Polarization Insensitive NOLM employing a Faraday Rotator Mirror

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Abstract *We present a polarization insensitive NOLM, employing a FRM and non-PM fibers as the nonlinear medium. The circuit is configured to operate as a compressor and its performance remains stable irrespective of any birefringence perturbations*.

Introduction

The Nonlinear Optical Loop Mirror (NOLM) [1] has been extensively used in a diversity of optical circuits performing various functionalities [2,3]. To perform these functionalities the NOLM operates as a nonlinear interferometer imposing differential phase shifts due to Self and Cross Phase Modulation (SPM, XPM) in a length of fiber within the interferometer. However, the use of long fiber spans, affects the practical use of NOLMs, due to the intrinsic fiber birefringence, which changes temporally under the influence of external vibrations. These changes lead to random fluctuations in the State of Polarization (SOP) of the interfering signals and random variations in the switching state of the NOLM, which might be disastrous for power sensitive devices following up the interferometer. To address this problem, NOLMs assembled entirely from Polarization Maintaining (PM) components and PM fibers have been presented [4,5]. However, PM fibers with special dispersion profiles are required to form a dispersion-managed loop, raising the complexity and cost of the device.

In this article we propose a polarization insensitive NOLM, employing a Faraday Rotator Mirror (FRM) as a birefringence compensator [6-8] and non-PM fibers as the nonlinear medium. The layout consists of two parts; A PM part, which is responsible for splitting and interfering of the signals, comprising a PM coupler and a Polarization Beam Splitter and a non-PM, fiber-based part which can be appropriately chosen, depended on the application. As an example we show for the first time a stable, NOLM-based pulse compressor exploiting the interplay of SPM and GVD in non-PM, low birefringent fibers. The inherent vibration insensitivity of the circuit renders it as a promising solution for the realization of various functionalities with enhanced stability against birefringence perturbations.

Concept and Experimental Setup

The experimental setup is shown in Fig. 1. The initial pulse train was generated by a DFB laser diode at 1549.2 nm, gain switched at 2.5 GHz to provide 8.8 ps pulses after linear compression in Dispersion Compensating Fiber. The pulses were amplified in an

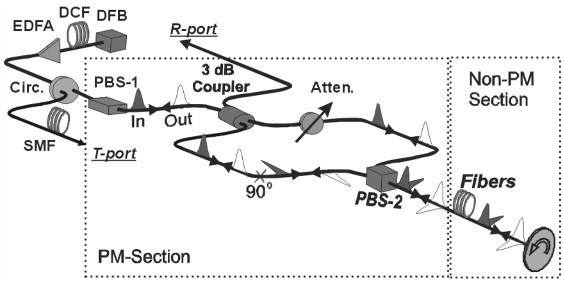

Fig.1: Principle of operation and experimental setup.

EDFA with average output power of 73 mW, passed from port 1 to port 2 of a fiber circulator and fed into a 50:50 PM coupler through the ordinary axis of a Polarization Beam Splitter (PBS-1). The output ports of the PM coupler were connected to the ordinary and extraordinary axis (via a 90^0 splice in this case), of a second Polarization Beam Splitter (PBS-2). At its common port, the two counter-propagating signals appeared with orthogonal SOPs. The unbalancing of the loop was performed by including a PM attenuator in one of the arms of the PM coupler. The attenuator was properly adjusted in order to achieve a differential phase shift of π between the two pulse components and a large frequency chirping was induced by SPM only to the signal that was not attenuated. The nonlinear medium was 9630 m of Dispersion-Shifted Fiber (DSF), with dispersion of -0.44 ps/nmkm at 1549.2 nm, A_{eff}=38 μm^2 and n_2=2.62e-20 m^2/W. The chirped pulses were successively compressed as they propagated through 270 m of Single Mode Fiber (SMF). The two pulse trains were reflected backwards by the FRM exchanged SOPs and propagated again through the same span of SMF completing the first stage of compression. The SPM phenomenon was stimulated again as the pulse trains propagated through the DSF for the second time and segregated at PBS-2. The two signals recombined at the PM coupler and the switched pulses were transmitted through PBS-1 at port 3 (T-port) of the circulator, where an additional spool of 380 m of SMF was used to compress the pulses again. The rejected pedestal appeared at the R-port of the circuit.

