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Temporal reshaping of picosecond pulses using quadratic soliton deflection in engineered film PPLN waveguide

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Abstract: We studied an ultra-fast nonlinear saturable absorber based on soliton emission in Ti:PPLN waveguide. We demonstrated efficient temporal reshaping of picosecond pulses in presence of large group velocity mismatch.

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1. Introduction

The principle of the temporal reshaping using the combination of a self-trapped beam and a slit has been already carried out in a KTP crystal at 1064 nm [1] and in film PPLN waveguide at 1550 nm [2]. This kind of processing is particularly interesting for high bit rate optical communication links where it could achieve all-optical reshaping of distorted pulses at very high speeds. We demonstrate the temporal reshaping of 4 ps pulses with pedestal using soliton emission processe in an engineered PPLN waveguide and in presence of a large temporal walk-off. This process offers the advantage to combine soliton propagation and a nonlinear deflection of the trapped beam which increase the nonlinear transmission of the device. Spatial soliton switching in settings with transverse variations of the phase-mismatch, which might be implemented with QPM, have been numerically predicted. In particular, in engineered QPM structures, the existence of soliton reflection/refraction phenomena [3, 4] and the presence of soliton emission phenomenon [5] have been studied and demonstrated. This latter phenomenon can be explained in terms of potential wells induced by the engineered nonlinear patterns and it depends on the structure's parameters, on the wavelength and on the incident power of the beams. For intensity close to the trapping threshold and for an aperture slightly equal to the soliton diameter, we obtained a complete cleanup of a noisy picosecond pulse.

We performed experimental and numerical investigations in a 58 mm long Ti:PPLN z-cut planar waveguide with a poling period of 16.92 μm. We used an all fiber laser system delivering 4 ps pulses at 1547 nm with a 2 nm spectral bandwidth and with a peak power up to

6kW. The laser beam was shaped in an elliptical gaussian spot ($56\mu m$ x $3.9\mu m$) for coupling efficiently into the waveguide. Under these conditions, the crystal length corresponded to 5.6 times the fundamental field (FF) diffraction length and the temporal walk-off was 5.4 times larger than the incident pulses duration. The soliton propagation was only obtained for positive phase mismatch values because of a large temporal walk off compared to the pulse duration.

2. Soliton emission

We launched the FF input beam in the PPLN region, close and parallel to the interface between the poled and the unpoled regions. For sufficient incident intensity we succeeded to excite a spatial soliton and we observed its spatial shift versus the input intensity. The beam experienced an effective spatial acceleration and consequently spatial velocity in the transverse dimension toward the region where the nonlinear interaction is more efficient (see figure 1). This phenomenon occurred from a small positive phase mismatch ($\Delta kL = 8\pi$) to a large positive phase mismatch ($\Delta kL \approx 48\pi$).

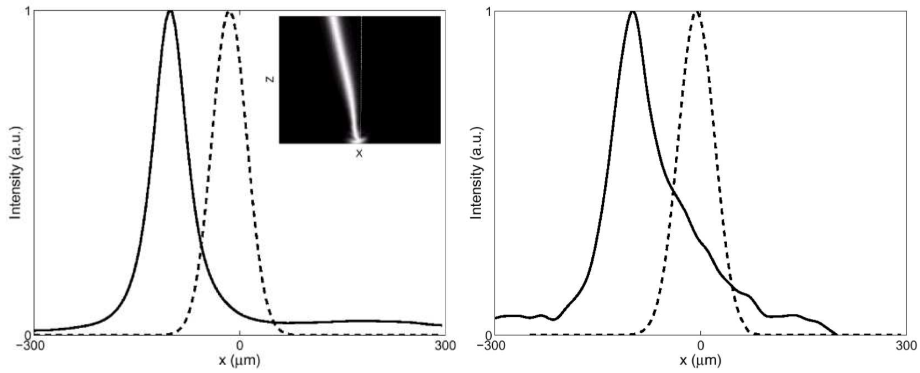

Fig. 1. Example of soliton emission obtained in PPLN/LN crystal. Left: numerical simulations, right: experiments (dot line: input beam, continuous line: output beam).

3. Investigation

We modified the adjustments of our laser system to deliver pulses with trailing pedestal. We launched the noisy signal in the PPLN in the vicinity of the nonlinear transition.

At low input intensity, signal and noisy pulses propagate along the interface, in the same spatial direction; the profile of the autocorrelation at the output was close to the input one and exhibited large shoulders. At high input intensity we observed spatial soliton emission of the signal; signal and noisy pulses propagate along different spatial directions and are almost completely separated at the output of the crystal. We placed a spatial filter at the output of the sample. The aperture of this filter was equal to the soliton width. We succeeded in suppressing the pedestal in the autocorrelation trace by placing the filter where the soliton is emitted. Typical experimental and numerical results are reported in Fig. 2.

The efficiency of the reshaping depended on the input intensity, the phase-mismatch condition, on the aperture width and on its position. The optimal temporal reshaping occurred for the maximum input intensity (200 MW/cm^2). This new proposed mechanism combines successively soliton propagation and soliton deflection which spatially separates signal and noise. These technique is more efficient than the reshaping method only using soliton propagation [5,6]. This all-optical processing can be used in optical communication links for ultra-fast reshaping of picosecond pulses.

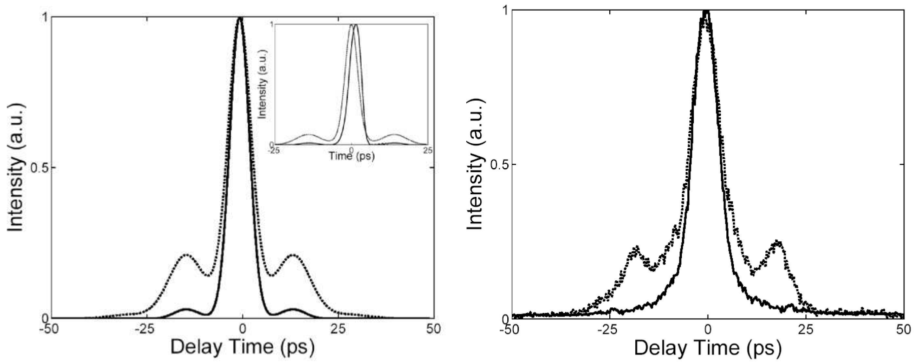

Fig. 2. Left, calculated and right, measured FF autocorrelation traces at input (dotted line) and at output after temporal reshaping (solid line). The inset shows the FF calculated temporal profile at input (dotted line) and at output (solid line). The input intensity is I=200MW/cm^2 and the temperature of the sample is T=150°C ($\Delta kL = 9\pi$).

4. Conclusion

We numerically and experimentally demonstrated that spatial soliton emission in non-uniform Ti:PPLN planar waveguide combined with a spatial filter placed at the output face of the waveguide can operate as an ultra-fast temporal reshaping device. A 4 ps distorted pulse at 1548 nm was significantly cleaned up using this nonlinear device.

References and links

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