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Ultra-fast reconfigurable spatial switching between a quadratic solitary wave and a weak signal

Paul-Henri Pioger, Vincent Couderc, Alain Barthélémy
I.R.C.O.M., Faculté des Sciences, 123 av. A. Thomas, 87060 Limoges, France
Tel :+33 555457256,Fax :+33 555457514,abarth@ircom.unilim.fr.

Fabio Baronio, Costantino De Angelis
Istituto Nazionale per la Fisica della Materia, Università di Brescia, via Branze 38, 25123 Brescia, Italy
Tel:+39 030 3715437,Fax:+39 030 380014,deangeli@ing.unibs.it

Yoohong Min, Victor Quiring, Wolfgang Sohler
Angewandte Physik, Universitat Paderborn, 33095 Paderborn, Germany
Tel:+49-5251-60-2714,Fax:+49-5252-60-3422,sol_ws@physik.uni-paderborn.de

Abstract: We present an ultra-fast reconfigurable switch based on the nonlinear interaction between a weak wave (the signal) and a solitary-wave (the control) at 1548nm. The non-collinear interaction gives birth to a third switched optical beam.

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1 Introduction

One of the most important goals for today's telecommunication systems is to develop all optical technologies enabling a significant increase of data rate processing and routing. Spatial quadratic solitary waves and their particle behaviors can lead to ultra-fast all optical switching. In this framework, many numerical studies [1-2] and experimental works [3-6] have demonstrated the feasibility of using fusion, scattering, spiraling of spatial solitons both in type I and type II geometries. In most of the proposed configurations, the operations of ultra-fast switching exploited two spatial solitons which required higher intensities than those typically used in telecommunication systems.

In this paper, we present a reconfigurable spatial switching that results from a non collinear interaction between a quadratic spatial soliton (a fundamental frequency, FF, and its second harmonic, SH) and a weak FF wave in a Ti:PPLN film waveguide. The principle of this ultrafast reconfigurable switch, see figure 1, is based on the parametric interaction between the weak beam (the signal) and the strong SH component of the soliton beam (the control). Difference frequency generation (DFG) between these two waves generates a third wave (the idler) at the FF in a direction that satisfies the wave-vectors phase-matching condition. The output position of the switched signal can be steered by varying the transverse position where the control beam is launched into the waveguide.

2 Experimental set-up

The experimental set up used for the spatial switching is shown in figure 2. The laser source delivers pulses with a gaussian temporal profile and a pulse width of 4 ps with a repetition rate of 20 MHz. The spectrum of the emitted pulses is centered at 1548 nm with a 2.2 nm width (FWHMI). This FF beam is splitted in two waves in a Michelson type interferometer. The relative spatial position and propagation direction of the two beams can be modified by the misalignment of one arm of the interferometer. We can also change the temporal delay between the two pulses by changing the length of one arm. The two waves are then focused, by means of a telescope, to a 50 µm spot onto the entrance face of a 63 mm long Ti:PPLN film waveguide.

The signal beam is a train of 4ps pulses at a repetition rate of 20MHz, modulated by a mechanical chopper at a frequency of 100Hz. The intensity of the signal, adjusted by an optical density placed on one arm of the interferometer (figure 1), is roughly 100 times lower than that of the control beam. The control beam (both FF and SH components) is obtained by launching an intense FF wave and exploiting SH generation in the PPLN crystal. The control beam is a train of 4ps pulses at a repetition rate of 20MHz, modulated by a rectangular signal at a frequency of 7 Hz (figure 1); its intensity is sufficiently high to excite a soliton beam during the propagation in the PPLN crystal. In the solitary wave propagation conditions, the SH wave is spatially and temporally locked and superimposed with the FF component thus mitigating the effect of group velocity mismatch (GVM). Moreover, the excitation of a trapped beam permits to compensate the divergence of the control beam and therefore to separate more efficiently the two beams at the output face of the crystal.