Experimental Results

To examine the polarization insensitivity of the layout, we have monitored the SOP of the transmitted signal

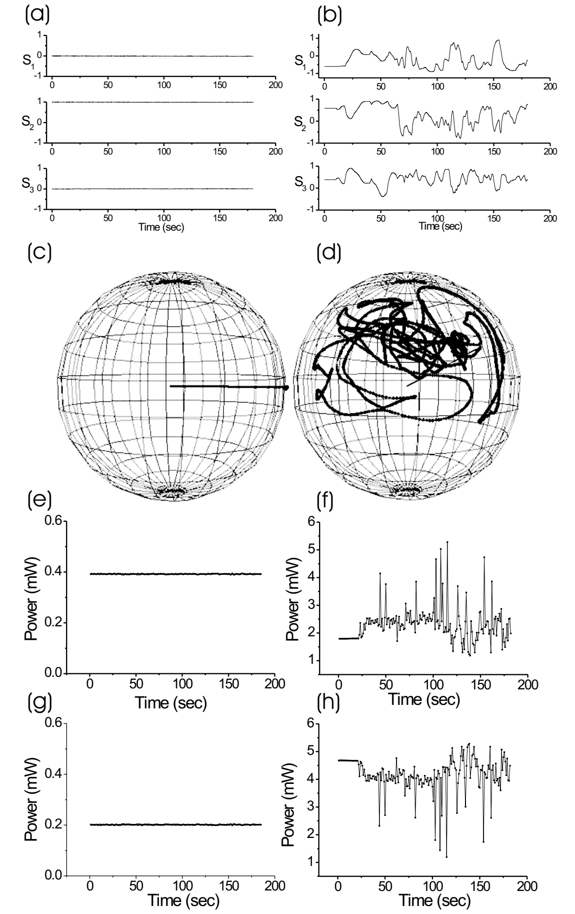

Fig.2: (a), (c) S-parameters and Poincaré sphere at T-port of proposed setup; (b), (d) corresponding graphs for conventional NOLM; (e), (f) transmitted power and (g), (h) reflected power of proposed and conventional configuration.

for the insensitive fiber compressor and compared the results with the ones recorded for a conventional NOLM compressor assembled entirely from non-PM components. These measurements were carried out with the presence of an external vibration source pointed at the non-PM set of fibers. Fig. 2(a) and (c) show the variation of the Stokes parameters and the corresponding Poincaré sphere for the proposed layout and reveal the ability of the circuit to provide a fixed SOP at its T-port irrespective of the applied perturbations. Fig. 2(b) and (d) show the same results recorded for the conventional NOLM. The random polarization changes are obvious due to the mismatch of the SOPs of the two interfering signals, which is caused under the influence of the perturbation source. To test the power clamping property of the circuit we have also measured the variation of the transmitted and reflected power for both schemes. Fig. 2(e) shows that the transmitted power is kept almost constant for the proposed scheme, whereas Fig. 2(f) shows that under the same conditions significant power fluctuations take place at the T-port of the conventional NOLM. Fig. 2(g) and (h) illustrate the

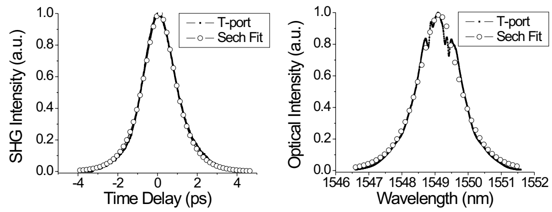

Fig.3: Autocorrelation trace and optical spectrum of the transmitted pulses and corresponding sech fitting.

corresponding reflected power and verify the power stability of the proposed circuit and the power exchange between the two output ports of the conventional NOLM. Both the polarization and power measurements were conducted for a time duration of three minutes and the sampling rate was one sample per second.

Fig. 3 presents the autocorrelation trace of the transmitted pulses and the corresponding optical spectrum. Pedestal free and almost transform limited pulses were formed at the output of the proposed layout. Assuming a hyperbolic secant profile, the transmitted pulses have a temporal and spectral width of 1.85 ps and 1.44 nm, corresponding to a time bandwidth product of 0.333, very close to the theoretically expected value of 0.3148. The sech shape of the transmitted pulses can also be verified by the ideal sech fit provided for both the autocorrelation trace and the optical spectrum. The inherent stability of the circuit allows for increased number of fiber spans in the compression stage to achieve even higher compression factors without affecting the stability of the compressor.

Conclusions

In conclusion, we have presented a simple technique to drastically reduce the susceptibility of fiber based NOLMs to environmental perturbations, which relies on employing a FRM as a birefringence compensator. To demonstrate the vibration insensitivity we have presented a highly stable, NOLM-based pulse compressor employing non-PM fibers in the compression stages. The generic design and topology of the proposed scheme makes it suitable for implementing a variety of functionalities.

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