MEASUREMENT OF STRESS-INDUCED MODAL BIREFRINGENCE IN FEW-MODE FIBERS

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The temperature-induced effective refractive index variation on the LP_{11} mode group of a 6-modes few-mode fiber is measured distributedly along the fiber by means of spectral correlation analysis on the fiber's Rayleigh backscattered signal.
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1. Introduction

In this work we show how to measure distributedly the impact of external perturbations on few-mode fibers (FMF) through the analysis of the fiber's Rayleigh scattering. The measured sample is a 6 mode-groups step-index FMF undergoing localized temperature variation. The scattering is acquired by means of coherent frequency-domain reflectometry [1].

2. The technique

The spectral behaviour of the Rayleigh scattering is strongly related with the propagation constant β of the signal generating it. In particular, a change $\Delta\beta$ traduces in a shift Δf of the backscattered spectrum such that

$$\frac{\Delta\beta}{\beta} = \frac{\Delta f}{f} = \frac{\Delta n}{n}$$

where f is the central frequency, n the effective refractive index and Δn the effective birefringence. Considering FMFs, we can state that, as a first approximation, the spectra backscattered by a certain fiber span $Z = [z_1, z_2]$ by two non-degenerate modes i and j differ only for a specific frequency shift $\Delta f_{i,j}$ proportional to $\Delta\beta_{i,j}$. This fact can be exploited to measure differential mode delay (DMD) along FMFs [2]. Mode dispersion makes the scattering generated in Z by modes i and j to arrive at detection with a relative delay equal to twice the DMD up to z_1, the factor of two accounting for round-trip propagation. Such delay can be recognized by setting up a reference time window $T_R = [t_1, t_2] = [2z_1/v_g, 2z_2/v_g]$, where v_g is the speed of mode i, computing its spectrum $\mathcal{F}(T_R)$, and finding the time window $T_A = [t_3, t_4]$ such that the correlation between $\mathcal{F}(T_R)$ and $\mathcal{F}(T_A)$ shows a maximum at $\Delta f_{i,j}$. The time shift between T_R and T_A, $\Delta t = t_1 - t_3$, corresponds to twice the DMD up to z_1. This technique can be exploited for the purpose of this work. In fiber sensing scenario is common to measure perturbations acting on the fiber evaluating the Rayleigh shift induced on the LP_{01} mode of a single-mode fiber [3]. This is done correlating the spectra of time (space) aligned T_R and T_A placed respectively on traces taken in the unperturbed and perturbed case. Since the correlated signatures pertain to the same mode, Δf will oscillate around $\Delta f = 0$. This concept can be extended, in principle, to any pair of modes (i,j) with few adaptations. The first is to ensure propagation of mode i in the unperturbed measure and mode j in the perturbed one. The second, owing to the need of correlating spatially-aligned windows, is to find the correct Δt for each position of T_R through the proposed technique. Finally, the frequency shift must be searched around $\Delta f_{i,j}$.

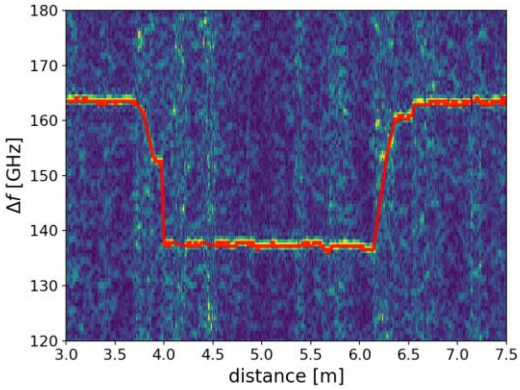

Fig 1. Results of the sample analysis

In Figure 1 the results of the analysis performed on the (LP_{01},LP_{11}) pair of a 6-modes FMF undergoing a temperature variation of 20 °C between z = 4 m and z = 6.2 m are reported. The measured Δf, leading to the induced Δn through (1) is reported on the y-axis, while the position along the fiber is reported on the x-axis.

3. Conclusions

In this work we showed an experimental characterization of the modal birefringence induced by temperature on the LP_{11} mode group of a 6-modes step-index FMF. Future developments can target other modes as well as other types of perturbation.

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References

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