Analysis of Fiber Inhomogeneity Using Time-Resolved Acousto-Optic Interaction

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Abstract: Time domain analysis of in-fiber acousto-optic interaction, using gated flexural acoustic waves, enables the analysis of fiber inhomogeneity with centimetric axial resolution. This technique permits the detection of tiny variations of the fundamental mode propagation factor along fiber sections of about 1 m. These variations can be correlated, for example, with submicrometric changes of the fiber diameter. We propose the use of this technique for an accurate characterization of dispersion fluctuations in nonlinear fibers and non-uniformities in other types of special fibers.
OCIS codes: 060.2270, 060.2400, 230.1040

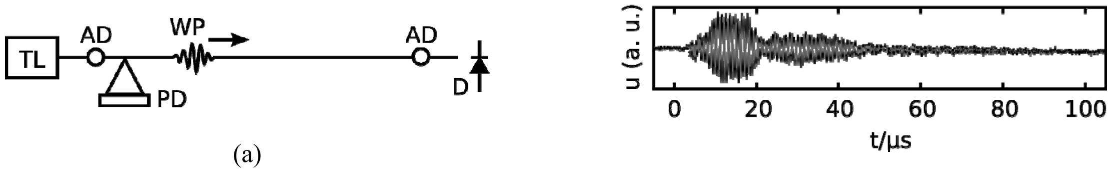
1. Introduction

Fiber inhomogeneity at the centimetric and millimetric scales is an important issue in a number of applications, including nonlinear fiber-optics and fiber gratings. In-fiber acousto-optic interaction has been developed as a technique to obtain dynamic devices in which the optical properties can be adjusted by controlling the amplitude and frequency of the RF voltage used for the generation of the acoustic wave. Most of acousto-optic devices assume the excitation of harmonic propagating acoustic waves –either the fundamental flexural, longitudinal or torsional mode. More recently some works have investigated the new possibilities that are enabled by using standing and pulsed acoustic waves [1].

The study of in-fiber acousto-optic interaction with a time-domain distributed approach has been hardly exploited [2,3]. Here, we propose the use of short acoustic wave packets in order to get information on fiber inhomogeneities through the analysis of fluctuations of the resonant coupling of optical modes, by recording in an oscilloscope the transmittance of the fundamental optical mode as a function of time. This technique provides a time-domain distributed analysis of the in-fiber acousto-optic interaction.

2. Experiments

In our experiments, the polymer coating of the fiber is removed in order to allow the acoustic wave to propagate, along lengths of about 1 m. In one end of the fiber, the fundamental flexural acoustic mode is excited by using a piezoelectric disk (PD) which couples the acoustic wave to the fiber by means of an aluminum horn. Exciting the PD with a RF burst, an acoustic wave packet is generated, which propagates along the fiber. The amplitude of the acoustic wave was measured using a fiber interferometer [4]. Figure 1 gives a schematic diagram of the experimental setup and the details of the acoustic wave packet generated with a 20 cycles RF burst of 2 MHz. The main lobe of the acoustic packet has a 10 μs width and it extends over 1.5 cm, since the phase velocity of the fundamental flexural mode is about 1500 m/s at 2 MHz.

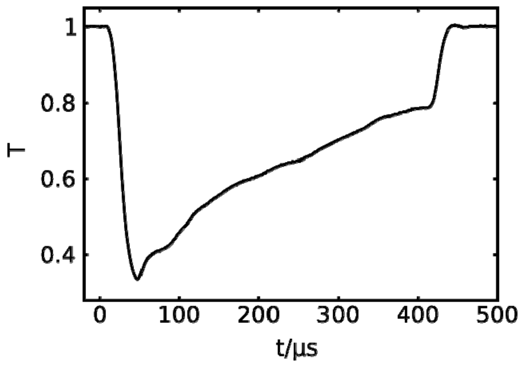


(a)

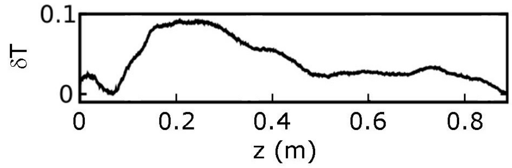
(b)

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

A tunable and linearly polarized laser diode is used to excite the fundamental optical mode (LP_{01}) of the fiber, and the transmittance is recorded by an oscilloscope while the acoustic wave packet propagates along the fiber. The resonant acousto-optic coupling between modes LP_{01} and LP_{11} could be scanned with the laser and different traces can be recorded in the oscilloscope as a function of wavelength. Figure 2 (a) gives an example of the trace recorded for about 1 m length uniform fiber, when the laser matches the resonant wavelength of the LP_{01}–LP_{11} coupling. In this trace, we can first identify the exponential recovery of the transmittance due to the attenuation of the acoustic wave along the fiber. The attenuation of the acoustic wave was also measured directly with the interferometric technique in an independent experiment. Second, one can observe small fluctuations along the fiber which could be interpreted at first as noise, but are stable and repeatable deviations produced by rather small changes of the mode propagation factors. Figure 2 (b) gives the details of the measured transmittance fluctuations along the fiber, once the attenuation of the acoustic wave has been corrected numerically. We should also mention here that the acoustic wave packet has a group velocity rather different from the phase velocity, in fact the group velocity is about twice the phase velocity. If we assume that the fiber inhomogeneity is caused by small variations of the fiber diameter, then the observed fluctuations could be correlated with submicrometric fluctuations of the fiber diameter.



(a)



(b)

Fig. 2. (a) Typical transmittance trace recorded in the oscilloscope. (b) Transmittance fluctuations along the fiber, once the attenuation of the acoustic wave is corrected.

3. Conclusions

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

References

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