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Characterization of polarization-imbalanced nonlinear loop mirror with input soliton pulses

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Abstract

In this work we presented a simulation of the imbalanced-polarization non-linear loop mirror (NOLM) using a symmetrical coupler with a 50/50 ratio. Our aim of work is to find the soliton pulses in the output of the NOLM. A soliton is a pulse that maintains its shape while traveling at a constant speed. Solitons are caused by a compensation of nonlinear and dispersive effects in the medium. These kinds of pulses are important for many applications. The results showed that for the input powers of 650 W and 970 W for 200 m of fiber length in clock-wise (CW) and counter clock-wise (CCW) directions respectively soliton pulses were obtained. We selected 800 W, as input power (peak power) for both directions (CW, CCW) to get soliton pulses at the output of the NOLM. With this power we obtained the spectra for different of fiber lengths; from 20 m to 1000 m. As a result for shorter length of fiber fewer fluctuations were obtained than the longer length. Furthermore for the shorter fiber length output spectrum were narrower than the longer fiber. Finally the transmission was less than 60% for longer fiber and around 90% for the shorter fiber.

Nolm, Soliton, Imbalanced Polarization

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Introduction

The nonlinear optical loop mirror (NOLM) which is identified as Sagnac interferometer, firstly presented by Doran and Wood (Doran & Wood, 1988), that has been typically used in many important applications, such as optical processing and optical switching (Boscolo, Turitsyn, & Blow, 2008), wavelength demultiplexing (Sotobayashi, Sawaguchi, Koyamada, & Chujo, 2002), passive mode-locking (Duling, 1991), pedestal suppression and pulse compression (Pelusi, Matsui, & Suzuki, 1999), and regeneration of ultrafast data streams (Pelusi et al., 1999). In fact, the NOLM involves a coupler that output ports are linked by a fiber. For operation of NOLM it is necessary to reach the nonlinear phase shift between counter-propagating beams inside the fiber loop. There are several techniques to achieve this.

One is creating imbalanced power by using an asymmetrical coupler. Other is imbalanced dispersion using different special fibers inside in the loop. Furthermore there is imbalanced polarization by using symmetrical coupler and a quarter wave retarder (QWR) inside the loop of the NOLM (Armas-Rivera et al., 2016). This technique has many benefits compare to the other two techniques that we mentioned above. (Finlayson, Nayar, & Doran, 1992) and (Ibarra-Escamilla et al., 2006). The advantages of this are that low-power transmission depends on the angle of the QWR and it can be adjusted in the range between 0 and 0.5 by rotation the QWR. In ordre to operate the imbalanced polarization NOLM, we used at the input circular polarization pulses; in this case, clock wise direction (CW) of propagation in the loop has a circular polarization while the counter clock wise direction (CCW) has a linear polarization after passing the QWR.

Linearly polarized light accumulates a nonlinear phase shift which is 1.5 times larger than the circularly polarized light (Pottiez, Kuzin, Ibarra-Escamilla, & Mendez-Martinez, 2005). Furthermore, by using a rotation of QWR, the nonlinear transmission can be adjuted (Agrawal, 2001).

An optical soliton is a pulse that propagates inside the fiber without alteration, due to balance between nonlinear and dispersive effect (Blair, 1998). This is generated by a nonlinear phenomenon caused by self-phase modulation (SPM), which means that the electric field of the wave changes the index of refraction of fiber and the group velocity dispersion (Wiora, Weber, & Chanbai, 2013). The soliton pulse is important for different applications such as all-optical switching (Nishizawa & Goto, 2002). The minimum time-bandwidth product for a soliton is ≈ 0.315 for sech^2-shaped pulses and ≈ 0.44 for Gaussian-shaped pulses (Kivshar & Agrawal, 2003). This means that for a given spectral width, there is a lower limit for the pulse duration.

In the present work we simulate the imbalanced polarization NOLM by using a 50/50 coupler, and fiber squeezer as QWR. Moreover, a circular polarization soliton pulses considered as the input of the NOLM. In order to obtain soliton pulses at the output of the NOLM, we used 800 W as the input power peak. Moreover the study of different length of fibers shows different nonlinear transmission. In other words for longer length of fibers 200 m , the first maximum transmission was for 250 W as an input power with 60% of transmission with time band-width product of 0.28. For shorter of fiber length 20 m the maximum transmission was around 700 W as an input power with 90% of the transmission, with a time band-width product of 0.2.

