Experimental investigation of a polarization attractor at telecommunication wavelengths

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Abstract

We report the experimental observation of a polarization attraction process taking place in an optical fiber around 1550 nm and based on a nonlinear interaction between two counter-propagating waves.

Introduction

Polarization sensitivity of a large number of systems, such as Nonlinear Optical Loop Mirror (NOLM) [1], coherent detection [2] or optical-fiber based transmission links [3], is a major drawback for both their implantation and their long-time stability. In this context, any device which can repolarize an arbitrarily polarized optical signal by means of a lossless and instantaneous interaction should be considered with great interest. A typical and remarkable example of such a system is the photorefractive crystal-based nonlinear polarizer reported by Heebner *et al.* in Ref [4]. In a more recent work, we have identified another type of polarizing process taking place in an optical fiber pumped by two counter-propagating beams [5]. More precisely, we have shown that a circularly polarized pump could act as a lossless polarization attractor for a signal beam propagating in the opposite direction. In this paper, we exploit these last results to design a fiber-based polarization attractor operating around 1550 nm.

Theoretical approach

Let us consider a system of two counter-propagating waves (a pump wave and a signal wave) with arbitrary polarizations injected into an isotropic optical fiber. As described in Ref. [5], the evolution of these waves can be modelled by a system of four coupled nonlinear Schrödinger equations which dynamic reveals that an attraction process can occur if the pump wave is injected with a circular polarization. Indeed, for this particular configuration, one can demonstrate that all input signal polarizations are attracted towards a unique well-defined polarization state imposed by the pump wave. This effect is illustrated in Fig. 1, where the evolution of the signal polarization is represented on the Poincaré sphere for 4 different input states (white circles). As can be seen, any input polarization converges asymptotically towards the right circular polarization state of the pump ($S_2 = 1$, white diamond).

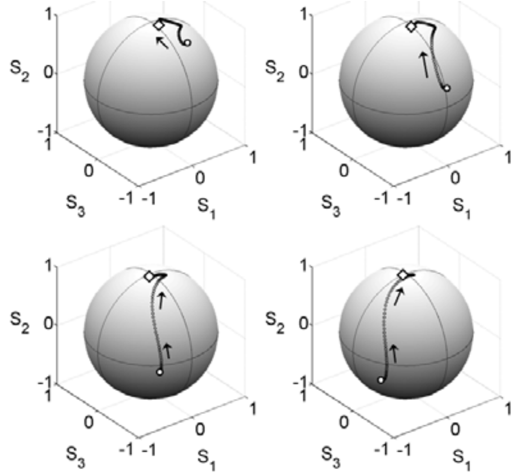

Fig. 1 : Evolution of the signal polarization state on the Poincaré sphere for four different input signal polarization states (white circles). The counter-propagating pump wave is injected with a right circular polarization ($S_2 = 1$, white diamond).

Experimental device

The experimental setup used to observe the polarization attraction process is represented in Fig.2.

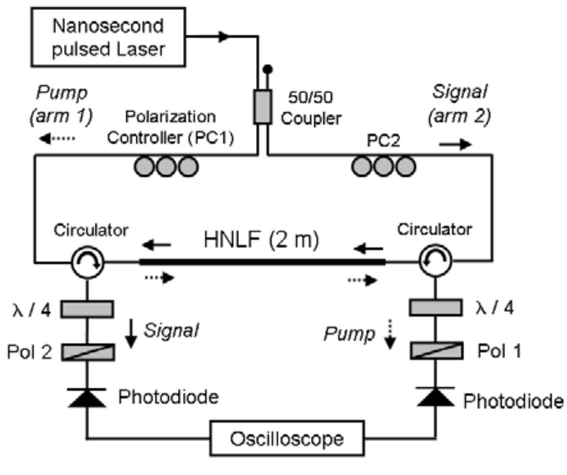

Fig. 2 : Experimental set-up

Two counter-propagating waves with identical peak powers are generated from a nanosecond laser emitting 10-ns square pulses at a repetition rate of

1 KHz around 1550 nm. The pump and signal polarizations were controlled by means of two polarization controllers (PC1 and PC2). Finally, two circulators were inserted to monitor the light emerging from a 2 m-long highly nonlinear fiber (HNLF from OFS). At one end of the fiber, the signal beam polarization was analyzed in the circular basis by means of quarter-wave plate followed by a linear polarizer (Pol 2). In order to observe the attraction process, the polarization controller PC1 was adjusted so that the pump beam propagates into the fiber with a right-circular polarization.

