Optical Signal Copying by Cross-Phase Modulation with Triangular Pulses

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Triangular optical pulses have a very simple intensity profile that can be attractive for a variety of applications [1,2]. In [2] it was demonstrated that triangular pulses created using superstructured fibre Bragg grating technology lead to a two-fold improvement in the performance of a wavelength converter based on self-phase modulation in fibre and offset filtering. Recently, we have introduced a method of triangular pulse generation based on the nonlinear reshaping of sufficiently powerful, positively chirped pulses that occurs upon propagation in a normally dispersive fibre (NDF) [1]. In this work, we propose a simple technique for all-optical signal manipulation in the time and frequency domains which utilizes cross-phase modulation (XPM) with a triangular pump pulse and subsequent propagation in a linear dispersive medium.

First, we focus on the spectral copying of optical pulses. Without loss of generality, we consider the co-propagation of a Gaussian pulse (signal) with width T and a higher-power triangular pulse, $I(t) = I_0(1 - |t/\tau|)\theta(\tau - |t|)$, in a highly nonlinear fibre (HNLF) with nonlinear coefficient γ and length l. In the case of temporally co-centered pulses (under the condition that their spectra do not overlap), due to XPM induced by the stronger triangular pulse and assuming small HNLF dispersion, the signal pulse acquires the phase modulation (nonlinear chirping) $\phi(t) = 2\gamma I(t)l = \phi_0(1 - |t/\tau|)\theta(\tau - |t|)$. The spectral amplitude of the resulting chirped pulse $\tilde{u}(\omega) = u_0 \int \mathrm{d}t\, \exp(-t^2/(2T^2) + i\phi(t) + i\omega t)$ can be calculated analytically, and it functionally depends on the maximum phase shift ϕ_0 and the ratio T/τ. Examples of spectral power density profiles for different values of ϕ_0 and $T/\tau = 0.3$ are shown in Fig. 1. The notable feature of Fig. 1 is that for non-zero ϕ_0, the shape of the spectrum evolves into a structure consisting of two equal peaks allowing spectral copying of the initial pulse (recall that the initial temporal intensity pulse profile is not affected). It is clear that this technique can be used also for frequency conversion or tunable wavelength adjustment. These applications of triangular pulses will be described elsewhere. The separation between the two spectral peaks grows with the increase of ϕ_0 while their form (in frequency domain) is preserved. We note that increasing T/τ enhances the peaks' formation and separation as a function of ϕ_0, while for values of T/τ greater than approximately 0.5 we observe the development of a low intensity multi-peak structures between the two main peaks. The proposed scheme also allows temporal copying of the initial pulse by applying subsequent propagation of the modulated pulse in a dispersive medium. The produced spectral separation of the signal components leads to their subsequent separation in time. The temporal shape and evolution of the pulse $|u(z,t)|^2 = |\int \mathrm{d}\omega\, \tilde{u}(0,\omega)\exp(i\beta_2\omega^2 z/2 - i\omega t)|^2/(4\pi^2)$ ($\tilde{u}(0,\omega)$ is the modulated spectral amplitude at the HNLF output and β_2 is the fibre group-velocity dispersion coefficient) can be controlled by adjustment of parameter ϕ_0. Specifically, it is possible to achieve a stage of width stabilisation (or even slight compression) which occurs over a short initial transition distance. Depending on the specific application, the propagation distance can be increased leading to pulse splitting into two identical pulses (optical copying) that separate in time while experiencing dispersive broadening. The transition distance shortens and the speed of pulse runaway grows with increasing values of ϕ_0. Figure 2 illustrates an example of such pulse evolution in NDF ($\beta_2 > 0$) for $\phi_0 = 4\pi$. The intensity and chirp (first time derivative of the phase) profiles at different distances are also shown.

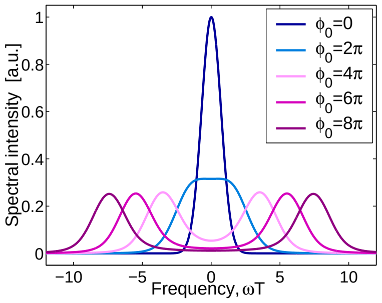

Fig. 1 XPM-modulated pulse spectra.

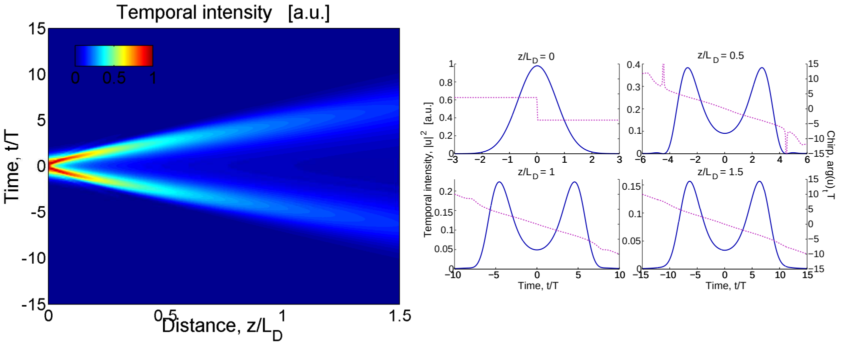

Fig. 2 Evolution of the modulated pulse in a dispersive medium for $\phi_0 = 4\pi$ (L_D is the dispersion length). Left, pulse intensity versus distance and time; right, intensity and chirp profiles at different distances.

In conclusion, we have presented a new technique of copying optical pulses in both time and frequency domains based on the combination of XPM induced by a high-power triangular pulse in a HNLF and subsequent propagation in a dispersive medium.

References

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