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Experimental Setup

The experimental setup of imbalanced-polarization NOLM that we used in the

Simulation is shown in Fig. 1. It consists of a symmetrical coupler with a 50/50 coupling ratio and fiber squeezer as QWR. For the moment in our simulation QWR is compsed of θ=0 for high transmission and high power and low transmission for low power, respectively. We used the second hyperbolic pulses with time duration of 0.4 ps and 1550 nm central wavelength as input signal. With this input pulse property we start to study and find the soliton pulses at the output. In order to obtain this we check the pulse performed as a soliton in CW and CCW directions respectively. At first, we consider the traveling of light inside the loop in CW direction passing through the QWR which converting the input polarization from circular to linear and it continues until it reaches to the output of NOLM. For the CCW direction the simulation procedure was similar to CW direction. The difference is CW direction the distance between the QWR and the input coupler is very short. It does mean that the intensity is 2/3 times less than the CW direction. With this difference we can produce the nonlinear phase shift. In our imbalanced polarization NOLM, different of fiber length inside de loop and different inputs power were considered. Moreover it is shown that the use of the symmetrical coupler allows very low transmission for low power.

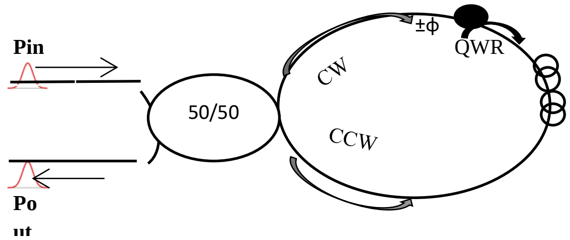

Figure 1: Experimental Setup

Results and discussion

In figures 2a and 2b are shown the input soliton pulse (blue line), the output soliton pulse (red line) and and the soliton pulse traveling in CW and CCW directions (black-line) for 200 m of fiber length and for input power of 650W and 970 W respectively. The results show that for CW direction the pulse duration is the same as input pulse soliton. However the output pulse shows a little broadening, it does mean that 650 W as an input power is not enough. Furthermore the results using 970 W as an input power shows that this power is more than power that need for soliton pulses because the pulse of output and CCW directions are compressed. Now we selected 800 W as an input power peak.

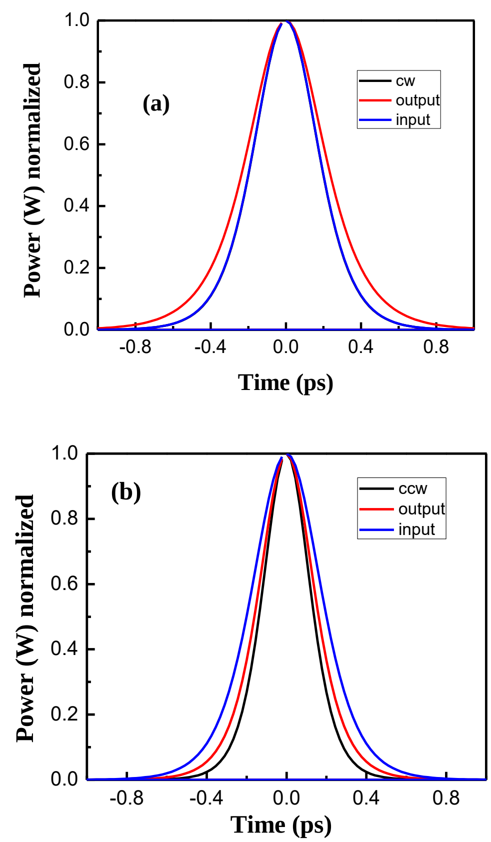

Figure 2: 200 m of fiber length a) CW direction, input power =650 W, b) CCW direction, input power=970

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Moreover in Figure 3a and 3b are shown the spectra for two different lengths of fiber 20 m and 200 m with 800 W as input power. From Fig. 3a, it is clear that for CW direction (black line) there is broadening but in CCW (red line) and output (blue line) there are some compressing. The compresing in the spectrum is one point of our interest. Fig. 3b shows that the spectra of CW (black line) direction is wider than input spectra, however for CCW (red line) and output (blue line) there are compressing. Comparison of different length shows that there are less fluctuation for shorter fiber than longer fiber.

Figure 4 gives the result of transmission with for different fiber lengths from 0 m to 200 m, we calculate every 5 m of fiber length. In this case can find that only for 20 m of fiber is enough to reach the first maximum of transmission.