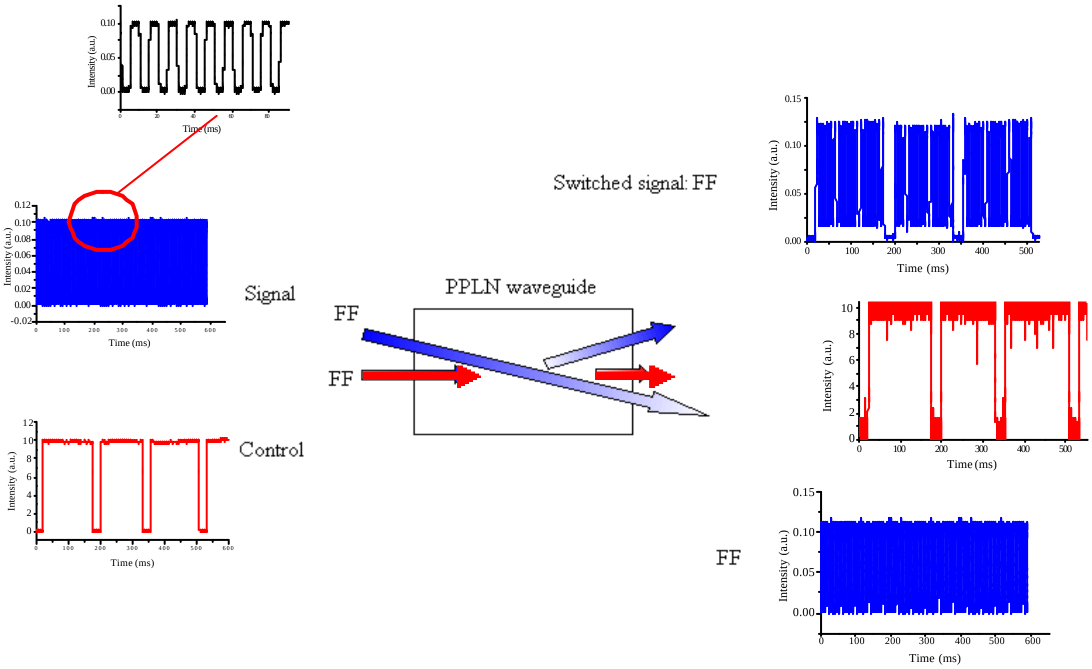

Figure 1: Experimental results of the non collinear switching device

3 Results

The two input waves (signal and control) were focused on the input face of the PPLN crystal with their wavectors defining an angle of 0.5^o. The output signals were recorded and analysed with a vidicon camera and a fast photodiode.

Through the DFG interaction between the SH component of the control beam and the signal at the FF, a switched signal at the FF is obtained (figure 1). The output position of the switched signal can be tuned by changing the relative propagation direction of the two waves and the crossing point position in the PPLN. Thus the output position of the switched signal can be steered by varying the transverse position where the control beam is launched into the waveguide. The switched wave was spatially filtered by an aperture before detection. It carried pulses of 0.18W peak power for a FF control peak power of 1500W and for an input signal of 15W. The efficiency of the spatial switching (–19 dB) depended on the space time overlapping between the two input beams; it could be improved with a reduction of the angle between signal and control and a longer waveguide. The contrast in the switched output was higher than 14 dB with reference to the non-switched pulses.

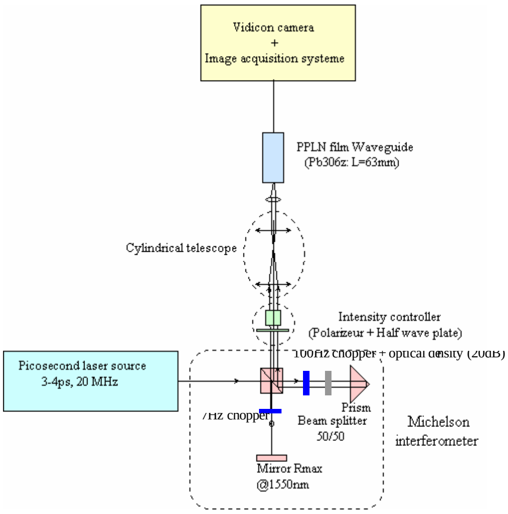

Figure 2 : Experimental set up used for non collinear spatial switching process

In this configuration, the main limitation in terms of repetition rate is due to the GVM between the fundamental frequency and the second harmonic waves. Nevertheless, in the present case, the temporal second harmonic walk off effect was compensated by the quadratic space-time locking of the fundamental and second harmonic control, as demonstrated previously by Pioger et al. [7]. This temporal locking between the FF and the SH components of the control beam increases the capability of this device to operate at very high bit rates. Moreover, the present scheme offers the advantage of a non phase sensitive switching together with the capability of processing weak signals. It could also allow simultaneous spatial switching and frequency conversion by using of a "control" radiation detuned in frequency with respect to the signal.

4 Conclusions

We realized and studied an ultra-fast reconfigurable spatial switch. The signal beam was a weak 4 ps pulse at 1548 nm with a peak power equal to 15W; the control beam was a solitary wave. The principle of the ultrafast reconfigurable switch is based on the parametric interaction between the signal and the control. Difference frequency generation (DFG) between these two waves generates an idler wave at 1548 nm, the switched signal. The output position of the switched signal can be steered by varying the transverse position where the control beam is launched into the waveguide.

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