Experimental results

Experimental evidences of the polarization attraction effect are shown in Fig. 3. Here, we have measured at the output of the fiber the ratio of the signal energy contained in the right circular polarization component (solid line) and in the left circular polarization component (dashed line) for different input polarization states as a function of the pump power. As can be seen, all the input signal polarization states are asymptotically attracted towards the right circular polarization imposed by the pump wave. Even for the worst configurations, more than 80 % of the signal energy is repolarized towards the pump polarization state.

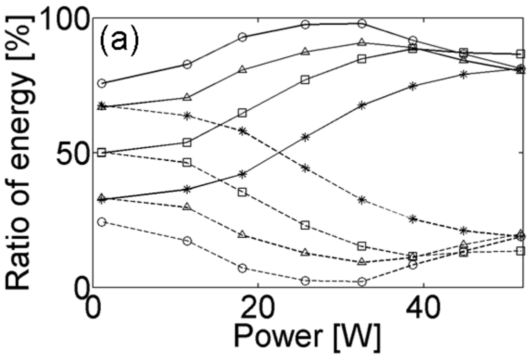

Fig. 3 : Experimental results : Evolution of the energy ratio contained in the right (solid line) and left (dashed line) circular polarization of the output signal wave as a function of the power for 4 different initial signal polarization states.

To better understand the physics of the attraction process, we have represented in Fig. 4 the pump and signal intensity profiles outcoming from the fiber ends and projected along the right circular polarization component. The signal polarization was scrambled at the input of the fiber whereas the pump wave was injected with a fixed right circular polarization at the other end of the fiber. For low pump and signal powers (1 W), and as expected in this linear propagation regime, no attraction phenomenon is observed : the output pump polarization remains constant (Fig. 4a) whereas the output signal polarization exhibits strong fluctuations due to the scrambling process (Fig. 4b).

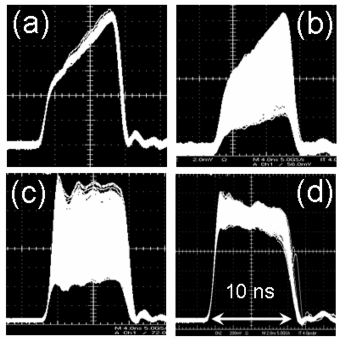

Fig. 4 : Output pump (a) and signal (b) for P = 1 W. Output pump (c) and signal (d) for P = 45 W. The signal polarization was scrambled before propagation in the optical fiber whereas the pump wave was injected with a constant right circular polarization.

When the power of both waves is increased up to *45 W*, the two counter-propagating waves interact thanks to the nonlinear polarization. An efficient signal polarization attraction effect is now observed as well as a spectacular transfer of polarization fluctuations from the signal wave (Fig. 4d) to the pump wave (Fig. 4c). The strong signal polarization fluctuations are now reduced and a quasi-constant circular polarization is obtained at the fiber output. These remarkable results have already been theoretically predicted in our previous work [5] and are confirmed by the numerical simulations presented in Fig. 5.

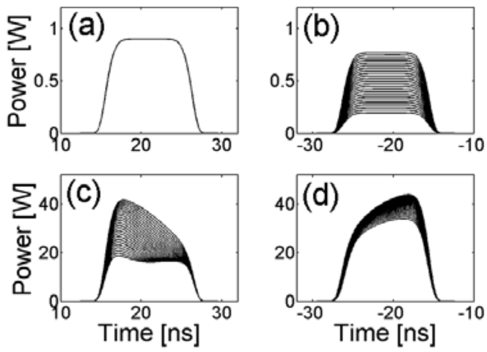

Fig. 5 : Numerical simulations corresponding to Fig. 4 : Output pump (a) and signal (b) for P = 1 W, output pump (c) and signal (d) for P = 45 W.

Conclusion

In this work, we present for the first time the experimental observation and numerical modelling of a polarization attraction process in the usual telecommunication band. This effect was observed by injecting two counter-propagating waves around 1550 nm in only 2 meters of HNLF fiber.

References

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