Fast light based on excited-state absorption in erbium-doped fibers.

Francisco Arrieta-Yáñez✉, Sonia Melle and Óscar G. Calderón.
Departamento de Óptica. Universidad Complutense de Madrid. C/ Arcos de Jalón 118, 28037 Madrid, Spain
✉Corresponding author e-mail: franarrieta@fis.ucm.es

Introduction

Coherent population oscillations (CPO) is a technique to obtain slow and fast light propagation (signal group velocities much slower or much faster than c) in various materials, such as rubi or erbium-doped fibers (EDFs) [1]. It consists on a modification of the absorption properties of a medium by modulating in intensity a light beam resonant with a transition of the medium. If CPO is performed when excited state-absorption (ESA) [2] is present, it can lead to fast light propagation without the needing of a pump beam [3].

Results

The energy levels system that describes the Er^{+3} ions is shown in figure 1 (left), where ESA is present at a wavelength near 787 nm. We can model the propagation of an intensity-modulated 787 nm beam, showing that when the ESA cross section is greater than the ground state absorption, a peak in the absorption spectrum of the modulated part of the beam appears, due to the CPO. Through the Kramers-Kronig relations it is easy to check that the index presents anomalous dispersion around the resonance frequency, and thus when the modulation frequencies fall into the absorption peak, the modulated part of the beam will propagate at superluminal velocities.
In order to observe fast light propagation in an EDF, we have modulated sinusoidally the output power of a 787 nm laser beam, and measured the the fractional advancement (the temporal advancement normalized to the modulation frequency) at the end of the fiber, as a function of the modulation frequency. The results are shown in figure 1. It can be seen, that the fractional advancement presents a maximum at a modulation frequency that corresponds to the width of the absorption peak. This technique allows us to obtain fast light in EDFs through CPO without the needing of gain in the medium, as in previous works [2]. This phenomenon was used by Bigelow et al to obtain superluminal propagation in Alexandrite [4], but we believe this is the first time that fast light without the needing of pump is achieved in EDFs.

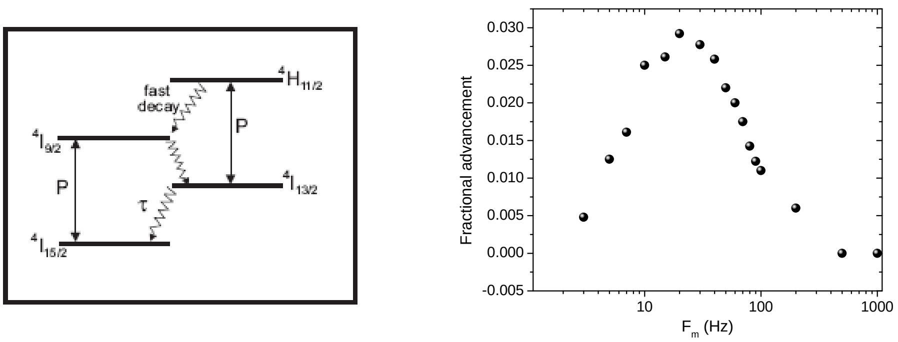

Fig. 1. Left: Er^{+3} ions energy levels, coupled by a 787 nm laser beam. Right: Fractional advancement measured for sinusoidal signals with different modulation frequencies, measured on a 1 m-long EDF with Er^{3+} ions density of $2{,}7\text{x}10^{25}$.

Acknowledgements. This work has been supported by the projects MEC-FIS2007-65382 and BSCH-UCM-GR58/08: 910133-1030. F. Arrieta-Yáñez would like to thank the financial support from the Consejería de Educación de la Comunidad de Madrid and the European Social Found.

References

[1] A. Schweinsberg, N. N. Lepeshkin, M. S. Bigelow, R. W. Boyd and S. Jarabo, "Observation of superluminal and slow light propagation in erbium-doped optical fiber", Europhys. Lett. **73**, 218-224 (2006).
[2] R. I. Laming, S. B. Poole and E. J. Tarbox, "Pump excited-state absorption in erbium-doped fibers", Opt. Lett, **13**, 1084 (1988).
[3] M. S. Bigelow, N. N. Lepeshkin and R.W. Boyd, "Superluminal and Slow Light Propagation in a Room-Temperature Solid", Science **301** p. 200-202 (2003).