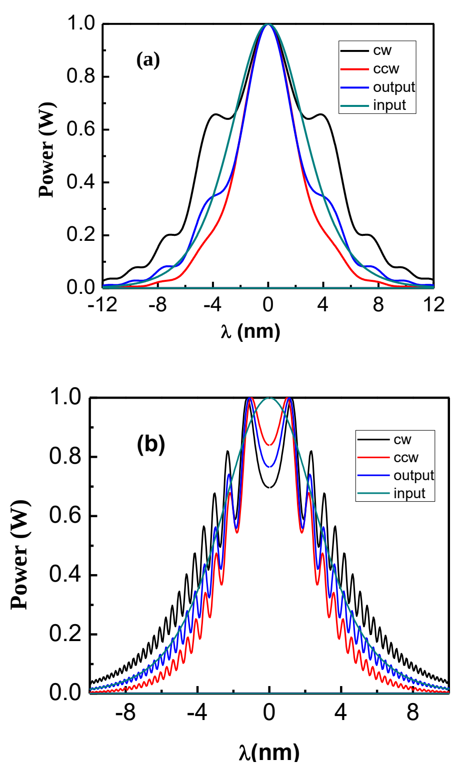


Figure 3**:** a) 20 m of fiber length, input Power 800 W, b) 200 m of fiber length, input power 800 W

Figures 5a and 5b show the transmission for 200 m and 20 m of fiber length with different power input from 0 W to 1000 W. From the figures it is clear that reaching to the first maximum transmission 60% for longer fiber length, we need less input power around 250 W. Though for the shorter fiber length reach to the maximum transmission 90%, we need almost three times more input power 700 W. In addition from this result, we calculate the time-bandwidth product, it was 0.2 and 0.28 for 20 m and 200 m respectively. As we already mentioned that the time-bandwidth is ≈ 0.315 for sech^2-shaped pulses, in our case time-bandwidth product is less than soliton pulses. We think that there is some compression in the output pulses of the NOLM.

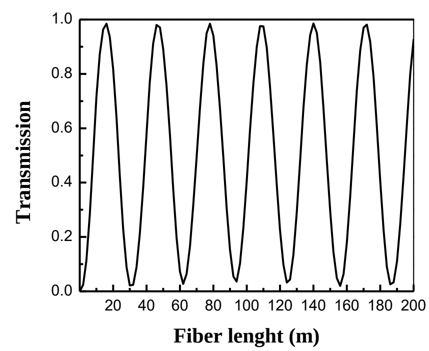
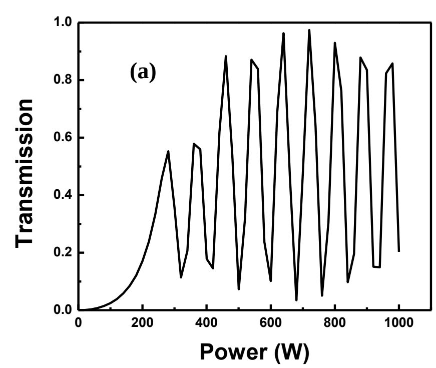


Figure 4**:** Transmission for different of fiber length with input power 800 W



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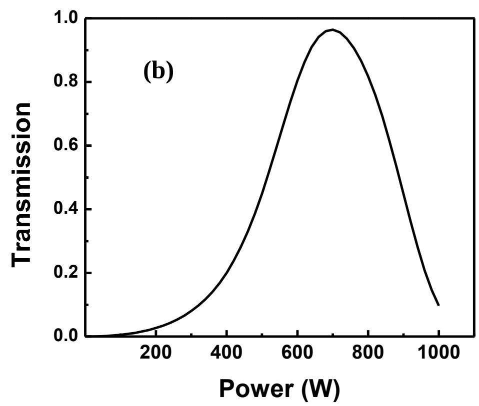

***Figure 5*:** a) Transmission for different input power for 200 m of fiber length, b) Transmission for different input power for 20 m of fiber length.

Conclusions

We have done our numerical simulation studies to get the soliton pulses at output of the imbalanced polarization NOLM. We studied different input power with different fiber length to find out suitable condition to get soliton pulses at the output of the NOLM. We measured the spectra for all input and output pulses. It is important to mention that in order to obtain soliton pulse at the output, the input power plays main role. We get that for 20 m, 700 W is required and the time-bandwidth was 0.2. Furthermore, for 200 m of fiber length the input power was 250 W and time-bandwidth product was 0.28.

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