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Letters to the Editor

Dispersion supported optical pulse compression

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We present a novel technique that can be used for optical pulse compression. This technique is based on interaction between an amplitude/frequency-modulated signal and fiber chromatic dispersion. We present analytical expression which describes this type of pulse compression.

1. Introduction

Compression of optical pulses is attractive for short pulse applications including high bit rate transmissions such as optical time division multiplexing and electro-optical sampling [1]. In general, the pulse compression techniques can be classified into two broad categories: laser techniques (for example, mode locked technique, gain switching) and technique based on the nonlinear effects (for example, fiber-grating compressors, soliton-effect compressors) [2]. In this paper, we present dispersion supported optical pulse compression. This technique is based on interaction between an amplitude/frequency-modulated optical signal and optical fiber chromatic dispersion.

2. Analysis of temporal profile and phase of an optical pulse

For the analysis we consider a Gaussian pulse with amplitude

$$A_{\mathrm{Gauss}}(t) = A_0 e^{-t^2/2\sigma^2} \tag{1}$$

where t is time and σ is the half-width at which the intensity drops by $e^{-1/2}$; we assume that $A_0 = 1$.

The Fourier transform of the Gaussian pulse is equal to

$$\mathscr{F}_{\mathrm{Gauss}}(\omega) = \sqrt{2\pi\sigma}\, e^{-1/2\omega^2\sigma^2}. \tag{2}$$

Here, we introduce the dispersion compensating factor $\vartheta(\omega)$ which is defined as

$$\vartheta(\omega) = e^{-j/2\varkappa\omega^2}. \tag{3}$$

Here j is the imaginary unit and $\varkappa$ is the parameter describing the impulse chirp.

The inverse Fourier transform of the product (2) and (3) is given by

$$\Psi(t) = \frac{\sigma}{\sqrt{\sigma^2 + j\varkappa}}\, e^{-\frac{1}{2}\frac{t^2}{\sigma^2 + j\varkappa}}. \tag{4}$$

Equation (4) can be rewritten as

$$\Psi(t) = \frac{\sigma}{(\sigma^4+\varkappa^2)^{1/4}}e^{-\frac{1}{2}\frac{t^2\sigma^2}{\sigma^4+\varkappa^2}}\cdot e^{j\int\limits_0^t\frac{\varkappa t}{\sigma^4+\varkappa^2}\mathrm{d}t} \tag{5}$$

where

$\dfrac{\sigma}{(\sigma^4+\varkappa^2)^{1/4}}e^{1/2}\dfrac{t^2\sigma^2}{\sigma^4+\varkappa^2}$ is the temporal profile of the optical pulse,

and $\displaystyle\int\limits_0^t\frac{\varkappa t}{\sigma^4+\varkappa^2}\mathrm{d}t$ is the phase of the optical pulse.

3. Analysis of optical pulse propagation along the optical fiber

The propagation along the optical fiber is described by the propagation term: $\exp(-j\beta L)$ [3], where L is the fiber length and β – propagation constant. Assuming that the propagation constant is slowly varying across the source linewidth we make a Taylor expansion of β around ω_0 and we retain terms up to the second order in $\omega-\omega_0$

$$\beta = \beta_0+(\omega-\omega_0)\beta_1+\frac{1}{2}(\omega-\omega_0)^2\beta_2+\ldots\ , \tag{6}$$

where: $\beta_1 = \dfrac{\mathrm{d}\beta}{\mathrm{d}\omega}$, and $\beta_2 = \dfrac{\mathrm{d}^2\beta}{\mathrm{d}\omega^2}$.

Here, the first and the second terms correspond to the signal phase and delay, respectively. The third term is responsible for the chromatic dispersion. We neglect, for convenience, the phase and group delay because boths terms have no influence on the distortion of the signal. Here, the propagation term is equal to

$$\exp\left(-j\beta_2\frac{L}{2}\omega^2\right). \tag{7}$$

Performing the Fourier transform the spectrum of the signal (5) may be expressed as

$$\Psi(\omega) = \sqrt{2\pi\sigma}e^{-1/2(\sigma^2\omega^2+j\varkappa\omega^2)}. \tag{8}$$

In the frequency domain the optical signal (Eq. (8)) at the end of the standard single-mode optical fiber is given by (losses are neglected)

$$\Psi(\omega,L) = \sqrt{2\pi\sigma}e^{-1/2(\sigma^2\omega^2+j\varkappa\omega^2)}e^{-j/2(\beta_2L\omega^2)}. \tag{9}$$

Using the inverse Fourier transform we obtain from (9)

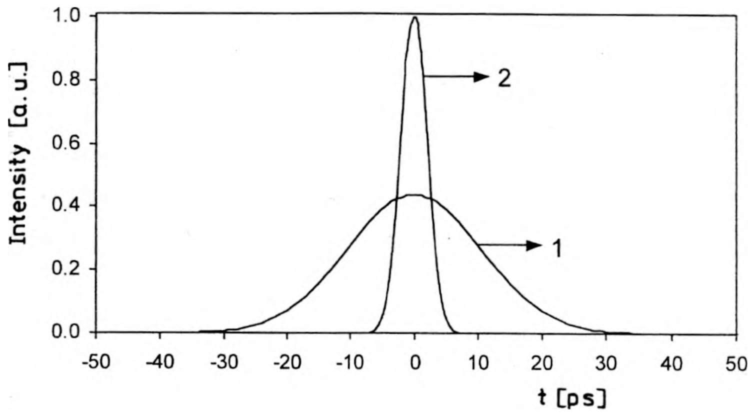
$$\Psi(t,L) = \frac{\sigma}{\sqrt{\sigma^2+j(\varkappa+\beta_2L)}}e^{-\frac{1}{2}\frac{t^2}{\sigma^2+j(\varkappa+\beta_2L)}}. \tag{10}$$

Then, if $\varkappa = -\beta_2 L$ the impuls length may be reduced from $\sqrt{\sigma^2 + \frac{\varkappa^2}{\sigma^2}}$ to σ.

4. Calculation and results

In our calculation, the values of the σ and $\beta_2 L$ are chosen to be 2 ps and -20.52 ps^{2}km/nm, respectively. We also assume that the parameter $\varkappa$ is equal to $-\beta_2 L$. The intensity profile of the input and output optical pulse is calculated using Eq. (5) and Eq. (10), respectively.

The Figure shows the intensity profile of the input and output optical pulses.



Temporal profile of the input (1) and output (2) optical pulse.

5. Conclusions

An analytical model for describing dispersion supported optical pulse compression was presented. The interaction between the input amplitude/frequency-modulated signal and optical fiber chromatic dispersion can generate compressed optical pulse at the end of the standard single-mode fiber. This type of compression is due to the conversion of frequency modulation to amplitude modulation caused by the optical fiber dispersion.

References

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