analysis with cm Resolution Using Gated Flexural Acoustic Waves

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For years, the in fibre acousto-optic interaction has been developed assuming harmonic excitation of a propagating acoustic mode –either the fundamental flexural, longitudinal or torsional mode–, and exploiting the dynamical properties of the interaction by controlling the amplitude and frequency of the RF voltage used for the generation of the acoustic wave. More recently, some works have investigated the new possibilities that are enabled by using standing and pulsed acoustic waves [1]. However, the study of the in-fibre acousto-optic interaction with a time-domain distributed approach has been hardly exploited [2].

Here, we present some experimental results in which the acousto-optic interaction is excited with short acoustic wave packets, while the optical transmittance is recorded in an oscilloscope as a function of time. Thus, we are able to analyse the distributed effects along the fibre, enabling a truly time-domain distributed analysis of the in-fibre acousto-optic interaction. Figure 1(a) gives a schematic diagram of the experimental setup. In our experiments, the fundamental flexural acoustic mode of the fibre is excited by using a piezoelectric disk (PD) which couples the acoustic wave to the fibre by means of an aluminium horn. Exciting the PD with a RF burst, an acoustic wave packet is generated, which propagates along the fibre. The amplitude of the acoustic wave was measured using a fibre interferometer [3]. Figure 1(b) shows, as an example, the wave packet generated with a 20 cycles RF burst of 2 MHz. Simultaneously, the fundamental optical mode (LP_{01}) of the fibre was excited with a wavelength tunable laser diode and the LP_{01} transmittance recorded by an oscilloscope. Scanning, with the tunable laser, the resonant acousto-optic coupling between optical modes of the fibre, in our case the LP_{01}–LP_{11} coupling, different traces can be recorded in the oscilloscope as a function of wavelength. Figure 1(c) gives an example of the trace recorded for about 1 m length uniform fibre, when the wavelength of the laser matches the resonant wavelength of the LP_{01}–LP_{11} coupling. In addition to the exponential recovery of the transmittance due to the attenuation of the acoustic wave along the fibre, one can observe small fluctuations along the fibre that are produced by rather small changes of the mode propagation factors. If we assume that the fibre may have small variations of the fibre diameter, then the observed fluctuations could be correlated with submicrometric fluctuations of the fibre diameter.

In conclusion, the time-domain distributed acousto-optic interaction has, in principle, the right characteristics to implement accurate fibre characterisation of inhomogeneities along sections of fibres of about 1 m with centimetric resolution. This can be of great interest in nonlinear experiments where short sections of fibre with precise dispersion properties are required. New sensor applications can be foreseen as well.

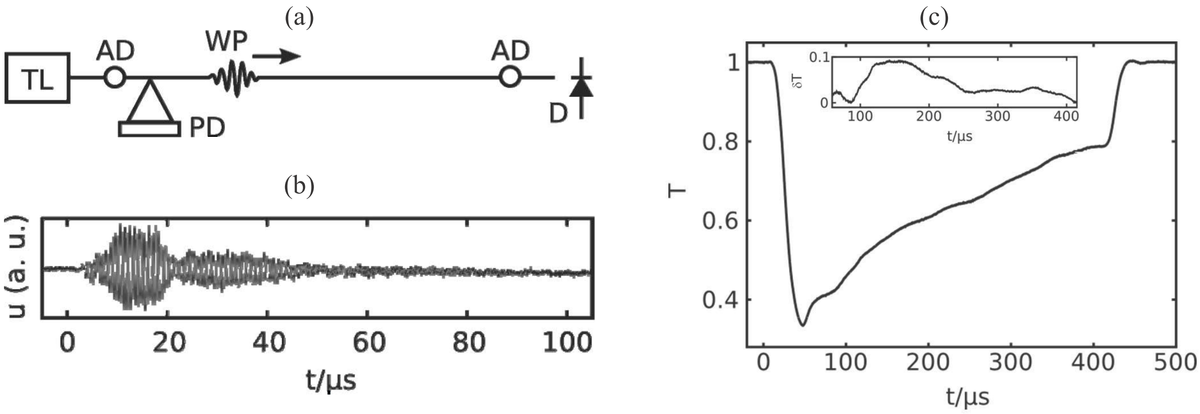

Fig. 1 (a) Schematic diagram of the experimental setup (TL: tunable laser, AD: acoustic damper, PD: piezoelectric disk, WP: acoustic wave packet, D: optical detector). (b) Acoustic wave packet generated when the PD is excited with a RF burst of 20 cycles at 2 MHz. (c) Typical transmittance trace recorded in the oscilloscope; The inset gives the transmittance variations along the fibre, once the attenuation of the acoustic wave is corrected.

References

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