Slow light propagation experiments in highly-doped erbium fibers

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Abstract: We experimentally study slow light propagation in highly-doped erbium fibers by using an amplitude modulated signal. The frequency of the maximum fractional delay shifts to smaller values when increasing ions density.

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1. Introduction

The ability to decrease the velocity of light propagation in erbium-doped fibers (EDF) is of great interest for their promising application in optical delay lines for telecommunications. It has been recently shown that both slow and fast light propagation can occur in erbium doped materials due to coherence population oscillations (CPO) [1, 2]. This phenomenon is based on the generation of a narrow hole in the absorption spectrum and it was used for first time to produce slow pulse propagation in a Ruby crystal at room temperature by Bigelow *et al.* [3]. Multifunctional integrated optical devices require very small volumes of highly doped materials. However, high ions concentration leads to undesirable effects such as quenching amplification. Our goal is to optimize the slow light propagation effect in highly-doped erbium fibers in the main optical communication window at 1.5 μm.

2. Experimental setup and results

We use a pigtailed DFB laser diode operating at 1535.82 nm with controlled power and temperature. The laser output signal is sinusoidally modulated with a small amplitude. This signal is split into two signals: one percent of the signal (reference signal) is sent directly to a photodetector while the other 99 % passes through a highly EDF connected to a second photodetector (EDF signal). The fibers used in the experiments are 1 m long and they have ions density ranging from $\rho = 1.6 \times 10^{25}$ m^{-3} (for Er20dB) to $\rho = 8.7 \times 10^{25}$ m^{-3} (for Er110dB).

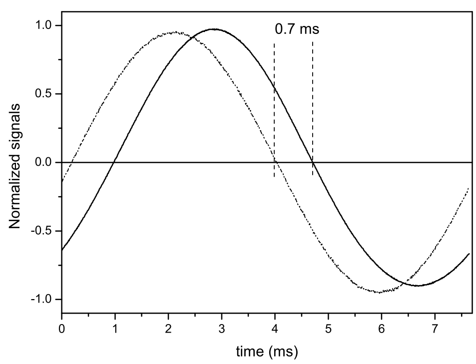

Fig. 1. Temporal evolution of the reference and EDF signals for a fiber with ions density $\rho = 6.3 \times 10^{25}$ m^{-3}. Laser power 16 mW, modulation amplitude 10%, and modulation frequency 130 Hz.

We study the delay time between the reference and the EDF signals for different modulation frequencies. As an example, Fig. 1 shows the temporal evolution of both signals averaged over 10 periods of the modulation frequency (130 Hz). A large time delay (0.7 ms) between both signals was measured for a modulation amplitude of 10%.

In Fig. 2 (on the left) we show the fractional delay as a function of the modulation frequency for fibers with different ions density: $\rho = 2.7 \times 10^{25}$ m^{-3} (Er40dB), and $\rho = 6.3 \times 10^{25}$ m^{-3} (Er80dB). As expected, higher concentrations leads to higher fractional delays although the ratio between the maximum fractional delay values is larger than the ratio of the concentrations. We also observed that the position of the maximum fractional delay moves to smaller frequencies when increasing the ions concentrations. Following the model used in ref. [2] the modulation frequency for the maximum fractional delay is proportional to both, the inverse of the metastable-level lifetime and the laser power. Higher doped fibers present stronger attenuation reducing the intensity value and therefore decreasing the frequency. On the right part of Fig. 2 we show the gain acquired by the modulation part of the EDF signal as a function of the modulation frequency. This relative gain observed for smaller modulation frequencies shows the hole in the absorption gain.

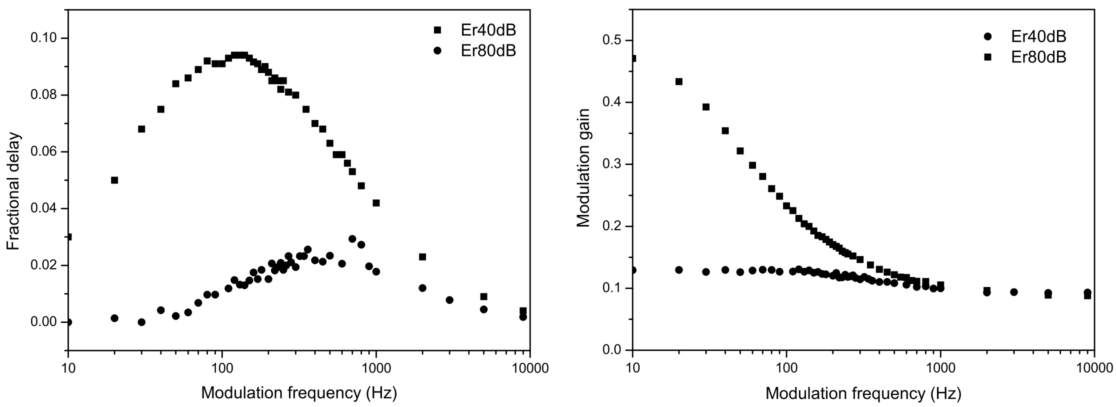

Fig. 2. Fractional delay (left) and modulation gain (right) as a function of the modulation frequency for erbium-doped fibers with different ions concentration. The laser input power (16 mW) was sinusoidally modulated with an amplitude of 10 %.

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